INSTRUCTION No. 65

MISCELLANEOUS REPAIRING: How to Solder; How to Braze; How to Case-Harden and Temper Steel, etc.; How to Straighten Metal Parts; Repairing and Adjusting Silent Chains; Gaskets; Radiator Repairing

EQUIPMENT FOR SOLDERING

The equipment required for soldering consists of a blow-pipe torch, soldering irons or coppers, and solder, acid or flux.

Blow-Pipe Torches[1]

There are many different methods of heating a soldering iron, the usual method being with the use of blow-pipe torches as illustrated below.

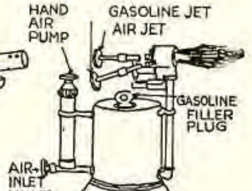
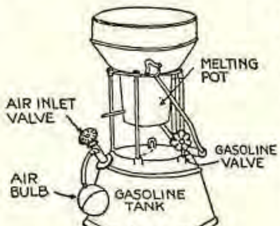


Fig. 1 Fig. 2 Fig. 3

Fig. 1. The "baby" blow-pipe torch does not require air to be pumped into the gasoline tank (B). It is intended for very light work.

Fig. 2. A single-jet blow-pipe torch.

Fig. 3. A double-jet blow-pipe torch.



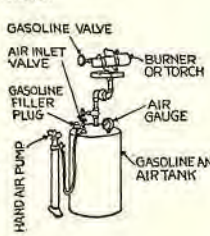


Fig. 4 Fig. 5

Fig. 4. A gasoline torch or "fire pot," designed for melting solder and lead; used extensively by plumbers for wiping lead joints.

Fig. 5. A large-size gasoline blow-pipe torch designed for brazing, pre-heating, and general work. The principle of operation is similar to that explained in Fig. 12. With the torch shown in Fig. 5, about 75 lbs. of air is pumped into the gasoline and air tank by the hand air pump. The tank is usually of a 10-gallon capacity.

A Home-Made Gas Blow-Torch

Small soldering jobs, especially in cramped quarters, may be most readily done by means of a blow-torch. Such a torch

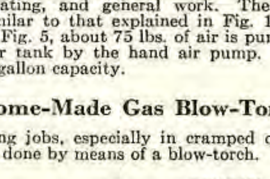


Fig. 6

may be made from pipe fittings in the manner illustrated (Fig 6). In brief, it comprises a piece of pipe, attached to the gas main by a length of rubber hose, with another piece of pipe, attached to the air line and welded to the gas nozzle, as shown. A spacer cross-brace is welded between the two pipes at the rear, making a torch a unit. A valve on the gas pipe renders regulation of the flame easy. Though this torch is somewhat small for brazing jobs, a heavier torch could readily be made for that purpose.

Gas Torch and Soldering Iron

(A) copper soldering iron; (B) gas-burner tube; (C) gas burner; (D) gas tube to connect hose.

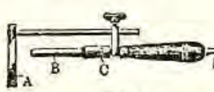


Fig. 7

The gas-heated soldering iron (Fig. 7) can be used with illuminating or acetylene gas by attaching it to a gas burner or to a Prest-O-Lite tank with a rubber tube. By removing the soldering iron, the burner can be used as a blow-pipe for brazing, and also for soldering aluminum. (For sale by automobile supply houses.)

Starretts Gas Heater

The heater (Fig. 8) will be found very useful in the machine shop, as it is convenient for tempering small tools, heating soldering irons, melting lead, babbitt, etc.; and as a forge for light work it will be found very valuable.

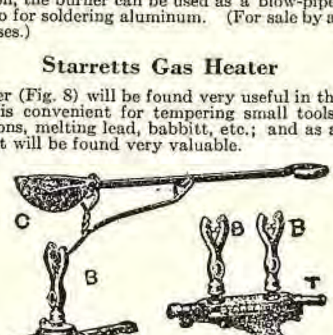
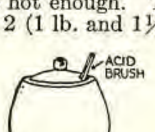


Fig. 8

It consists of one, two, or three burners (B), with or without a tool holder, and is connected to the ordinary gas jet at (T). A ladle (C) 14" long, holding 12 oz., can be had of the same company, L. E. Starrett, Athol, Mass.

Soldering Copper or Iron

A soldering copper or iron (Fig. 10) is a wedge-shaped block of copper, fitted in an iron fork with a wooden handle. Preparatory to its use, it is placed in a clear fire, or gas or blow-pipe torch burner until it is hot enough. The usual size used is No. 1 or No. 2 (1 lb. and 1½ lb. in weight, respectively).



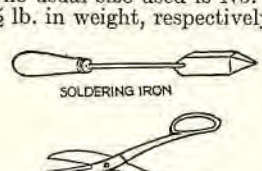


Fig. 9 Fig. 10 (above)
Fig. 11 (below)

If the copper is a new one, it must be tinned. When hot, file off the scale on both sides and ends

[1] Imperial Brass Mfg. Co., Chicago, Ill., and Clayton & Lambert, Detroit, Mich., manufacture blow-pipe torches.

for a quarter of an inch from the tip, so that the metal will be clean and bright. Dip the nose in the soldering fluid for a second, and then apply it to the stick of solder. A globule will melt off on to a piece of dry brick or tinplate which must be ready to receive it. Rub the nose of the copper in this solder, which will adhere to it as quicksilver does to zinc. The copper can then be used. Copper is used because copper readily absorbs heat and will retain it longer and give it off again rapidly.

The soldering copper must not be allowed to get red hot, as the tin will be burned off and the tinning process must then be repeated. The reader should practice soldering at leisure.

How to Solder*

In soldering two parts together, it is necessary that the contact surfaces be perfectly clean. A clean file, scraper, emery cloth, or a little acid is generally used in cleaning the surfaces. Sometimes, especially in old work, the emery cloth will not get a clean surface. A dark spot may be a depression; the file must then be used.

If the work to be cleaned is greasy, clean it first with hot water and soda.

After cleaning, the surface to be soldered should be warmed, and swabbed with prepared acid—that is, muriatic acid which has been prepared by dissolving in it as much zinc as it will hold.

The flux or acid generally used may be prepared in the following manner: To ¼ pint of muriatic acid add scraps of zinc in a pot (Fig. 9) until the acid ceases to bubble and a few small pieces of the metal remain. Let this stand for a day; then carefully pour off the clear liquid, or filter it through a piece of blotting paper. Add to this a teaspoonful of salammoniac, and when dissolved the solution is ready for use.

A solution of salammoniac and borax also makes a good flux for soldering copper and brass.

Wire solder, containing a flux, is generally used, thus saving the necessity of a separate flux or acid

Soldering Pointers

The melting point of the soldering material must be lower than that of the article being soldered (see Index for melting points of different metals).

Hard soldering or brazing is a term used when the soldering mixture is composed largely of copper, brass, or silver. Use borax for flux. Hard soldering is best where the material will stand intense heat.

Soft soldering is the ordinary half-and-half (one-half lead and one-half tin). Plumbers' solder has 2 parts of lead to 1 of tin, and is therefore still softer than half-and-half, in order to fit it for working on lead pipe. See pages 738, 736 for solder for radiator repairing, known as "50-50" solder.

Sweating is a term used where the solder is applied to a surface to be soldered and the hot iron is then held on it until it "sweats" or runs in.

For electrical work use resin or a soldering paste, as acid sets up a resistance in the joint.

After an iron has been cleaned and heated and is then rubbed on a piece of "fluorite," the tin or solder will spread readily thereon.

How to Operate a Gasoline Torch—Single-Jet Type

Fill about two-thirds full of gasoline; the filler plug on this type of torch is at the bottom of the tank. The torch is turned up-side-down, the gasoline is poured in, and the plug is screwed up tight, making sure that it does not leak.

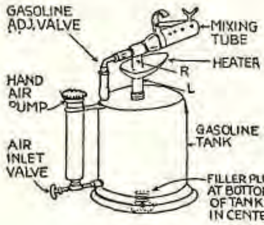


Fig. 12

Air is then pumped into the tank by the hand air-pump plunger, after first opening the air inlet valve (Fig. 12), and after making sure that the gasoline adjusting valve is closed.

Next hold the hand over the mixer tube, and slowly open the gasoline valve at which point gasoline will drip into the heater. Light this gasoline with both valves closed. This heats the pipe (**R**).

After the gasoline in the heater has burned up, the heat should be sufficient to vaporize the gasoline, causing air and gasoline to flow through the pipe (**L**) and (**R**) from the tank to the burner or mixer, when the gasoline valve is opened. A match is applied to this mixture, and the resulting flame should be blue in color; if it is yellow, the heating is not sufficient, and the operation must be repeated. It is advisable to protect the flame from wind while heating.

All torches work on the same principle. Some, however, have two valves (as shown in Fig. 3, page 719); this type is termed a "double-jet." They are also constructed with pots over the flame in which to melt lead; these are termed "fire pots" (Fig. 4).

For brazing, a similar principle is resorted to, except that a larger tank and burner and a separate air pump are used, as shown in Fig. 5, page 719.

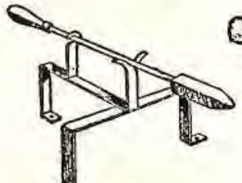


Fig. 13

Fig. 14

Fig. 13. A soldering-iron stand which can easily be made and is well worth the necessary time and labor.

Fig. 14. The usual method of placing a soldering iron on a blow-pipe torch to be heated. Where an air compressor is at hand, the torch can be filled with air by drilling a hole and soldering a tire valve stem (**T**) into it.

Soldering Aluminum

There are various compounds on the market for soldering aluminum, but this operation depends more on the workman than on the solder, and unless considerable experience has been had, it is probably better to purchase solder than to attempt making it.

*See pages 690, 691.

The chief difficulty in soldering aluminum is that the heat is dissipated so rapidly that it cools the soldering iron. Furthermore, aluminum oxidizes instantly upon exposure to the air. This extremely thin film effectually prevents a perfect union being made. If the parts are well heated and melted solder is kept melted by allowing the iron to stand on it, the surface can be scraped beneath the melted solder by the point of the soldering iron, thus preventing oxidation to a certain extent. In this way the metal can be tinned. When both parts to be brought together are well tinned, the parts can be united with some chance of success, nitrate of silver, resin, or zinc chloride being used as a flux.

The parts to be united must be thoroughly cleaned. If the surface is of such a shape that it cannot be readily cleaned by scraping, it can be cleaned by dipping it into a solution of nitric acid in three times its bulk of hot water containing about 5 per cent of commercial hydro-fluoric acid. This causes a slight action on the surface of the metal, as shown by bubbles. Rinse the metal after removing from the acid bath and dry in hot sawdust; or thoroughly clean and allow it to stand two or three hours in a strong solution of hyposulphate of soda before being operated upon or cleaned in the acid bath described above.

* **Aluminum solder:** The following formula, in the hands of a competent man, can be used to unite aluminum or aluminoid parts: tin, 10 parts; cadmium, 10 parts; zinc, 10 parts; lead, 1 part. It is best however, to purchase the solder ready made.

Soldering Cast Iron

To solder and tin cast iron, dissolve as much zinc as possible in one quart of common muriatic acid. Take a half-pint of warm water and dissolve in it 2 oz. of sal ammoniac. In a half-pint of warm water dissolve 2 oz. of chloride of tin. Then mix all thoroughly.

Where cracked cylinders, etc., are to be repaired, half-and-half solder is melted with some copper added. If this is used with the acid just described, excellent results will be obtained. A mixture of about 5 parts tin and 1 part copper is also recommended.

Another method of soldering cast iron: Clean the parts with a file until bright; also use muriatic acid. Wash the acid off with water. Then use a hot soldering iron and soldering acid (muriatic acid cut with zinc), so as to clean the pores of the iron where it is to be soldered. The work must be brought up to the heating point required to melt solder. When the work is thoroughly cleaned and heated in this manner, cool it with a solution of copper sulphate (copper sulphate dissolved in water). This will give a coppered surface. After coating, wash the surplus off; then use soldering acid, the solder and a hot soldering iron, and sweat or run the solder in. (*Sheet Metal.*)

Flux for Soldering Different Metals[1]

Iron and steel: sal ammoniac or chloride of zinc.

Tinned iron: borax, sal ammoniac.

Zinc: chloride of zinc.

Copper and brass: rosin or chloride of zinc.

Lead: tallow or rosin.

Lead and tin: rosin and sweet oil.

Gasoline Feed-Line Repair

A broken gasoline feed line (taken as an example of soldering) may be quickly repaired by scraping the tube near the break, and winding it for 1 in. on each side with clean copper wire. The wire should then be heated, covered with soldering flux, and sweated together with solder. A solid sleeve is thus formed that makes the pipe stronger than originally.

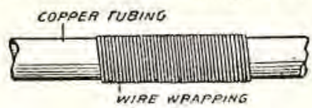


Fig. 15

Gasoline pipes sometimes get loose in the sockets of the unions. This is due to bad fitting, and shows that there is not sufficient elasticity in the pipe; it is too rigidly held. The screwing up of the union strains the pipe, and the vibration on the road causes the pipe to give way at its weakest point, namely, the soldered joint. If the pipe gets loose more than once, it shows that there is something wrong. A longer pipe should be put in, having a U-bend in it, or a complete circle, to give elasticity. The U-bend, or circle, should lie horizontally, with a drop towards the carburetor, otherwise there may be what is called an air-lock in the pipe, and the gasoline will not pass through.

If the carburetor float leaks (if of metal), it can be repaired with solder. Sometimes it is difficult to find the leak. For one method of locating it see Index under "Carburetor float repair."

Brazing

Brazing is infinitely stronger than soldering. It is by brazing that bicycle frames are built up. Bicycle makers use a gas blow-flame. This consists of two parallel pipes—one for gas and one for air. The air, which issues under pressure, causes a strong and very hot flame. The air pressure is produced by a small bellows worked by the foot. The work may be done with the torch shown in Fig. 5 (page 719).

The hard solder, as it is sometimes called, is a brass that melts at a low, red heat. It is generally bought in packets, and is in grains about the size of a pin's head. Brass wire is also used. After being wound around the part to be brazed, it melts and runs into the joint. The **flux** used for brazing is powdered borax.

Brazing a flange: If, for example, it is desired to braze a flange on to a pipe, the flange is placed on the pipe and the pipe is expanded by hammering till it is a tight fit. This is necessary, as it may shift its position in the act of brazing.

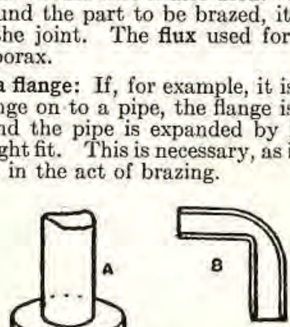


Fig. 16

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[1] One popular brand of flux for soldering radiators and for electrical work is "Rubyfluid," made by the Ruby Chemical Co., Columbus, Ohio.

* See pages 690, 691.

The flange and pipe (A) (Fig. 16) are put in a clear fire in the forge. Then as it gets hot the spelter, with borax, is sprinkled round the joint, which melts and finds its way into the space between the pipe and the flange. If the reader has a gas or gasoline blowpipe, it will make the work easier, as the heat can be directed where required from above. When cool, the superfluous brass is filed off. In many cases it is impossible to keep the two pieces of metal in the correct places in the forge; therefore a pin or rivet must be put in, so that they cannot shift.

Wiping a Joint

Joining two pieces of lead pipe is termed "wiping a joint." The pipe is first cleaned and prepared, by spreading one pipe with an expander, as at (1) (Fig. 17), and pointing the other ends, which are slipped together, shown at (2). The solder is then melted in a ladle, as shown in (3), and poured around the joint. A pad about 3" or 4" square and about ¼" thick, of canvas or velvet, is held in the hand under the pipe as shown (3), the surface being greased with tallow. The bottom layer may be an asbestos sheet, so that the molten metal will not burn through.

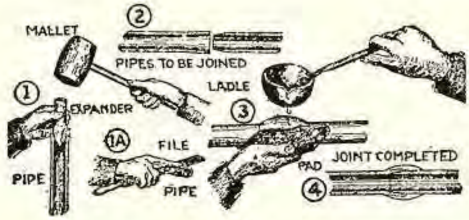


Fig. 17 .

As the melted solder is poured on the pad, it is wiped around the joint until it is heaped up all around it. The amount of metal used depends upon the size of the pipe. Rub the pipe on each side of the joint with a tallow candle to prevent the metal adhering to where it is not wanted.

Although copper or brass pipe may be joined without difficulty by the ordinary methods of soldering or brazing, the "wiping" method is about the only practical way to couple **lead pipe.**

MISCELLANEOUS

How to anneal, to bend tubing, to use a metal saw, to make small springs and to repair a cracked cylinder, are explained in the pages following.

Annealing Tubing

The copper or brass tubing used for gasoline pipes, carburetors, etc., can be purchased either annealed or not annealed. When not annealed, it is stiff and hard. It is difficult to bend it when hard. The

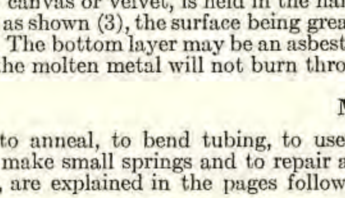


Fig. 18. Annealing copper tubing.

tubing can be softened by heating, as shown in Fig. 18 (called annealing). Iron rods and other metals of like nature can also be softened by annealing.

Bending Metal Tubing and Small Rods

The problem of bending metal tubing is one that comes up quite often in the motor vehicle repair and construction shop. Frequently when you undertake to bend some of the new kinds of metal tubing you are surprised to have it break, even though the usual precautions may have been taken to prevent a fracture of this nature. Fill the tube with fine sand packed tight, otherwise the walls are very liable to break, or they are liable to collapse.

First of all, it is best to **determine** the character of the **composition of the tubes.** Many tubes are made by different manufacturers and are finished nearly alike, and you cannot very well determine what procedure to follow when desiring bends or scrolls in them. But the file test will quickly make this clear; or even the point of a cold chisel will do to determine the nature of the metal. Then you can work accordingly.

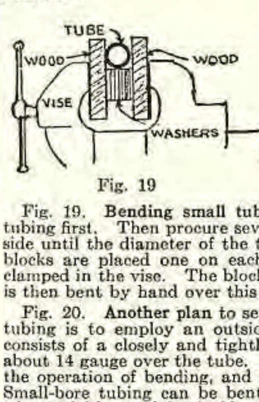


Fig. 19

Fig. 20

Fig. 19. **Bending small tubing:** It is well to anneal the tubing first. Then procure several washers, and place side by side until the diameter of the tubing is obtained. Two wood blocks are placed one on each side of the washers and are clamped in the vise. The blocks serve as guides. The tubing is then bent by hand over this form.

Fig. 20. **Another plan** to secure a uniform bend of smaller tubing is to employ an outside mandril on the tube. This consists of a closely and tightly wound spiral of iron wire of about 14 gauge over the tube. This distributes the stresses in the operation of bending, and it can be unwound afterwards. Small-bore tubing can be bent by placing a piece of copper wire (a fairly good fit) inside, and withdrawing it afterwards. A piece of string solder well greased can be used and then melted out.

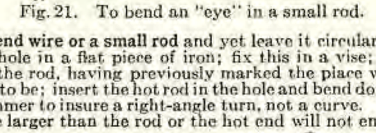


Fig. 21. To bend an "eye" in a small rod.

To bend wire or a small rod and yet leave it circular in form: Drill a hole in a flat piece of iron; fix this in a vise; heat the end of the rod, having previously marked the place where the bend is to be; insert the hot rod in the hole and bend down, using the hammer to insure a right-angle turn, not a curve. The hole must be larger than the rod or the hot end will not enter.

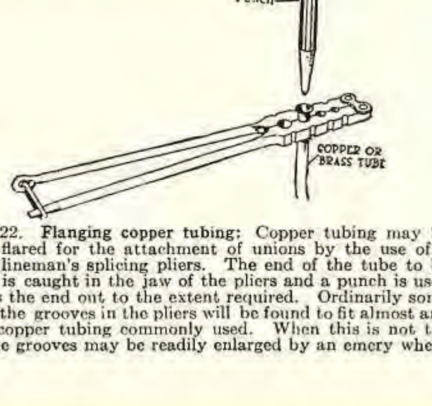


Fig. 22. **Flanging copper tubing:** Copper tubing may be readily flared for the attachment of unions by the use of a pair of lineman's splicing pliers. The end of the tube to be flanged is caught in the jaw of the pliers and a punch is used to press the end out to the extent required. Ordinarily some one of the grooves in the pliers will be found to fit almost any of the copper tubing commonly used. When this is not the case, the grooves may be readily enlarged by an emery wheel.

How to Use the Metal Saw

The fine-toothed blades should be used for iron and steel, and the **coarser** ones for brass and soft metals. For **cutting through a brass or steel tube** use a fine-toothed blade, as the teeth rip off the coarse ones. Before sawing, make a true circumferential line round the tube where the cut is desired; then, by turning the tube round a little between each cut, the latter will be true and square. The broken blades are useful at times for small repairs, as they are readily softened.

Another method for sawing tubing is shown in Fig. 23.

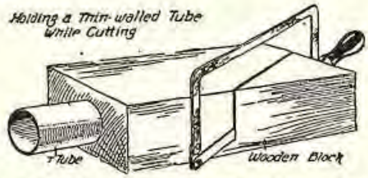


Fig. 23. Method of sawing through tubing. Consists of a wooden block with a drilled hole to receive the tube.

How to Make Small Springs

Spiral springs are now so readily obtained in a large variety that it is not often one is at a loss for a particular size of spring. The occasion may arise where a certain unusual size of spring is required. Figs. 24 and 25 illustrate two methods of winding small spiral springs.

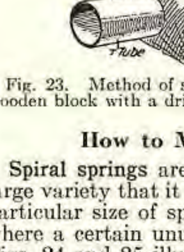


Fig. 24

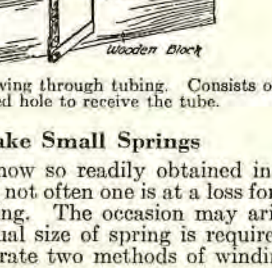


Fig. 25

Fig. 24. Springs of various sizes may be wound on the **spring winding outfit** illustrated. A cast-iron frame supports two uprights that act as bearings for the spring-winding spindle. These spindles are tool steel rod, having a diameter somewhat smaller than the inside diameter of the spring to be wound. One end is bent to form a crank and handle, the other being notched to receive the spring wire.

Fig. 25. How a spring is made by winding wire around a bolt.

Repairing a Cracked Cylinder[1]

Repairing a cracked cylinder: Welding is best, but if this is not convenient, repair with copper as directed below:

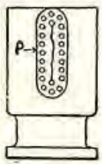


Fig. 26

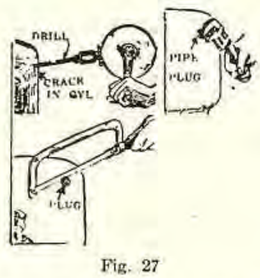


Fig. 27

A small hole should be drilled at each end of the crack, or a little beyond it (Fig. 26), for the crack may go farther than is visible to the eye. A quarter-inch hole should be drilled and tapped, and a screw inserted and screwed home, and the end filed off flush with the metal. Then a piece of stout sheet copper (P) (not less than 1/12″ thick) should be cut out, covering the crack extending about ¾″ all around. This must be bent to fit the cylinder and fixed down with a number of 3/16″ or ¼″ screws. Put a piece of canvas smeared with red lead, putty, or thick oil paint under the copper. The patch may leak a little at first, but will probably "take up" in a few days.

Plugging is another plan. A very small crack in a cylinder, probably caused by freezing of contained water, may be mended as follows. Drill a small hole in each end of the crack, and tap it for a small copper plug (Fig. 27). Scrape the surfaces near the crack until the metal is bright. Cover the crack with soft copper filings and melt them in with the blow-torch. Use a flux of rosin dissolved in alcohol, or simply drill and thread hole, if not too large, and screw in a pipe-plug tap, and saw off.

Rusting up a small leak in a cylinder: ¼ lb. of sal ammoniac to 1 quart of water, poured into the cylinder and left to stand for 48 hours has caused rust enough to form to close a small hole entirely. Be sure to wash out thoroughly. Another remedy is an "iron cement," secured at supply houses.

Cider or vinegar will cut rust out of cast-iron cylinder water jackets, if left standing for two or three days. See also page 151.

Smooth-on, it is claimed, will repair breaks in castings and also radiator leaks. Write for free pamphlet Smooth-On Mfg. Co., Jersey City, N.J. See also page 814.

HEAT TREATMENT OF STEEL

In ordinary shop practice this consists of the following: (1) the process of **annealing;** (2) the process of **hardening;** and, (3) the process of **tempering.**

Annealing Metal

Annealing or softening renders a metal in such a condition that it can be easily cut, machined, or bent. See Fig. 18, page 722, showing how tubing is annealed.

To anneal steel: Heat to a dull-red heat and then remove the metal from the heat and permit it to cool in the air.

Where the work is of great importance, an oven or crucible is used. A simple oven is shown in Fig. 28 and in Fig. 30, page 724.

A piece of gas pipe is used, large enough to admit the tool or metal to be heated. One end is closed and placed in the coals until the inside of the pipe has been heated to a bright red. Then the part to

Fig. 28

be heated is placed in the pipe and brought to the desired heat. Then, instead of cooling in the open air, the work is placed in a bed of non-heat-conducting material, such as charred bone, asbestos fiber, ashes, lime, fire clay, or sand. The metal should be left for a long period of time, well covered, until cool.

Brass or copper is heated to a low red heat and quickly dropped into cold water.

[1] There is a spelter which can be used in connection with an ordinary gasoline blow-pipe torch (or any heat up to 300° F.) for filling up cracked water jackets, cracked cast iron, steel, brass or bronze. It is claimed this can be used instead of brazing and welding on cracks.

Hardening

The process of hardening is accomplished by bringing the metal to the proper temperature, slowly and evenly, the same as for annealing, and then cooling more or less rapidly, depending on the grade of the steel being worked upon.

The degree of hardening is determined by the grade of steel, the temperature from which it is cooled, and the temperature and kind of cooling bath into which it is plunged for cooling.

Steel to be hardened is placed in the oven and permitted to come to a heat of about 650° or 700°. It then is placed in a heating bath of molten lead, fused cyanide of potassium, heated mercury, or some other preparation designed for the purpose. The degree of heat to which a piece of steel must be brought depends on the percentage of carbon contained within the steel. The more carbon, the lower the heat required to harden it.

It is essential that the cooling bath be of the same temperature during each process of cooling.

Ordinarily, steel is cooled in water, but many other liquids are used. If cooled in strong brine, the heat will be extracted very rapidly and the degree of hardness will be much greater. If cooled in mercury, a still greater degree of hardness is obtained.

If toughness is wanted without extreme hardness, the metal may be cooled in lard oil, fish-oil, or neats foot oil.

In hardening carbon steel, bring to a cherry-red heat, plunge into cold water (brine is best), and hold until hissing ceases; then remove and place in oil for complete cooling.

For hardening high-speed tool steel, see page 726.

When hardening brass, bronze, or copper, the work is accomplished by hammering or working while cold.

Tempering

Tempering differs from hardening, in that tempering is the process of making steel tough so that it will hold a cutting edge and not crack or check. Tempering makes the metal stronger and the grain finer. Tempering may be considered as a continuation of the hardening operation.

To temper, the metal or tool is heated slowly, to a cherry-red heat, then dipped into water (Fig. 29), to a depth of about ½" or ¾" above the point. When the piece has cooled to the point where the portion above the water has not lost its redness, remove it from the water and quickly rub the end with fine emery cloth.

Fig. 29

While the heat from the uncooled portion of the metal gradually heats the point again, a change of color occurs at the polished point. When a **certain color** has been reached, the entire tool should be completely immersed in water and permitted to remain there until cold.

Colors for different work are as follows: Wood saws and springs: **dark blue,** 600°; cold chisels and screwdrivers: **dark blue** or **light purple,** 600° or 520°; punches, drills, and wood-working tools: **brown,** 510°; taps and reamers: ordinary **straw color,** 450°; lathe tools, planers, shapers, and slotter tools: **light straw color,** 430°. Colors darker than the dark blue, ranging through green and gray, signify that the piece has reached its ordinary temper, which means it is partially annealed.

After a **spring** has been properly hardened by dipping in fish-oil or lard, it may be held over the fire while still wet with the oil and permitted to catch fire. After the oil burns off the spring, it has been properly tempered. Self-hardening steel should never be placed in water.

Drills and small tools can be tempered quite well in a flame. Larger parts are better tempered on an iron plate on which has been placed a thick layer of fine sand and the flame allowed to play underneath. This insures the part being uniformly tempered.

Difficulty is often experienced in lathe work on **nickel-steel stock** through the failure of the tool to retain its cutting edge. To overcome this, heat the tool nearly to white heat and plunge it into kerosene oil. See also, page 725.

Case-Hardening

The process of hardening the surface of the steel, leaving the inside strong and tough, is termed "case-hardening." More carbon is added to the surface of the steel, which offers good wear-resisting qualities and has the effect of forming a very hard coat on the outside while leaving the inside practically unaffected. In other words, the outer surface only is hardened, as for instance, gear teeth or nuts which are hardened to only about 1/50" deep (see page 725).

Example of Case-Hardening Steel

The outer surface of any piece of soft steel may be made hard by case-hardening. Its purpose is to increase the strength and wearing qualities of the steel. All machine work to be done on the steel should be done before the case-hardening, as grinding alone can be done afterward. (If any part of the piece must be left soft, this may be done by covering that part with asbestos paste or paper.)

The hardening compound: Mix 9½ parts of fine charcoal with 2½ parts of table salt. Place 2½ parts of kerosene oil in a dish, and put with it as much sawdust as is required to soak the kerosene up. Now mix the sawdust and oil with the charcoal and salt. This compound may be used many times.

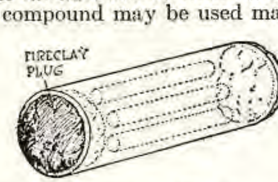


Fig. 30. Case-hardening steel. The pieces are packed in a pipe with the hardening compound—but they must not touch

The crucible: Get a piece of iron pipe long and large enough to hold the pieces to be hardened (Fig. 30). Pack the pieces in this pipe with the hardening compound. Do not let one piece touch another, or touch the pipe side, but keep them well apart with the compound. Now close both ends of the tube with fire clay.

A large forge fire is necessary for heating the pipe, and the pipe should be heated to a bright-red heat. The length of time varies, depending on the size of the pieces and the depth of case desired.

Ordinarily two hours at bright-red heat will give 1/16″ case. This heat should be held as evenly as possible to give an even case and reduce warping effects.

To produce the maximum strength, two heat treatments are necessary after hardening. First heat each piece to a bright red and plunge in oil. Then again heat it to a dull red, and plunge. This will give a fine grain, both in the core and in the case.

Quick case-hardening: If a thin case is desired, this may be applied quickly by heating the piece to redness and sprinkling the part to be hardened with potassium cyanide. Keep the temperature constant for 4 or 5 minutes, then plunge the piece in water or oil. An exceedingly thin case will result that will increase the wearing qualities of the steel, better its appearance, and prevent rust.

To harden tools quickly: The tool should be heated to the correct temperature and then thrust into a potato, after which draw to the proper temper.

Another Method of Case-Hardening

It is possible **to case-harden small pinions** quite well by bringing them to a uniform bright-red heat and plunging them into finely-powdered yellow prussiate of potash, repeating the operation three or four times, and finally plunging into clean cold water while still at a red heat. The mild steel absorbs carbon from the potash to a depth of about 1/50″, and this surface hardens perfectly on the final cooling. Nuts so treated resist rough usage with the spanner much better than an ordinary soft-surface nut.

In treating parts of this class it is, however, important to remember that the threaded part should be filled up with clay so that it does not come in contact with the carbonizing material, otherwise it will be certain to be spoiled. Any roughness of the surface, such as on the teeth of pinions, can be smoothed off with emery cloth wrapped over a thin flat file. Parts made from tool or high-carbon steel are readily hardened by making them red-hot and plunging them into cold water. The correct heat is important, because if the parts be heated to a very bright red, they may be spoiled or decarbonized, and if heated to a white heat, they will certainly be decarbonized. On the other hand, if heated barely red, the parts will not harden.

Straightening Warped Pieces

Uneven heat and uneven cooling warps the steel. Case-hardened pieces cannot be straightened by pressure or by pounding, as this cracks the case.

To straighten a warped piece of case-hardened steel:

1. Find the high or "bowed" part. Mark this with a chalk line.
2. Heat the piece slightly—never near a red heat. (The amount of heat depends on the warp, and can be determined only by trial.)
3. Clamp the piece in a vise between the blocks, as shown in Fig. 31.
4. Direct a stream of water at the chalk line. This will contract the long side and make the piece straight.

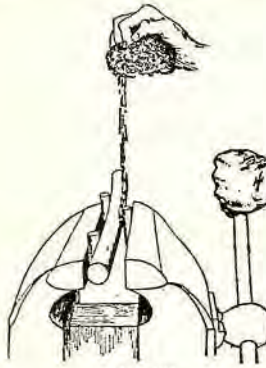


Fig. 31

How to Make Lathe Tools

High-speed steel should usually be heated until the tip of the tool starts to melt, and then plunged in oil, or buried in common salt until thoroughly cool.

High-carbon steel gives the best results when heated to dull red and plunged in oil.

Only **the tool point** proper should be heated to the plunging temperature, the heat being applied slowly at first, to be followed by the blast being turned on and the point heated to the required plunging temperature.

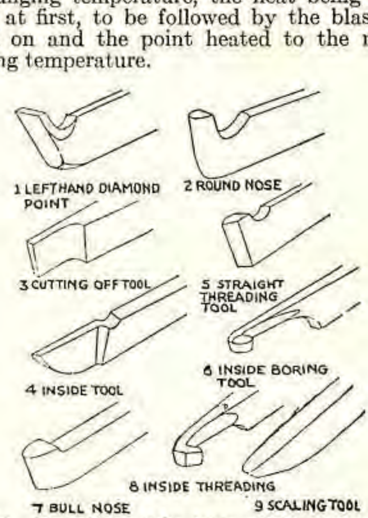


Fig. 32. There is a tool for doing each job most efficiently.

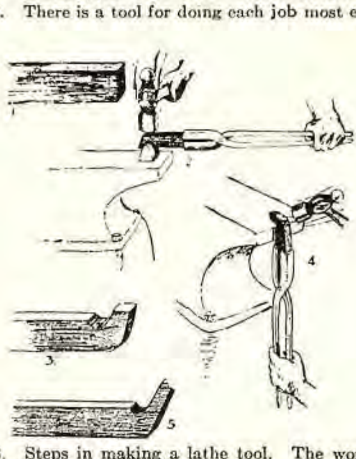


Fig. 33. Steps in making a lathe tool. The work hould be done during one heat.

The tool should be plunged into the oil **when the heat is increasing,** and in the case of carbon steel at the instant the point reaches the plunging temperature—dull red, the fusing temperature in the case of high-speed steel. This is particularly necessary with high-carbon steels, as heating the steel white hot, allowing it to cool to dull red, and then plunging it in oil will make a poor tool.

High-speed steels, after hardening and grinding, are ready for use. Carbon-steel tools, however, must be tempered.

This may be done in two ways, the best being to plunge only the point of the tool in oil after heating to a dull red, thus leaving some heat in the heel of the tool.

When the point is black, remove the tool and rub the cutting edge with emery paper mounted on a stick. Watch the point closely, and as the heat is driven from the heel to the point, the color of the surface being polished will turn light straw, dark straw, and blue. When the point of the tool is straw color, plunge the whole tool in oil and cool it entirely.

The **other method of tempering** is to cool the tool after the first heating, polish the point, slowly heat it again until straw color, and then plunge it.

Almost any grinding wheel may be used for grinding the tool but care must be taken not to draw the temper or burn the tool. The tool should be held lightly against the wheel and frequently cooled in water. Grind the tools to the shape desired, following as closely as possible those illustrated. Finish the cutting edges with an oil stone.

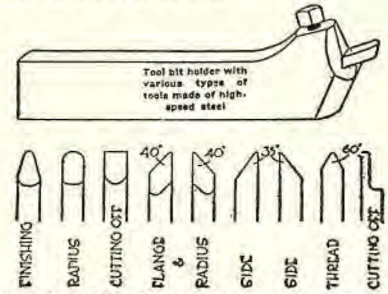
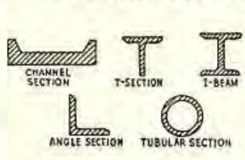


Fig. 34. **A tool bit-holder and a set of high-speed lathe tools.** Excellent for repairshop purposes. They cover a great variety of work. Tool should be changed to suit the work, rather than regrinding tool each time.

Channel, Angle, I-Beam, etc., Sections

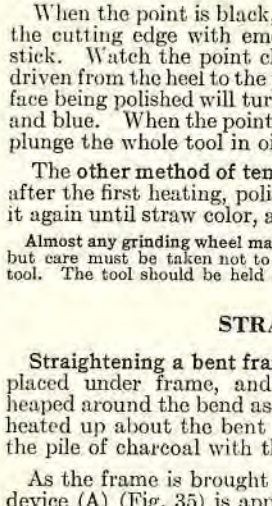


These terms are often used in connection with some of the metal parts of the automobile. For example, many front axles and engine connecting rods are **"I-beam section,"** and parts of the chassis frame are often **"channel section."** The terms or names are derived from the shapes, as shown.

STRAIGHTENING BENT FRAMES, FENDERS,[1] ETC.[2, 3]

Straightening a bent frame: A pan of charcoal is placed under frame, and pieces of charcoal are heaped around the bend as shown; the frame is then heated up about the bent portion by playing upon the pile of charcoal with the flame of a blow-torch.

As the frame is brought to a cherry-red heat the device (A) (Fig. 35) is applied and used in connection with a wooden beam (B) which supports the jack.



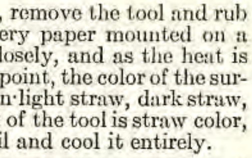


Fig. 35 (left). Straightening a bent frame by heating.

Fig. 36 (right). Another method of straightening a bent frame.[2]

The torch now is set aside, the charcoal removed, and while one man carefully operates the jack and slowly draws the bent member back to its proper shape, another assists the operation by tapping and shaping the heated section with a hammer.

This hammering is quite necessary and an important factor in bringing about a successful result as it assists the molecular action of the steel, and prevents the end of the frame from springing back out of line as the job cools off.

The entire straightening process must be done while the injured section is red hot, and the job must be completed before the red color is lost.[4]

Bent frame horns may be pulled back into place by a chain,[2] providing the force is applied in the proper place. The method of attaching the chain is shown in Fig. 37, and the force is applied by twisting the chain with a steel pinch bar. A jack placed against wooden blocks and with a chain sling over it, as shown, may be used to straighten the side members of the frame.

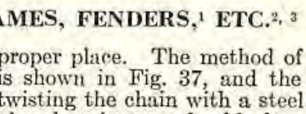


Fig. 37

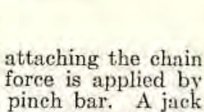


Fig. 38

Frames may be straightened without heating, and sometimes without even dismantling the car, by means of the simple device shown (Fig. 38). It consists of a wooden beam 4 in. x 6 in. x 5 ft., reinforced with iron ¼" thick on each side. The beam forms the base of the device, to which are attached the steel arms which fasten to the frame. A powerful jack is used to apply the required pressure to bring the frame back to normal. A chain may be substituted for either of the arms.

Other methods of straightening bent frames are shown in Figs. 39 to 42.

Straightening dents in bumpers and similar articles can be done in minimum time with the device illustrated in Fig. 43.

[1] **Fender damage is one of the most frequent auto casualties.** The fender business is usually a replacement business. One manufacturer of fenders for replacement on a great number of cars is The Fostoria Pressed Steel Corpn., Fostoria, Ohio.

When assembling a fender, be sure the frame of the car is not bent and start assembly of bolts from the running board side. Do not tighten any bolts until all of them have been started.

[2] **See footnote 3, page 694, where to obtain literature on a hydraulic-operated device for straightening frames, etc.**

[3] See page 690 where to obtain literature on **tools and other equipment for body and fender repairing,** also a book on body and fender repairing including reconditioning a used car.

[4] **Whenever it can be done without danger of cracking, cold straightening is preferred.** This method does not affect the heat treatment that may have originally been given to some frames. Also applies to a front axle and other parts.

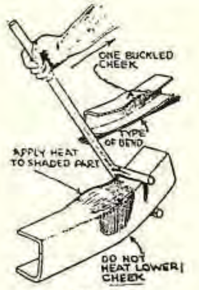


Fig. 39

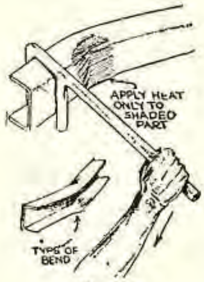


Fig. 40

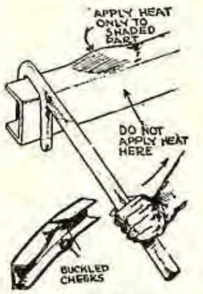


Fig. 41


Fig. 42

Fig. 39. When one cheek and part of the face are buckled, only the bent parts should be heated.

Fig. 40. When the face is buckled very little heat should be applied to the cheeks.

Fig. 41. When both cheeks are buckled heat should not be applied to the face but to the shaded portion.

Fig. 42. Small crimps may be taken out with heat and a monkey wrench.

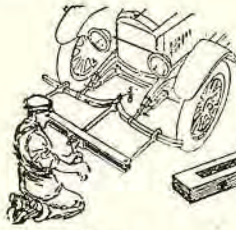


Fig. 43

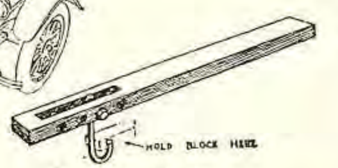


Fig. 44

It is not necessary to remove the bumper from the car. The central member, which does the pulling, may be slid from one end to the other as required, so that a dent in any part of the bumper may be removed.

A fender straightener, made of oak 3″ x 4″, is shown in Fig. 44.

Fig. 45. Easy method of removing dents from fenders with the use of a shaped wood block.

TOOLS[1] AND POINTERS ON STRAIGHTENING FENDERS, ETC.

With a small investment in tools, a little practice, and care in their use, a new department may be developed that will show a profit, and that will also feed other departments.

There is but one secret to sheet-metal straightening: to support all parts except that which is to be straightened, and to go slow, working the metal back to its original form by light blows.

To do this requires many special tools, some of them taken directly from the tinsmith trade; others can be developed on the job.

The Tools

1. **The blacksmith's fuller:** This is used as a hand anvil, either in conjunction with the light mallet, or the light hammer, particularly to remove small dents. The combination of flat surfaces with the rounded edge will cover a wide variety of work.
2. **Half-round file:** After all dents or indentations have been removed by use of the mallets, hammers, and hand anvils, this file is used to remove any small pits or hammer marks.
3. **Heavy wooden mallet:** Used in the preliminary straightening in order roughly to form the metal back to shape. The flat wooden surface does not dent the metal on flat or crowned surfaces.
4. **Light wooden mallet:** The most useful tool of all. After the metal has been pounded back to its original shape, the light mallet, in conjunction with some one of the hand anvils, is used to smooth up the work.

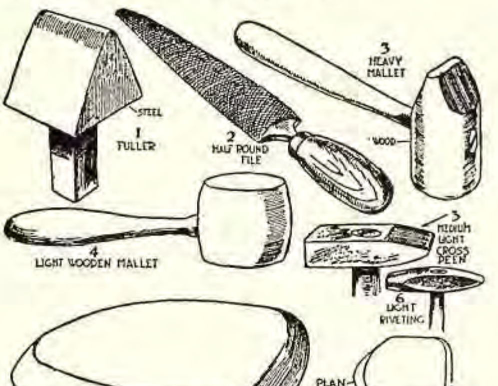


Fig. 46. Mallets, hammers, files, and special tools for straightening fenders, etc.

5. **Medium cross-peen hammer:** A tinsmith's hammer, used to smooth up the surface still further. Wooden mallets will not remove all of the smaller indentations. Hence this hammer must be used as it strikes the required concentrated blow over a limited area.
6. **Light riveting hammer:** Any minor indentation, not smoothed by No. 5 hammer, is taken out by the light riveting hammer. The cross-peen is used to finish corners, prior to filing.

[1] See also pages 683, 690, 691.

7. **Hand block:** A steel block, roughly about 4″ square, and 1″ thick, with the corners rounded and beveled. The curves and beveled edges vary, so that some part of the block may be fitted to almost any part of the work. This and the light wooden mallet are the most used combination.

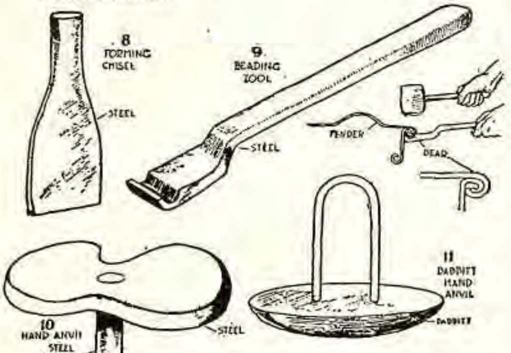


Fig. 47. Some unusual-shaped tools used in straightening fenders, etc. Can be secured of auto supply houses (see pg. 687).

8. **Forming chisel:** Made in an infinite variety of widths, shapes, and sizes. The one shown is used to form sharp corners, or edges. One with a half-round edge is used to reshape a groove. By grinding the edge to the desired form, the metal may be readily driven to that form.
9. **Beading tool:** The side strips on most fenders are held in place by rolled-in edges. When bent, these edges open. After straightening to the original form, the bead may be again closed by the aid of this tool, and a mallet or hammer.
10. **Hand anvil:** An irregular-shaped steel plate or block, mounted on a steel handle. The edges are beveled, and will fit almost any curved surface.
11. **Babbitt hand anvil:** Made in an infinite variety of forms by pouring melted babbitt into an unbent portion of the part to be straightened. When hard, the shape is that to which it is desired to form the bent portion. Make the handle as shown.

Reshaping Bent Metal

It is not usually advisable to attempt to straighten mudguards and lamps having broken surfaces.

The first step is to work it roughly back to its original shape with a heavy wooden mallet. Care must be taken not to break the surface or to draw it beyond the original shape.

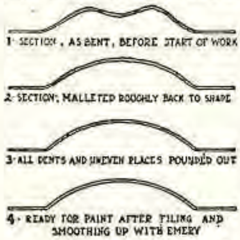
A hand anvil of some sort should always be used in conjunction with the hammer or mallet, to support the edges of the bent surface. Many light blows, rather than few heavy blows, should be applied, and the blows should be drawn, rather than applied dead on. The main thing is to go slow, to feel the dents with the hand anvil, and to direct the straightening blow to the point of bend.

After the surface has been malleted to approximately the original shape, the smaller dents should be removed, using first the small mallet and then one of the metal hammers. This is slow work.

Filing

By passing the hand over the surface, many of the smaller dents may be felt and removed. Some, however, will still remain. These may be located by filing the surface down. The file will hit the high spots and pass over the low spots. Then the low spots may be pounded up to shape.

Finally it will be found that the file will touch all of the surface except the smallest indentations. Then file the whole surface down to a smooth surface and polish with emery paper.



The four steps in removing a dent from a sheet of metal are shown in Fig. 48, the section being that of a crowned mudguard. But whether the part to be straightened be mudguard, lamp or body, the principle involved is absolutely the same. (*Motor World.*)

Painting Fenders After Repairing

Before applying the paint, the surface must be **thoroughly cleaned with turpentine.** This removes all grease that would otherwise prevent the paint from sticking. If the surface is that of a mudguard, the under side should also be cleaned and painted to prevent rusting.

For hurry-up jobs a quick-drying enamel or a black japan may be used to paint the repaired section, the latter, of course, being suitable only for use on black guards or parts. The japan, mixed in turpentine, will dry in about 15 minutes, and, after a few washes, cannot be detected readily.

Enameling Fenders, etc.

Enameling of fenders (baked enamel) and other metal parts requires special equipment such as ovens, enamels, etc. Some of the concerns who supply equipment of this kind are Young Bros. Co., Detroit, Mich.; Gehnrich Indirect Heat Oven Co., Long Island City, N.Y.

Fenders can also be finished with lacquer. See page 756.

Painting Outfit

The subject of painting a car is treated on pages 647 and 756.

A book covering the painting subject, *Automobile Painting* ($1.50), by F. N. Vanderwalker, can be obtained of Geo. E. Watson Co., 62 W. Lake St., Chicago, Ill.

A free booklet, *Modern Cleaning Methods for Service Stations, Garages, Paint Shops,* will be furnished by Oakley Chemical Co., 22 Thames St., New York, N.Y.

Straightening Bodies

Upholstery must be removed or the body must be raised to get at both sides of the surface. Another difficulty is that two men are often required—one to hold the hand anvil and the other to use the mallet or hammer. The co-operation between the two must be perfect, or the anvil will not be back of the hammer blow and the surface will be bent still further. Body work is more difficult.

To Stop Noises about the Car

When seeking to stop **rattling noises** about the car, attend first to the fenders, then to the brakes, hood fasteners, and lamps, and finally to doors and springs. As a rule the fenders, doors, and springs are the most troublesome source of noises on the average present-day machine.

Dent in Gasoline Tank

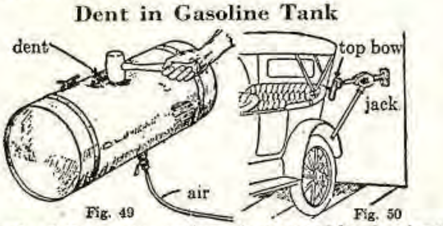


Fig. 49 Fig. 50

Fig. 49. **A dent can sometimes be removed by plugging the vent, filling with water, and applying a 20-lb. air pressure.** A lead or wood mallet is used by tapping gently around the outer edge of the dent. (*Motor World.*)

Fig. 50. An ordinary jack may be used to advantage in straightening bent parts by backing the car up to garage wall.

FITTING EXHAUST CUT-OUT VALVES AND EXHAUST HORNS

Fitting an exhaust cut-out valve: Mufflers sometimes are not large enough, or are clogged up, and offer back pressure or resistance to the full passage of the exhaust. An exhaust cut-out is helpful in this instance and in climbing hills and assists in keeping the engine cool. It also provides a convenient method of ascertaining (by listening) whether all cylinders are firing regularly.

Fig. 51.

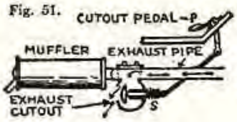
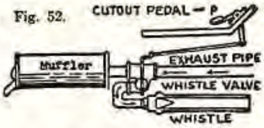


Fig. 52.



Exhaust cut-out valves are installed by cutting a hole in the exhaust pipe just ahead of the muffler (Fig. 51), then clamping valve over the hole.

Note. When ordering an exhaust cut-out, measure the outside diameter of the exhaust pipe to which it is to be fitted, and specify this measurement. (See Index under "Sizes of exhaust pipes.")

The exhaust cut-out is not intended for roaring through towns or villages, but for the purpose of testing the firing and carburetion and is often termed a **tuning valve.**

Cleaning Muffler

Attention to the cleaning of the muffler must not be neglected, for this is a point having a great effect upon efficient operation of the engine.

Although it is necessary to remove the muffler for a thorough cleaning, it is quite possible to effect a satisfactory **temporary cleaning** of the badly obstructed passages by tapping its sides all over lightly with a hammer or mallet. The result will be that much sooty accumulation will be knocked off and blown out through the tail pipe.

Fitting an Exhaust Whistle or Horn

Fitting an exhaust whistle: The exhaust whistle (Fig. 52) is blown by the exhaust pressure.

When fitted to an exhaust pipe, the exhaust is temporarily cut off from the muffler and thrown into the whistle by a special valve attached to the exhaust pipe. Multiple cylinder engines blow a whistle almost steadily, but single and double-cylinder engines blow in jerks or uneven blasts.

WATSON STABILATORS

Watson stabilators are friction brakes to hold the car down against the rebound or throwing action of the car springs. Stabilators do not in any way stiffen the car springs against compression, but leave the springs perfectly free and supple to act as soft cushions in protecting the car and passengers from road shocks. The braking resistance produced by Stabilators is always automatically in **proportion** to the mildness or viciousness of the rebound force.

Just how this proportional resistance is accomplished can be seen from the illustrations. Drum (5), Figs. 53, 53A, is electrically welded to the Stabilator cover member which is bolted fast to drum (6), which is a part of the main base casting which in turn is bolted fast to the car frame. The Stabilator spring is held on mandrel (1), and its power is transmitted to the Stabilator brake shoe (4) by means of ring (3) which passes through a narrow space or slot between drums (5) and (6) and which is hooked into the brake shoe. The spring can be wound to any desired tension by turning mandrel (1) which is locked in any desired position by means of locking pin (2). The spring is thus constantly tending to pull the shoe around the stationary drums (5) and (6) and is likewise constantly tending to wind up the strap (7) which is riveted to the end of the brake shoe (4).

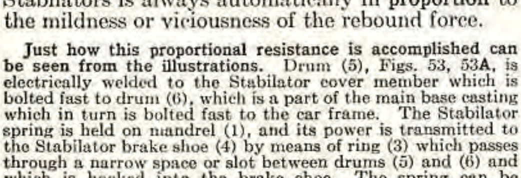


Fig. 53. Showing parts disassembled. First illustration at left is the cover assembly; next, shoe assembly; next, spring assembly; next, base assembly.

Fig. 53A. Sid. .nternal view (left) and front external view (right) with base removed.

While the car is standing, the spring cannot pull the brake shoe around the drums and wind up the strap because the other end of the strap is fastened to the axle of the car and thus holds all parts stationary in spite of the pulling of the Stabilator spring.

When the car hits a bump and the axle and frame are driven together and the car spring is compressed, the Stabilator spring is then no longer held back by the strap and instantly and like lightning turns the brake shoe around the drums and winds up the strap to whatever extent the car body and axle have been caused to approach each other (see Figs. 54, 54A, 54B).

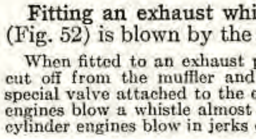


FIG. 54

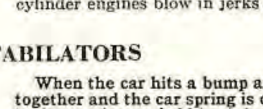


FIG. 54A

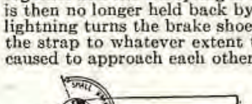


FIG. 54B

As the car spring recoils, forcing the body and the axle apart, the strap must pull the brake shoe back around the drums. This pulling of the brake shoe in this backward direction, being resisted by the pull of the Stabilator spring at the end of the shoe, causes the strap to bind the shoe against the drums, producing a friction brake against the recoil of the car spring. It will be noted that not all of the Stabilator shoe is in active contact with the drums (5) and (6). Only that portion is active which has been run under the strap and is thus bound by the strap against the drums.

Figs. 54, 54A, 54B. Action of the Stabilator during rebound of the spring.

The amount of active braking area is therefore precisely regulated by the extent of spring compression and the approach of car body and axle. Thus, the size of the Stabilator brake is automatically set by each different extent of spring compression correctly and adequately to resist each variation in rebound force, as shown in Figs. 54, 54A, 54B.

Adjustment: There are two points in the adjustment of Stabilators: (1) the strap should be pulled down and attached to the axle bracket so that the strap eyelet (Fig. 55) is about ½" below the top edge of the Stabilator window when the car is standing on a level floor with no passengers; (2) front Stabilators should be wound up by the mandrel (1) (adjusting nut) to the 5th or 6th notch into which the locking pin (2) is held in the cover.

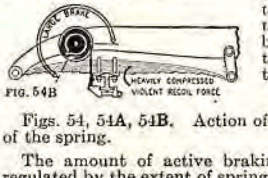


Fig. 55. External view of Stabilator. There are two front and two rear fitted to a car. The front have stronger springs than the rear and are designated by the letter (D) stamped on spring retaining ring, while the rear is designated by letter (B). The eyelet in a front strap is 6" from nearest pair of rivets, while a rear strap is 4".

Rear Stabilators should be wound up to 7 or 8 notches. There are 6 notches to one complete revolution of the adjusting nut.

If these adjustments have been carefully made and if the instruments have been properly installed so that the straps are held in practically a vertical line and are thus not rubbing against either edge of the Stabilator window, the care of Stabilators amounts to practically nothing. Stabilators should never under any circumstances be lubricated. Any form of lubricant will not only deteriorate the Stabilator shoe, but will also cause the Stabilators to cease to hold just as wheel brakes would cease to hold if they were lubricated.

Adjusting wrench: A special adjusting wrench is supplied with each set of Stabilators, and should Stabilators not be giving complete satisfaction the adjustment of mandrel (1) (adjusting nut) should be checked up as follows: Turn the adjusting nut very slightly in the direction indicated by the arrow stamped on the nut. This slight movement will enable you to pull out the locking pin far enough to allow the nut to turn back into the next notch into which the pin will fit. Take a new hold with the wrench and in the same manner allow the nut to go back one more notch and so on until the adjustment is off or "dead." From the "dead" position wind up the front Stabilators to 5 or 6 notches and the rear Stabilators to 7 or 8 notches as mentioned above.

This adjusting of the Stabilators in no way alters the position of the strap eyelet, but by placing more spring tension on the end of the Stabilator shoe, the strap is caused to bind the shoe more tightly against the drums in pulling the shoe backward around the drums, and this causes a greater and increased resistance to the recoil of the car springs.

Any detailed information as to installing, adjusting, removing, or disassembling can be obtained by writing to the Stabilator manufacturers, John Warren Watson Company, 24th and Locust Streets, Philadelphia, Pa.

HOUDAILLE (HOO-DYE) HYDRAULIC SHOCK ABSORBERS

Houdailles are double-acting hydraulic shock absorbers for controlling the action of the car springs by cushioning the compression and checking the rebound. The resistance is not equal both ways, being less on compression of the springs. The hydraulic resistance is compensating, and automatically changes to govern the varying spring movements, whether slight or violent. The resistance is developed by a fluid being forced through check valves and controlled ports.

The absorbing unit has two main chambers, the working chamber and the reservoir. **The working chamber** is divided by a stationary wing "2" in two compartments "AD" and "BC" in which works one end of the oscillating piston "4." In the stationary wing are check valves "1" which permit the flow of fluid in one direction. The ports "3" in the oscillating piston are controlled by a needle valve "5." Each pair, either front or rear units, are of opposite resistance to permit of uniform installation. The internal parts of units of opposite resistance are not interchangeable. In fact, each shock absorber is an individual assembly.

The absorbing unit is bolted directly to the frame or axle and through lever on the oscillating piston, and a pitman rod is connected to the axle or frame. On compression of the springs the wing shaft moves in a counter-clockwise direction. The ball check valves "1" unseat, allowing fluid to pass from "A" to "B" and from "C" to "D" with very little resistance on slight movement, but cushioning severe action. On rebound the balls seat, and resistance to clockwise motion is afforded to the flow of fluid through the controlled ports "3" from "B" to "C" and from "D" to "A" in the wing shaft. The same charge of fluid is used continually in the working chamber.

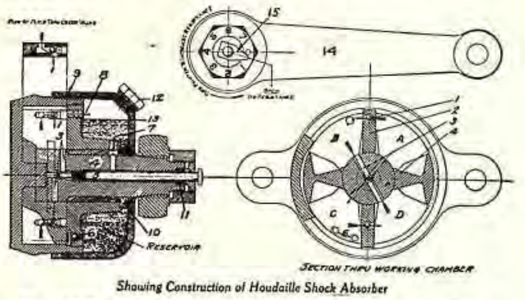
The reservoir contains a reserve supply of fluid. The pumping action of the piston tends at all times to draw in fluid from the reservoir through ball check valves "6" in the flange. The high pressures developed in the working chamber are relieved at "7" before reaching any packing. All fluid escaping from the working chamber is caught in the reservoir to be used over again.

The pitman rod consists of two ball joints on ends of link studs locked in place with check nuts. The ball joints are booted and provided with lubricators.

Adjustment (Fig. 55H): Resistance adjustment is obtained by varying the size of the valve opening within the instrument controlled by the movement of needle valve "5," which has right-hand threads. **Clockwise movement—increasing resistance. Counter-clockwise movement—decreasing resistance.** (Note the needle valve pointer "15" actuates the needle valve stem "5".)

All units are filled with glycerine, obtained at any drug store, with which is mixed 10 per cent denatured alcohol. Never refill with lubricating or other oils. Additional fluid should be added to the reservoir every five to eight thousand miles; under continuous driving, more frequent inspections would be advisable. The absorbers require no other lubrication.

Pitman-rod assemblies should be kept thoroughly lubricated. Semifluid oil or grease of good quality is recommended. The installation should be periodically inspected for loose bolts and nuts. Changing or disassembling outside the factory voids the warranty. The Houde Engineering Corporation, 177-237 Winchester Avenue, Buffalo, N.Y., Manufacturers.



Showing Construction of Houdaille Shock Absorber

Fig. 55H. Construction of Houdaille shock absorber: 1, ball check valves; 2, stationary wing; 3, controlled ports; 4, oscillating piston; 5, needle-valve stem; 6, intake check valve; 7, pressure relief; 8, air vent; 9, cover packing; 10, flange packing; 11, valve-stem packing; 12, filling plug; 13, fluid level; 14, lever; 15, needle-valve pointer.

REPAIRING AND ADJUSTING SILENT CHAINS

Silent chains are used to drive the cam shaft, generator, water pump, magneto, fan, etc., instead of gears.

The Morse silent chain, as used on many cars, differs from other silent chains only in that the Morse employs two pins in the joint, one called the "seat pin" and the other "rocker pin" (see Figs. 56, 63).

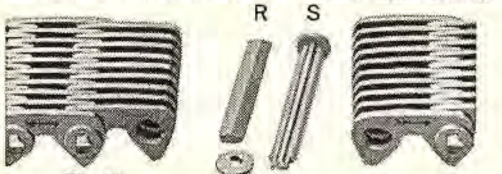


Fig. 56

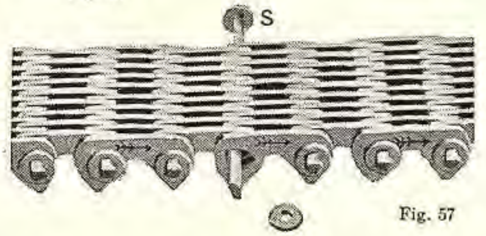


Fig. 57

To connect the ends of this silent chain: Place the chain over the wheels to run in the direction indicated by arrows. On all automobile front-end drives the arrow side of the chain will be the near side, as shown in Figs. 56 and 57.

Bring the ends of the chain together and lap the link plates in regular order, as shown in Fig. 57; insert "seat pin" (**S**) (with washer riveted on one end) from the far side of the chain, taking care that the ribbed side of the pin points in the direction of rotation of the chain as shown in Fig. 57.

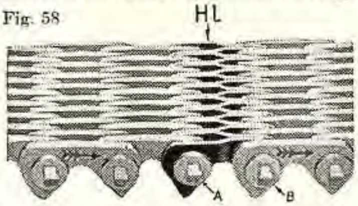
Insert "rocker pin" (**R**) from the near side of the chain as shown by Fig. 57, with the segmental, or pointed, side of the pin against the flat side of the "seat pin," and toward the direction of rotation of the chain. The relative positions of the two pins, when properly inserted, will be as shown by Fig. 63.

Place the washer on the end of the "seat pin" and, after backing up with a bar or wedge, rivet over the end with a few sharp blows of the hammer.

To shorten the chain one pitch by removing the "hunting link": All chains containing an odd number of links must include the thin-leafed section (**HL**) (Fig. 58). This row of leaves (collectively) is called the "hunting link."

To remove it, move the chain until the hunting link is on top of a wheel; then with a chisel in vertical position and the edge of the blade at right angles

Fig. 58

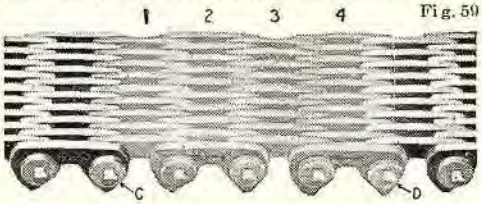


to the plane of the washer, strike sharply with a hammer until washers (A) and (B) are split sufficiently to make them fall off. This releases the pins in the two joints which can then be driven out, and the leaf-plates of the hunting link will fall away when the chain is lifted up.

The chain is thus reduced in length one pitch (one link), and all that is necessary to put it again in running order is to bring the ends together, mesh the link plates in regular order, and make proper connections as stated above. **The "pitch" of a silent chain** is the distance from center to center of the pins.

To shorten the chain one pitch, by removing four links and inserting three, one of which is the "hunting link": Arrange the chain with the arrow side as the near side, either flat (as shown) on some solid foundation, or on top of one of the wheels.

Fig. 59



Select a joint at the **head** of an arrow, and, with hammer and chisel, cut washer (C) (Fig. 59) until it falls off. Move to the right four links and cut washer (D), also at the **head** of an arrow, in the same manner.

Be careful that each severed washer is at the **head** of an arrow, otherwise the leaf-plates of the three-link section will not mesh in regular order with the chain.

Drive the pins from joints (C) and (D) and remove the links marked 1, 2, 3, and 4 in Fig. 59. Insert a three-link section in place of the removed section, making sure that the arrow on the new section points in the same direction as the arrows on the old chain. Bring the ends together, mesh the leaf-plates in regular order, and make connections.

Note. It is necessary to remove only four links and to insert the section of three links, as described above, where the chains are used with an even number of links and do not contain a hunting link (HL) (Fig. 58). If the chain contains a hunting link, it should always be shortened as described in the comments on Fig. 58.

Silent Chain Adjustment[1]

Various methods are used for adjusting chain tension: For instance, if the chain drives the generator shaft, the generator can be moved in the slot holes to adjust the chain tension, as shown in Fig. 37, (page 75), or the shaft on which the sprocket is mounted can be rotated on an eccentric bearing (Fig. 36, page 74), or, if mounted in a separate case, shims can be installed under the case.

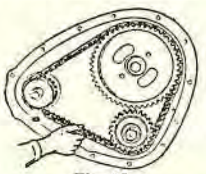


Fig. 60

To adjust while running, tighten the chain until it becomes noisy; then slacken to the point where noise ceases. The chain should be as tight as possible without causing noise.

To adjust where the cover is removed, as in Fig. 60, take hold of the chain and pull the long strand as far as it will go, to test the free movement. The total **free movement** will vary with the **length** between sprockets. If the length is from 5'' to 7'', the total free movement should be $\frac{3}{8}$'' to $\frac{1}{2}$''; if the length is from 8'' to 11'', the free movement should be from $\frac{1}{2}$'' to $\frac{5}{8}$''. When worn and noisy, remove 2, 4, or 6 links each; never an **odd** number.

Chain alignment: When tightening a silent chain by movement of the generator, make sure that it is moved in perfect alignment, otherwise it will cause the chain and sprocket to wear rapidly. This is important. If too tight, it will sing and cause wear.

The Morse adjustable sprocket (Fig. 61) is designed for shafts, such as generator shafts, etc., when the shaft cannot be removed for adjustment.

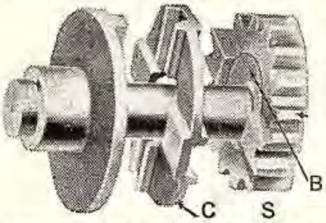


Fig. 61. The sprocket (S) rotates on a bearing (B) which is eccentric to the shaft. (This shaft does not revolve with sprocket (S), but can be rotated for adjustment.) By rotating the bearing (B), the sprocket is moved, thus adjusting the chain tension. The drive is through the sprocket to a plate-type universal joint (C) at the left and thence to the generator shaft. This joint also tends to relieve vibration of the chain, and is called a **vibration dampener.** (Manufacturer, Morse Chain Co., Ithaca, N.Y.)

Some of the engines on which Morse front end drive is used: Auburn six, Cadillac, Case "(Y)", Chandler, Chrysler, Cleveland, Essex six, Flint six, Hudson, Hupmobile, Jordan, Lincoln, Loco Jr., Moon, Oakland, Packard, Peerless, Rickenbacker, Stearns, Studebaker Standard six, Star, Continental Motors and Lycoming Motors.

American High Speed Chain Co., Indianapolis, Ind., (Jno. C. Hoof & Co., Chicago, Distributor) **supplies silent chains for replacement** on all makes of cars using silent chains for engine accessory drive. Other chain manufacturers are Link Belt Co., Indianapolis, Ind.; Dalton & Blach, Chicago, Ill.; The Whitney Mfg. Co., Hartford, Conn.; Duckworth Chain & Mfg. Co., Springfield, Mass. See also supply houses, page 687.

Example of Silent Chain Disassembling and Assembling (Cadillac models 53 and 55)

Detecting looseness: Looseness in the silent chains grows so gradually that it is scarcely to be noticed until the chains have become so loose that they jump the teeth of the gears. This, of course, destroys the timing. **The extent of the looseness may be felt** by grasping the generator shaft and rocking it back and forth. Any great looseness destroys the proper timing of the valves and necessitates a replacement of chains.

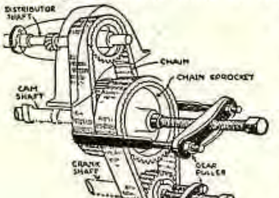


Fig. 62. Using special pullers, both gears and chains together with the distributor housing are removed at once. The generator universal must first be disconnected.

[1] See pages 74 and 75 for remeshing timing gears when using silent chains. Chains have a tendency to wear in the pins, so much so that they will often have sufficient slack to strike the case covering it. When maximum adjustment is reached, usually, a new chain is necessary, or enough links must be removed to take up the slack and thus obtain minimum adjustment again.

Disassembling: After removing all parts so that access is gained to the chains, then turn the engine until one tooth of the cam-shaft-driven sprocket (A) (Fig. 64), which is marked with an arrow, is diametrically opposite the tooth with an (O). A tooth on the crank-shaft sprocket (B) has a similar arrow upon it, and the two teeth opposite each have an (O) mark. All should line up, as shown in Fig. 64.

Apply the special gear puller, as shown in Fig. 62, to the crank-shaft gear; next apply the special cam-shaft gear puller, as also shown in Fig. 62.

Working both pullers together, remove both cam-shaft and crank-shaft gear, at the same time sliding the distributor housing and fan-drive chain forward. All will come off together. (The usual method is first to cut the riveted head of one of the seat pins on the driving chain, and to remove the seat pin and rocker pin. The driving chain is then removed. In refitting the new chains by this method, it is necessary to rivet the seat pins while on the gears and in the case. This is a difficult and tedious job. By the method outlined here, the chains are riveted on the bench easily, quickly, and with a certainty of the work being right.) Place the gears, chains, etc., on bench, removing cam-shaft driving chain.

The repair: Cut off the riveted head of one of the seat pins on the fan-shaft driving chain, and remove the seat pin and rocker pins. Remove the fan-shaft driving chain. Clean all parts with gasoline, and examine the gears for wear. If worn, the faces of the teeth will be ridged, showing the marks of the chain links, and must be replaced.

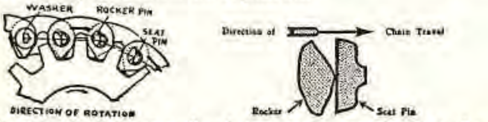


Fig. 63. In replacing the chains, make certain that the **arrows point in the direction of rotation,** and that the rocker **and seat pins are in the position shown.** Otherwise the chain will quickly ruin itself.

Place a new fan-shaft chain over the fan-shaft gear with the arrows on the outside links pointing in the direction in which the chain is to run (Fig. 63).

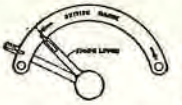
Rivet a small washer to one end of a seat pin in a vise. Bring the ends of the chain together. Insert a rocker pin; then drive the seat pin with its washer into place. Be certain that the rocker pin and seat pin are in the position shown in Fig. 63. Head over the end of the seat pin. Rivet up the new camshaft driving chain in the same manner.

Assembling: Place the cam-shaft gear on the fan chain with mark (O, Fig. 64) in the lowest position. Place the cam-shaft chain on the gear, with the arrows pointing in the direction of rotation. Place the crank-shaft gear into the cam-shaft chain with the marks as shown in Fig. 64. Now slide the whole assembly into place on the engine, driving the gears home with a brass bushing and machinist's hammer. Replace the nut and washer on the crank-shaft end; and then replace the parts which are disassembled.

Fig. 64. The marks on the cam-shaft gear **(A)** should line up with those on the crank-shaft gear **(B)** before the gears are removed, and should be replaced in exactly the same position. Note the arrow points on chain.

The valve timing: The valve timing was automatically cared for in replacing the cam-shaft driving chain as directed, providing the valve tappets have the proper clearance. The exhaust tappet should have .003" clearance, the intake .002"; the exhaust should close and the inlet open on dead center. The inlet should never open at a point more than 1" past dead center on the flywheel. (See page 1052.)

Ignition timing: Open the compression relief cocks, crank the engine until No. 1 cylinder (the one nearest the radiator, on the right-hand side when facing the engine from the front) is on the firing center. The pointer above the flywheel will then be exactly over the mark 1-5 on the flywheel, and both valves of No. 1 cylinder will be closed.



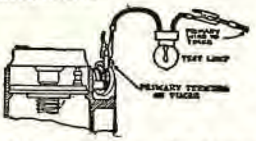


Fig. 65 (left). Position of the spark lever, when timing the ignition. The end of the lever on the quadrant should line up with the point of the arrow, as illustrated.

With the timer open, as shown in Fig. 6A, page 215, loosen lock screw (A) slightly. Then set the spark lever as shown in Fig. 65.

Connect the test lamp into the primary circuit, as shown in Fig. 65A. When the breakers are closed, the light will be lighted, if the ignition switch be closed.

Fig. 65A. (right). By placing a test light in the primary circuit, the exact instant that the spark occurs can be determined, as the light then goes out.

Replace the distributor rotor, and turn by hand until the distributor brush is under the terminal marked No. 1 on the distributing cover. Turn on the ignition switch. The light should light. Turn the rotor very slowly, in the direction in which it is driven by the engine, until the lamp goes out. Remove the rotor; tighten screw (A) of Fig. 6A, page 215.

Replace the rotor and retard the spark. Then move the spark lever slowly back toward the point of the arrow, as shown in Fig. 65. When the point of the arrow is reached, the light should go out. If it does not, reset the rotor and cam as directed.

GASKETS[1]

Gaskets are used on the engine, transmission, rear axle, and other parts of the car, the purpose being **to provide a seal** between two metal surfaces that are connected together. Thin gaskets are generally used on joints that come together fairly even. Metal-to-metal joints would require an expensive "ground joint" to make both surfaces meet absolutely even so that they would not leak. It is for this reason that some sort of flexible material is interposed between the surfaces to make up for the unevenness.

There are several kinds of gaskets: Paper, fiber, asbestos, asbestos wire-lined, metallic, copper, copper-asbestos lined, steel-asbestos lined, cork, and felt; and, in some instances, lead or soft iron can be used.

For engine cylinder heads of the detachable type, a soft copper gasket, lined with asbestos on each side, or copper on each side with asbestos inside (usually the latter), is used to prevent leakage of compression between the cylinder block and cylinder head and also to prevent leakage of water from the water jackets into the cylinders.

[1] Gaskets for cars and trucks are obtainable from distributors or auto supply houses. **Free booklets:** "*McCord Gasket Guide* (also "*McCord Radiator Guide*" and "*McCord Muffler Catalog*" giving information on radiators, cores and mufflers for replacement purposes) can be obtained by writing McCord Radiator & Mfg. Co., Detroit, Mich. (Mention *Dyke's Automobile Encyclopedia.*)

When taking off cylinder head for any purpose, or if there is a water or compression **leak,** a **new cylinder-head gasket** should be used. **In emergencies,** the old gasket can be used if it is not damaged and is carefully applied.

Where old gaskets are used over again, the important point is to see that the surfaces are **clean,** and that the gasket is not damaged. Put shellac[2] on each side of the gasket and apply before it dries, but be sure to scrape and clean the surfaces carefully before applying, otherwise a leak will occur. Alcohol is used to clean surfaces which were previously coated with shellac. Bear in mind that **if there are any rough surfaces, the gasket will leak.**

When using a new cylinder-head gasket, the use of **shellac is not recommended.** It has a tendency to set after the engine has run a short time, which interferes with the final tightening.

One of the leading manufacturers of copper-asbestos gaskets states that while grease and shellac are used in applying gaskets, experience dictates that the best practice is **to see that the face of the head and cylinder block, as well as the gasket itself, are thoroughly clean,** and then to apply the gasket without grease or shellac, as this prevents the soft copper from working into the unevenness in the metal faces. If, however, such a material is used, be sure that there are no lumps or foreign particles in it.[1]

Soaking cylinder-head gaskets in water before applying them is a practice frequently employed, particularly where cylinder head or block may be slightly warped.[3] The moist asbestos tends to more closely conform to the uneven space between a warped head and a flat cylinder block. See p. 151.

In the absence of manufacturer's instructions (which are always best to follow), the order in which cylinder-head stud-nuts can be tightened is shown in Fig. 66. The same *general principle* applies to "fours," "sixes," "eights," and "twelves." A socket wrench is generally used.[4, 1]

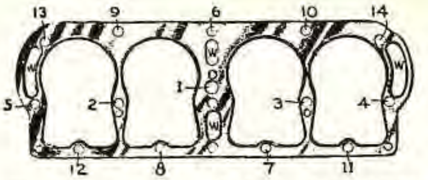


Fig. 66. When putting on a cylinder-head gasket tighten the cylinder head stud-nuts in order indicated above; that is, tighten 1, then 2, 3, and so on to insure against lessening of compression and against leakage of water into the cylinders. In general, start at the center of the head and work toward the ends and sides, tightening the corners last. This illustration also shows the shape of a typical **copper asbestos-lined open edge cylinder-head gasket** used on cylinders with detachable heads. Example is for a 4 cylinder engine.

The stud holes are numbered 1 to 14. The holes in the gasket provided for water circulation from the cylinder head to the cylinder water jacket are the other holes (W). **Sometimes, when gaskets do not fit properly, the water works its way into the cylinder, thus causing water in the crank case, as well as a loss of compression.** See also pages 715, 716.

When applying a new gasket, in order to insure compression in all cylinders, the cylinder head should be drawn down firmly on the gasket and block with an **even pressure at all points** before the later operations of tightening are attempted.

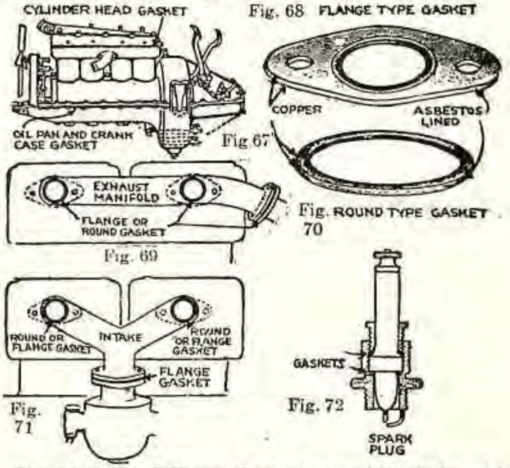
After first drawing down the nuts evenly and snugly, but not tightly, go over them in the same order a second and third time until they are as tight as it is safe to make them. Drawing nuts too tightly and unevenly may result in a broken stud, stripped threads, cracked head, or *distorted* cylinder block.

The final tightening should be done after the engine has been run and is thoroughly **warmed up.** It is advisable to again retighten after a few hundred miles of operation.[1] The *important point* is to have all stud-nuts to the *same degree of tightness.*[4]

A type of gasket used extensively is made of pure copper and asbestos.[5] When properly installed, they will not leak or blow out. See Fig. 66, showing a typical example of this type of gasket, and Fig. 67 showing how it is placed between the cylinder head and the cylinder block of the engine.

Other types of cylinder-head gaskets are: (1) Steel-asbestos gaskets are made similarly to copper-asbestos gaskets except that cadmium-plated steel is used in place of copper. (2) Graphited asbestos gaskets consist of asbestos with one layer of copper or steel. On some types, the copper or steel covers the bottom surface. On some types, the copper or steel is in the center and both top and bottom surfaces are asbestos. In either type, the exposed asbestos surfaces are covered with graphite.

Gaskets can be obtained extra thick for the purpose of reducing compression.



Figs. 67 to 72. Different places where gaskets can be used.

Copper (also brass) asbestos-lined gaskets, termed the "flange" type (Fig. 68) are used extensively for placing between the intake manifold and cylinder (Fig. 71), and also between the carburetor and the intake manifold; between the cylinder and the exhaust manifold; between the exhaust manifold and the exhaust pipe (Fig. 69). The round type of copper asbestos-filled gasket (Fig. 70) is used under spark plugs. See footnote p. 732.

Paper or fiber gaskets are often used on many parts of the car not subjected to high temperatures. Paper gaskets are often used where very close clearances are required, such as on oil pumps, starting-motor mountings, engine timing cases, etc. Paper or fiber gaskets are used in a great many places, such as between oil pan and crankcase, between crankcase and cylinder block, on transmission, rear-axle housing, engine-valve case covers, etc. Fiber gaskets are more compressible than paper and do not require as good a fit between the surfaces.

[1] See also pages 151, 152. **Always follow manufacturer's instructions where possible to do so. On aluminum cylinder heads, flat steel washers should be placed under the nuts to prevent gouging of the aluminum and to facilitate easy removal of head in the future.** [2] **Or gasket cement.**
[3] If badly warped, see **Resurfacing** on page **814B.**

[4] **A wrench which will register the pressure applied** is made by the Cedar Rapids Engineering Co., Cedar Rapids, Iowa. A *free circular* issued by this firm states: "It is important that all stud-nuts and cap-screws be uniformly tightened in motor reconditioning work if unequal stresses are to be eliminated. Uneven tightening sets up strains in the metal that may cause a properly rebuilt engine to lack power or use excessive oil."

[4] See page 691 for other **torque-indicating wrench** manufacturers. [5] Steel-asbestos gaskets are also frequently used.

Paper gaskets should be oil- and water-proof. If not obtainable and it is necessary to make a paper gasket, select a heavy wrapping paper.

Many repairmen coat the gasket with grease in order to hold it in place while fitting the parts together. Shellac is also used.

A gasket in paste form, known as Permatex Form-a-gasket, is applied with finger or knife blade, and the manufacturers claim it produces leak-proof assemblies on gear-case covers, cylinder heads, crank-cases, water jackets, etc.

Fibrous sheet packings that resist the action of hot or cold water, oils, and gasoline and are suitable for such joints as valve and gear covers, oil pans, carburetor flanges, axle housing covers, water connections, etc., where the temperature does not exceed about 200° F., are obtainable. Some of the brands are Seigelite, Vellumoid, Victorite.

Cork gaskets are not suitable for cylinder heads, as they would burn or blow out under the extreme heat and pressure to which they are subjected in this particular spot. The cork gasket is used extensively for the same purposes mentioned in connection with paper gaskets, such as for oil, water, and gasoline connections. They are particularly adaptable for pressed-steel parts because of their flexibility, which enables them to fill up all the rough spots and unevenesses in such parts. Their main applications are between the oil pan and the crank case; on the oil-pan bottoms; on the valve-plate covers; in the water-manifold connections; in the timing-gear case; on hand-hole covers on the transmissions, clutch and differential housing, and hub flanges of wheels, and for all similar purposes.

Felt gaskets are used to a great extent for oil retainers, washers, etc.

Gaskets of all kinds can be obtained of automobile supply houses.

To remove paper on the running-boards of new cars: A new car usually has brown paper over the running board and floor boards, to protect them in transit. A good way to remove this neatly is to fasten a safety-razor blade in a small block of wood and trim close. No ragged edges will then be in evidence.

Cutting Gaskets

Perhaps one of the first things at bench work that a young repairman is taught on entering a shop is that of cutting gaskets.

The gasket between the base of the cylinders and the crank case and the cover of the gear box are usually made of paper (or of cork, which is obtained already cut. Paper gaskets are also obtainable from the manufacturer, already cut).

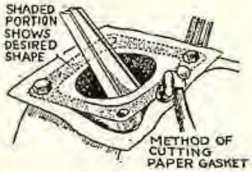


Fig. 73

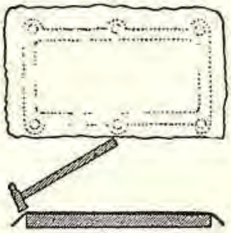


Fig. 74

Fig. 73. Cutting a gasket for the lower part of the cylinder, where it fits to the crank case.

Fig. 74. Cutting a gasket for the transmission cover.

If care is not exercised in removing a cylinder from the crank case, or other parts, the paper gasket may easily be damaged by part of it adhering to the cylinder and another part to the crank case. Should the gasket be ruined by any chance, a new one can easily be made in a few minutes.

Cutting gaskets: A sheet of fairly heavy wrapping paper should be obtained and a hole made just large enough to accommodate the piston. The paper is then rested on the crank case or cylinder (Fig. 73), and with the aid of a ball peen hammer tapped all around the edges. It is, however, best first to mark the holes for the holding-down bolts, and to insert the latter to hold the paper in position.

When making the corners and also the holes for the bolts it is best to use the peen or round end of the hammer. It is not necessary to strike the paper a hard blow, a series of slight taps only being required. With these, it will be found that the gasket will have a nice clean cut edge, and will conform exactly to the desired shape.

The hardest part of the whole procedure is to keep the paper in place on the crank case, but if the holes for the holding-down bolts are first made and the bolts are then inserted, as shown in the illustration, no difficulty should be experienced.

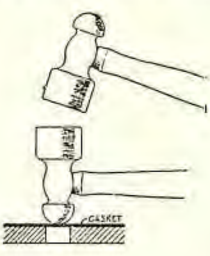
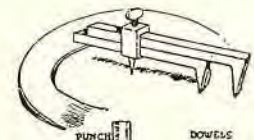


Fig. 75



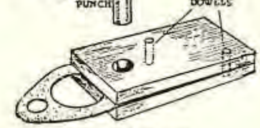


Fig. 76 (upper)
Fig. 77 (lower)

Fig. 75. When cutting gaskets from metal and asbestos packing, felt, and other materials, it is sometimes difficult to **cut bolt holes,** especially those close to an edge, without damaging the material. A way out of the difficulty is to use two round-headed hammers, placing the round head of one over the hole and striking it with the other.

Ball bearings of various sizes are also useful in cutting small holes, such as for studs, in gaskets. After the gasket is cut to shape by hammering around the edge of the gasket flange, a ball bearing is put over the hole and hammered until the hole is cut in the gasket. This method produces sharply defined edges. In cutting paper gaskets it is advisable to grease the paper first, so that it will stick to the surface.

Fig. 76. **A device for cutting circular gaskets** may be made out of two pieces of steel shaped as shown and fitted with a clamp which forms the center. The two cutting members are adjustable, so that practically any size of gasket may be cut.

Fig. 77. It is difficult to cut holes in gaskets and not have ragged edges. When there are a great **many holes of a given size to be made, it is advisable to construct a die** consisting of two plates of metal doweled together and with a hole or series of holes through which the dies may be pushed. The gasket material is slipped between the plates, and then the die is forced through with a hammer.

Another method is to file a chiseled edge on short sections of different sized iron pipes, which can be used as punch cutters.

Cutting gaskets for gear box or transmission cover: The same principle applies here (see Fig. 74). Be careful in tapping to see that the edges are not broken. Sometimes it is possible to press the paper by hand and to make indentation enough from which to cut the gasket.

Other gaskets, such as those made from mobilene and asbestos service sheet packing, are made in a similar manner, but are usually marked off by pressure of hand or finger, when placed over the part to be fitted, and then cut out with a sharp knife.

Water Pump Packing

Water pump packing can be obtained in three forms: (**1**) asbestos twine treated with graphite; (**2**) molded split rings of asbestos and graphite; (**3**) asbestos and graphite paste that is inserted into the packing nut.

Adjustment. Tighten packing nut only when leaking water. On some engines a spanner wrench or blunt punch can be used to tighten the notched packing nut or gland; on others, a special wrench is required, and on some the packing nut is hexagon. Adjustment should be made, on old or new packing, only when the water is hot and tested with engine at idling speed. Do not adjust the packing too tight as it may score the shaft and cause unnecessary wear on the fan belt (if driven by belt as explained on page 151). One prominent manufacturer's instruction book reads: "Packing nut should not be drawn tighter than from 1 to 2 flats more than necessary to stop the water drips in order to avoid excessive friction on pump shaft."

Repacking. When the packing nut has reached its limit of travel against the packing, install new packing by backing off nut, removing old packing (not on all cars) and installing new packing. Be sure that the pump shaft is smooth before packing it. When installing packing rings having joints, it is advisable to place the joints between 120° to 180° apart to prevent a possible leak. If installing "twine" or "wick" packing see page 150.

Packless type of water pumps. Water in this type is prevented from entering the pump body by a *seal* which is under spring tension. This type only requires lubrication at regular intervals.

Lubrication: On some types of water pumps non-soluble waterproof "water pump grease" is applied to the packing and pump shaft where grease is supposed to be used for lubrication, for reason explained on page 151. Many types of water pumps use oil; some have an oil reservoir; some use only a few drops; some have two places to lubricate and some are self-lubricating. Always follow the *manufacturer's recommendations* for adjusting, repacking and lubrication.

Shellac

Shellac is a preparation to insure a tight joint. Shellac dries up; but a way to keep it and handle it is to have a wooden stopper (Fig. 78) which can be used for applying the shellac as well as serving as a stopper. Another plan is shown in Fig. 79.

Fig. 78

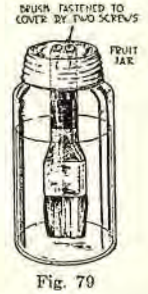


Fig. 79

How to mix and use shellac: Secure an open-mouth bottle; fill nearly full of flake shellac, and pour in alcohol, and let it dissolve. This will make a very thick solution. To make it thinner, put in fewer flakes of shellac. The flakes can be secured at any drug store. Only the smallest possible amount should be used, and this should be quite thin.

Shellac is not used as much for gasket work as formerly; other products which possess a greater heat resistance and which can be more easily separated without damage to any part have taken its place. Shellac is often used in emergency cases, such as a filler for a damaged gasket where a new one is not obtainable, or where there is difficulty in stopping a water or oil leak, as it makes a very tight joint.

A new gasket should always be used if possible, but if one is not available, shellac can be used to help make a tight joint. Clean the shellac from the surfaces and also clean the old gasket with alcohol. Shellac can then be used on both sides, as there will probably be some rough surfaces still left. Draw gasket up tight before the shellac dries and draw up again after it dries. If used on a cylinder head gasket, run the engine to warm it up, and tighten again after running car a day or so. If the surfaces are not clean on an old or new gasket it stands a chance of leaking, therefore care must be used to tighten it. See also pages 151, 152, 733.

To make leak proof joints on gasoline, grease, oil and water connections, products known as "*Form-A-Gasket*" and "*Gasket Goo*" are recommended (can be obtained at auto supply dealers).

RADIATOR REPAIRING

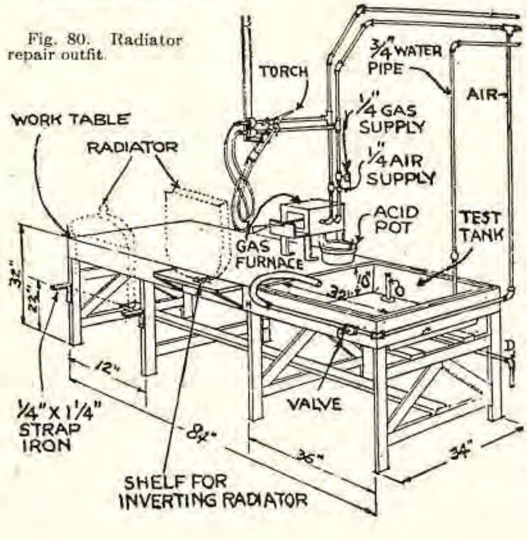
Radiators are divided into two classes: **tubular radiators** with straight vertical tubes with crimped fins, as in Fig. 14, page 147, and with vertical tubes with horizontal fins, as in Fig. 15, page 147. The **cellular type** comprises both the tubular type, resembling the genuine cellular, as in Fig. 18, page 147, and the cellular type, as in Fig. 19, page 147.

Equipment

The equipment necessary for repairing tubular radiators, as well as those of the cellular type, consists of the following:

1. **A table,** as shown at (1) (Fig. 81) for assembling or disassembling. The repair outfit (Fig. 80) also includes a work table, dimensions of which are given on the illustration, covered with tin, and with racks for turning radiators upside down or otherwise.
2. **A test tank,** as shown in (2) Fig. 81, or in Fig. 80. Air pressure is necessary, but not over 8 or 9 lbs.
3. **A compressor** (12) (Fig. 81) should be provided for the air pressure, and a hot-water tank can be used for an air receptacle with a gauge (8) on the tank to indicate pressure. This air tank can be used for testing radiators, as explained on pages 736, 737. It can also be used for the air supply to the torch (Fig. 80), in connection with gas.

Fig. 80. Radiator repair outfit.



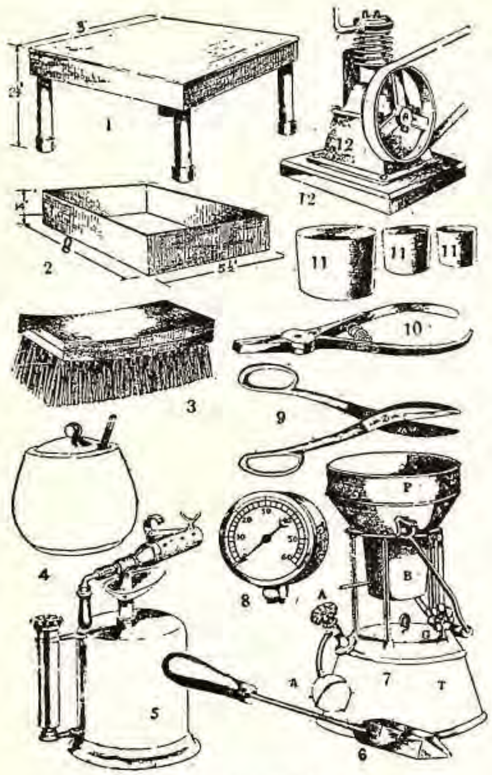


Fig. 81. Radiator repair tools and devices.

4. **A gasoline fire-pot torch** (7) (Fig. 81) or a gas furnace (Fig. 80) must be provided for heating the soldering irons.

5. **Two soldering irons** (6) (Fig. 81) heavy enough to convey sufficient heat to the work. The iron should taper to a flat point as in Fig. 82. Long-pointed irons for core work are also necessary.

6. **Acid** (4) (Fig. 81) must be kept in a stone pot. It is made of commercial muriatic acid cut with zinc, that is, zinc is placed in the acid and left in it until boiling stops. It is used for cleaning parts before soldering, and as a flux for soldering. See also page 721 for soldering flux.

7. **A blow-pipe torch** (5) (Fig. 81) must be used, but should be of a type which will give a concentrated or flooding flame. It is used for soldering, loosening, or removing sections.

8. **A combined gas and air-type torch** (Fig. 80) is necessary. This torch should throw a fine needle-point flame (see page 751). With such a torch and with wire solder, inside core leaks, honeycomb radiators, and hard-to-get-at places can be reached, but a torch of this kind must be kept in motion, otherwise part will be burned.

9. **Wire brushes** (3) for cleaning off rust. See also page 740 for small scrapers.

10. **Metal snips,** or shears (9).

11. **Weaver pliers** (10) for straightening core material, also rods for running through bent tubes.

12. **Rubber plugs** (11), ½" to 4" diameter in ¼" sizes for closing openings in radiators when testing with air. See also pages 737, 740.

Soldering Pointers

Solder: Use "50-50" solder. It can be secured in wire or bar form. See also pages 738, 720.

The soldering iron should be well tinned. When iron becomes so dirty that it cannot be cleaned on sal-ammoniac it should be filed and re-tinned.

To tin an iron, heat it, dip it into the acid, and rub it on a piece of sal-ammoniac, at the same time holding a bar of solder on the iron and thus coat its surface with the solder. Or, if a pot of molten solder is at hand, dip the iron into it. Never permit the iron to become red hot.

To clean old fittings hard to solder, heat the part light red and plunge it into raw muriatic acid.

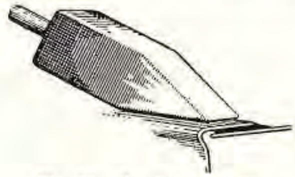


Fig. 82. Sweating a seam.

Sweating: When extra strength is desired, seams are "sweated." Sweating is accomplished by first putting the soldering iron (Fig. 82) on the seam to be sweated so as thoroughly to heat the metal. The solder is then flowed on to and between the pieces of metal to be united. The iron is again laid on the seam, in order to make sure that the solder flows in as deeply as possible. The iron must be **very hot.**

Torch for radiator work: Although the soldering iron, which is drawn to a very fine point, is used extensively for soldering radiators in close places, the torch can also be used, especially for reaching the inner part of cells of a cellular radiator. The torch must throw a very fine **needle-point** flame. In the book mentioned in footnote, page 740, it is stated that the best needle-point flame is obtained from gasoline.

A very desirable radiator torch is one manufactured by F. L. Curfman Mfg. Co., Maryville, Mo., **which will burn gasoline gas,** the gas being produced by forcing air through gasoline. Air from any source can be used just so the flow is steady. A reducing valve in air line from high-pressure tank or a small rotary compressor meets this requirement. This torch has a larger range of flame adjustment than from other gases, producing a heavy brush flame to a long needle flame.

A small air compressor that can be operated from a ¼ to ⅛ h.p. motor and which will compress from 7 to 10 lbs. pressure is also made by the same concern. With this compressor no supply tank is necessary; simply turn on the motor and there is a continuous supply of air which can be used **for testing radiators** as well as **for torches.**

The compressor has two openings, one for **compressing,** the other creating a **vacuum** which is sometimes used to suck the anti-leak compound from the holes in a radiator.

Testing Radiator for Leaks

After the removal of the radiator from the car, the first thing to do is to test it. The inlet, outlet, and filler cap must be plugged, so that air pressure may be applied to the overflow pipe. Then if the radiator be put under water, the bubbles will show where the leaks are.

When removing a radiator, the hose and flange are left on, as shown in Fig. 83. If the radiator is to be repaired, then the lower hose is removed.

The openings in the radiator are then stopped up by means of expanding rubber plugs, or by an arrangement as shown in Fig. 84. Can be secured of auto supply houses (see page 687). One plug is inserted in the intake, another in the water return, and another in the filler opening.

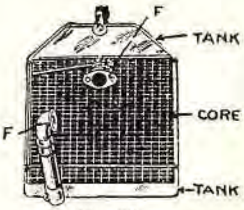


Fig. 83


Fig. 84

The air pressure is applied to the radiator through the overflow pipe, by slipping the rubber hose from the air line over the overflow tube. The radiator is then immersed in a tank full of water (Fig. 85), and the **leaks determined by the bubbles.** The leaky parts are then marked.

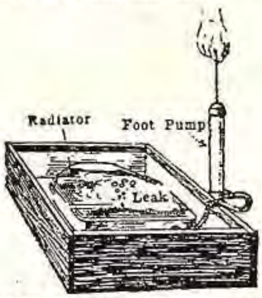


Fig. 85. Testing a radiator submerged in water with air pressure.

Another method for closing up a radiator for testing is to solder a piece of tin in the filler opening and to put a rubber plug in the bottom outlet and bolt a rubber gasket at (F) (Fig. 83). Then place the air-pressure hose on the overflow pipe.

Another plan is to remove the radiator from the car and plug up all but one opening; then run the tube of a tire pump through a **cork** and place the cork in this last opening.

Note. **A radiator should never be subjected to a pressure greater than 2 to 4 lbs.** New units will withstand from 8 to 15 lbs., but that is seldom necessary.

The next procedure is to determine if the radiator is a tubular or cellular type, by studying page 147.

Removing Core of Radiator for Repairs

The core of a radiator consists of all the tubes or cells through which the water flows from the upper tank to the lower tank (see Fig. 83). The core is connected to the upper tank and the lower tank by projecting it into the tanks and then soldering it.

The core can be a tubular or cellular type, as shown in Figs. 86 and 87.

In the cellular type (Fig. 86), the water flows **around** the cells and air circulates **through** the cells, whereas **in the tubular type** of core, the water flows **through** the tubes (Fig. 89), and air circulates around the tubes.

When a **radiator core is damaged badly,** the core must be removed. Place the radiator on the repair bench, face down, and unsolder the lugs which hold the shell to the body. Then with a torch and a pry bar (Fig. 87), unsolder the core from the bottom tank; next unsolder the core from the top tank, starting at the lower flange or header. The core can then be removed. Do not hold the flame in one place too long.

Fig. 86

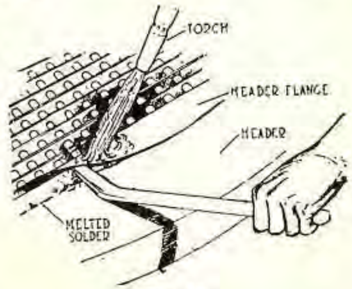


Fig. 87

Fig. 86. Cellular type of radiator core.

Fig. 87. Tubular type of radiator core.

Repairing Radiator Tubes

To straighten damaged radiator tubes when the core is removed, use a long steel bar (Fig. 88). This will also clean the tubes and all tubes should be subjected to this process.

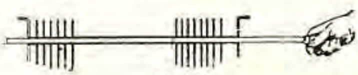


Fig. 88

When only one or two tubes are damaged,[1] the tube can be cut out of service altogether; for instance, see (A) (Fig. 89). Make holes at the extreme top and bottom of the tube and as close to the header as possible, using a prick punch. Flow solder into the holes liberally, and let it set until hard. See (A) (Fig. 89).

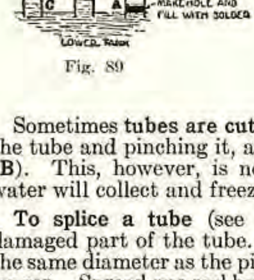


Fig. 89

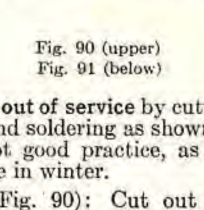


Fig. 90 (upper)
Fig. 91 (below)

Sometimes **tubes are cut out of service** by cutting the tube and pinching it, and soldering as shown at **(B)**. This, however, is not good practice, as the water will collect and freeze in winter.

To splice a tube (see Fig. 90): Cut out the damaged part of the tube. Select another piece of the same diameter as the piece removed, but slightly longer. Spread one end by reaming with a punch or any tapered tool, and make the other end smaller by making a few cuts in it lengthwise, and then compress the end. Fit the large end **(D)** over the end of the tube being repaired, and the other end over the other part of the tube, and solder.

[1] It is not necessary to remove the core or to tear down the radiator for slight repairs. Simply force the fins to one side and straighten them after the repair. Before making a repair, it is, of course, necessary to test, in order to find out where the leak is. This should then be soldered without removing the core, if it is only a slight leak.

Another method (see Fig. 91) is to wrap a piece of light brass or copper around the injured part of the tube, so that the edges of the patch just meet or fail to do so by a slight margin, and then to solder it.

There are many methods of repairing radiators: A method for repairing a leaky tube is shown in Fig. 92.

The radiator is placed on a bench, and the leaky part of the tubes is heated with a blow-torch. When quite hot—a little hotter than boiling—muriatic acid soldering solution is poured through the fins, all over the leaky tubes, to clean their surfaces. The cleaning process is very important.

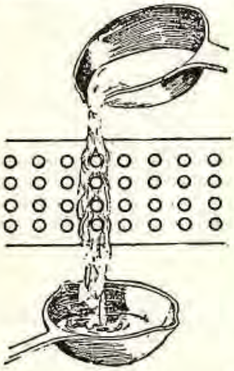


Fig. 92

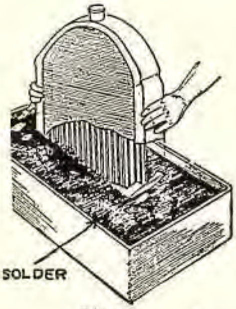


Fig. 93

Fig. 92. Illustrating how solder is poured over the leaky radiator tubes.

Fig. 93. Illustrating dipping a radiator in a solder bath.

A ladleful of solder is then melted. The radiator is bolstered up from the bench on blocks, and the melted solder is poured through the fins, over the leaky tubes. Note the method of catching the excess solder.

Then the radiator is turned over and the solder is poured in from the other side in exactly the same manner.

A little more acid is then added and a torch is applied to melt the solder and sweat it into all the leaks, closing them permanently.

What is known commercially as "50-50" solder is adapted to this work.

Though leaks and splits of quite a large size may be fixed in this way, it is occasionally necessary to tear the radiator down and to put in new tubes. The hardest part of the job is tearing the radiator down to the core and building it up again. New cores can be purchased with the top of the bottom tank soldered on.

There are many other methods of cleaning and soldering leaks. The leaky parts are often scraped bright with small **scrapers** made from three-cornered files with the teeth ground off, and then acid is applied and the parts are soldered with **a soldering iron made especially for this work** by taking a 1½ lb. soldering iron, heating it red hot, and drawing out long and slim. Then tin the iron carefully.

Soldering by dipping: In large shops the tubular radiator is dipped into a solder bath (Fig. 93). The parts to be soldered are thoroughly cleaned and treated with muriatic acid solution, then dipped. The solder naturally will adhere only to the parts that are clean. **The solder** is made of 50 per cent lead and 50 per cent bar tin melted together.

Radiator Fin Repair

Where the lateral fins of a tubular radiator (Ford type) have been removed for a repair, a false fin (**D**) may be made as shown in Fig. 94, by folding a ¾" strip of light brass, copper, or even sheet iron longitudinally upon itself to make a double strip ⅜" wide. Bridge it across the gap in the fin or fins, and then paint the patched place the same color as the rest of the core.

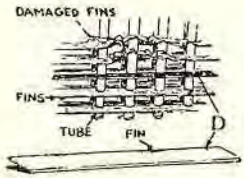


Fig. 94

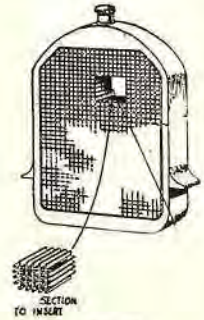


Fig. 95

Repairing Cellular Cores

The cellular core is removed from the tank by melting the solder with a blow-pipe torch. As inch by inch is melted away, insert a piece of sheet iron between the core and the tank, so that when the flame is removed the solder hardens and the core and tank are not reunited.

Inside leaks in cellular cores[1] can be soldered with a torch throwing a fine needle flame. Be very careful, however, to not burn the light metal up. Squirt acid or soldering flux on the spot with an ordinary oil squirt can. Deposit solder on the spot, using wire solder and the blow-torch. Smooth the solder over afterward with a small thin iron. A suitable iron for this work may be made from ordinary ¼" iron.

To remove a leaky cellular section from a core, the leaky section is **cut out** (Fig. 95) **with a scroll** or hacksaw blade or with a special chisel or torch. A new section of the same dimensions is built up, inserted in the core, and properly soldered.

It is advisable to secure an old radiator core and to practice soldering it before attempting a repair

Remember, when soldering parts of the radiator, that the metal must be scrupulously clean before the flux is applied, or else the solder will not hold.

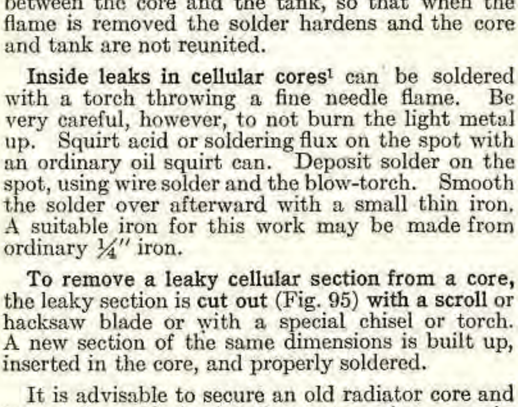


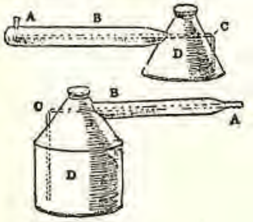
Fig. 96

[1] It is not necessary to remove the core from the radiator shell unless there are several leaks or the core is damaged.

After completing the soldering, file smoothly and then place the radiator in the water and again test it with air pressure, in order to see if the leak is properly repaired. **Small leaks** [1] are dealt with on pages 151, 152.

Painting a Radiator

It is very difficult to paint a radiator quickly and thoroughly with a paint brush, and the usual plan, where a great deal of the work is done, is to dip the radiator in a paint solution. A very satisfactory job can, however, be quickly done with a spraying outfit.[2] A simple home-made device is illustrated.



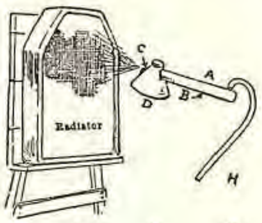


Fig. 97. **A home-made sprayer** for painting radiators. Two sizes and designs are shown, both of which comprises a can (D) for the paint, consisting of a mixture of lampblack and turpentine, a hollow cylindrical tin handle (B) attached to the can, and air pipe (A) passing through the handle and through the can, as indicated by the dotted lines; and another similar pipe or tube extending downward at right angles from the one end of the horizontal tube into and near to the bottom of the can, as is also indicated by dotted lines. This is an adaptation of the principle employed in most atomizers.

Fig. 98. **Showing how the paint is sprayed on the radiator.** When a stream of air is forced through the air tube (H) and (A), passing through the handle, and directed across the opening (C) at the top of the vertical tube, the fluid from the inside of the can is drawn up and sprayed on to the radiator. It is best to tilt the radiator when spraying, so that the solution will drain off.

A home-made spraying outfit similar to the one shown above consists of a 1/2-gal. oil can (Fig. 99) made into an atomizer by attaching a tire pump to the end of the air pipe (B). A piece of small brass pipe (A) is mounted in one side of the can, the upper end of it extending a short distance outside of the top. A second piece of pipe is mounted in a horizontal position in the top of the can, as shown at (B). If a handle is attached to the can, as at (C), the piece of pipe (B) may pass through it lengthwise and extend a short distance beyond the end of the handle. Both pipes are soldered to the top of the can, and the screw top is provided with a gasket to make it tight.

Fig. 99

When the air is forced through the horizontal tube (B) and caused to pass across the opening in the upper end of the vertical tube (A), the liquid in the can is drawn up and forced out in a fine spray. A mixture for spraying the radiator may be made of lampblack and turpentine. A sheet of paper should be placed back of the radiator to protect the engine, and around the outer edge, to prevent the liquid from bespattering the finish. Wipe before it dries.[3]

Paint for radiator: See p. 647. **Paint for fins:** Drop-black ground in japan and gold size, thinned with turpentine.

Cleaning the Cooling System and Radiator

Flushing the cooling system. Run the engine to loosen up sediment, then stop engine and drain the cooling system by opening the drains in the cylinder block as well as on the radiator. The car should stand on a level surface so that it will drain completely. After the system is empty and with all drains still open, run water into the radiator. Run engine and occasionally accelerate. If the water runs clear, stop engine, close drains and refill. **Tighten** connections and add **rust preventive** as explained on page 151.

If the water does not run clear and there is rust and scale, then use a good **cleaning compound,** particularly if engine has **tendency to overheat.** If car has **aluminum cylinder head,** follow manufacturer's recommendation. See page 151.

If a cleaning compound is not available, a soda solution can be used as follows: Run the engine to get it warm and loosen up sediment. Stop engine and drain the cooling system. Make a solution of about 1/2 lb. of sal soda (washing soda) thoroughly dissolved, to each gallon of hot water.[4] Fill the cooling system almost full of this solution and close the radiator cap tight, and run engine at moderate speed until thoroughly hot (about 180°) but not so hot that the water will steam. Engine can be heated up more quickly by covering the radiator. Stop engine and allow to stand for a few minutes (in order to dissolve the sediment), then open all drain cocks and drain thoroughly. *Be careful to avoid scalding hands.* After temperature has been reduced, fill cooling system with clean water and run engine until the water is hot and drain again. Repeat this operation until the water is clear and free from rust and all traces of the cleaning solution are removed. *Note.* Caustic soda and alkaline solutions are not recommended on engines equipped with aluminum cylinder heads; see page 151.

Reverse Method of Flushing

First, use a good cleaning solution to loosen the rust, scale, and grease. Then use the reverse method of flushing the radiator and engine block separately, **to remove same.** The **water thermostat** should temporarily be **removed** while flushing.

Before replacing the water thermostat, test it by immersing it in water. *Follow manufacturer's instructions* if available. The average thermostat valve *starts to open* at about 140° to 160° F. and should be *wide open* at about 175° F., more or less. *When heating the water to test thermostat,* do not allow thermostat or thermometer to rest on bottom of the container, as this will cause the thermostat or thermometer to be at higher temperature than the water.

High-temperature thermostats operating at temperatures about 20° higher are usually used with **hot-water heaters.** Only *non-volatile antifreeze solutions* are satisfactory for use with these thermostats.

To flush radiator: Remove upper and lower radiator hose and replace the radiator cap. Attach a lead-away hose at the top of the radiator. Attach a piece of new hose to the lower opening of radiator. Insert the flushing-gun[5] in this hose and connect the water hose of the flushing-gun to a water outlet and the air hose to an air line. Turn on the water, slowly at first; flush upward, being sure drain cock is open so that the water will flow freely, as a **radiator will only stand a limited pressure** and, if clogged, pressure would build up. When the radiator is full, turn on air in **short blasts,** producing a pulsating action, allowing radiator to fill with water between each blast. (The air-valve handle controls the amount of air pressure applied.) Continue this flushing until the water from the lead-away hose runs clear.

To flush engine cylinder block and head. Attach a lead-away hose to the water pump inlet and a piece of new hose to the water outlet at the top of the engine. Insert flushing gun in this water-outlet hose. Turn the water on and fill the cylinder block; when full, turn on the air intermittently, or in short blasts. Continue until the water from the lead-away hose runs clear.

The hot water heater can be flushed in a similar manner as the radiator.

After flushing drain thoroughly, tighten all connections and put in a **rust preventive** (see page 151). **Blow dirt and bugs** out of radiator air passages from the rear, with air pressure.

Where radiators cannot be cleared of obstructions, or leaks cannot be stopped, they should be taken to a radiator specialist who will determine if the radiator should be *boiled out, repaired* or if a *new core* is required.

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[1] **A common radiator leak** is where the hose connection fitting is attached to radiator tanks, top and bottom. Clean thoroughly and tap holes for small screws, and sweat over and around the screws after screwing them in tight.

[2] **Eclipse** Air Brush Co., Newark, N.J., manufacture sprayers. Literature free.

[3] **From** *Popular Mechanics.*

[4] **Kerosene** is sometimes used in connection with the soda in the proportion of 1 qt. per gallon of water. It is put in the radiator first, then the soda solution, then finish filling with water.

[5] **Flushing-guns** are available of service station equipment dealers. The following manufacturers will supply descriptive literature on flushing-guns: Miller Tool and Mfg. Co., Detroit, Mich. ("Miller"); National Carbon Co., 30 E. 42nd St., New York ("Eveready"). See also page 690 for *literature on various subjects,* such as *The Automotive Cleaning Hand Book.*

Cleaning a radiator in order to solder it: It is necessary to remove all grease, dirt and corrosion in order to solder so it will hold. Scraping bright by means of metal brushes and special tools which will reach the leaks is necessary, and these can be made from time to time. After the part to be soldered is thoroughly cleaned, the spot is swabbed with flux and then soldered, and right here is where the skill of a good radiator repairman is tested.

Boiling of the radiator in a solution of some commercial cleaner,[1] caustic soda or lye in a specially made boiler (similar to Fig. 101) is often done by rapairmen where the entire radiator is to be cleaned of grease, paint, etc. For the solution, lye is probably the easiest to obtain and use: about a one pound can to each seven gallons of water, or a strength that will produce best results. Before boiling, the radiator should be flushed out with the hose, and thoroughly flushed afterwards.

Where radiators have lime or hard deposits, a muriatic acid bath in a lead-lined wood vat is sometimes given, after which the radiator is washed thoroughly inside and out, and again put into the boiling solution to neutralize the acid. The radiator is then washed again and unless worked on at once, should be placed in a vat of clear water, to seal from exposure to the air. If this is not done, exposure to the air after this cleaning process, will soon oxidize the radiator and require a repetition of the cleaning process.

The subject of cleaning a radiator is thoroughly treated in the book mentioned in footnote.[3] In addition to giving the method of removing such matter as dope, chewing gum, cements, etc., which were placed in radiator temporarily to stop leaks, it also explains how to make the boiler, scraping tools, etc., and gives many other valuable pointers.

When it is necessary to clean the radiator spaces of accumulated mud, the radiator should be flushed from the rear, not from the front. In that way you avoid getting water into the magneto or ignition system, which is often short-circuited when the moisture enters it.

Radiator Repair Tools and Supplies[2]

Following paragraphs will give an idea as to where to obtain some of the parts, such as cores, tools, etc.

The core of a radiator is the principal part, and can be purchased separately from the upper and lower tanks. It is usually the part to be replaced. A new core in an old radiator saves the necessity of buying a new radiator.

The core can often be purchased cheaper than it can be repaired. For instance, if any great number of tubes, say more than ten, need repairing, then a new core is advisable.

Cores are usually sold by the square inch. The height of the core is multiplied by the width, to find the number of square inches in a core. Standard thicknesses are 2", 2¾", 3", 3½", 4", 4½". Seventy per cent of cars and trucks use tubular-type radiator cores. Always replace the core with the same type and design as the original, a tubular for a tubular and a cellular for a cellular.

Some of the firms who manufacture or supply radiator cores for replacement purposes are: Fedders Mfg. Co., Black Rock, Buffalo, N.Y.; McCord Radiator & Mfg. Co., Detroit, Mich.; Rome-Turney Radiator Co., Rome, N.Y.; United Motors Service, Inc., The G. & O. Mfg. Co., New Haven, Conn. Can also be obtained of auto supply houses listed on page 687.

Core material and other repair material is often obtained by the repairman from disassembled radiators he has worked on. The repairman should be careful to select only the best grade, and new material is advised, which can be obtained from supply houses.[2] Some of the miscellaneous material and tools that will be required are:

Side walls, bottom and lower tanks, filler necks, brass rivets, etc. **False fins** made of tin or brass. **Brass pipes** 5/16" tinned, for overflow pipes, 29" long. **Copper tubing** tinned.

In addition to the tools listed on page 736, the following are further suggestions: Tools of this kind can be obtained of auto supply houses or firms mentioned in footnote[2].

Electric flash light for examining close places, and also a special magnifying mirror. **Brushes** for cleaning, acids swabs, etc.

Soldering irons made specially for small places. **Scrapers** for close places.

Rubber stoppers: a gasoline torch of special design with a needle-point flame. **Torch** with larger flame. **Flux** and a flux squirter. **Soft sheet brass,** hose clamps, drain cocks, etc.

Air compressor of the type mentioned on page 739.

Gasoline gas generator for use with a gasoline torch.

Coil spring for placing in copper overflow tubing, so that it can be bent, etc.

Radiator Solder and Flux

Cleaning parts to be soldered is most important. This can be done by scraping and also, if in a close place, by using muriatic acid applied to a cloth attached to a wire.

Soldering flux, which is applied after cleaning in order that the solder may stick, is made of cut muriatic acid, as described on pages 736, 720, 721. See also, footnote page 721.

Wire solder with acid or flux in the core of the solder is used for radiator work.

Thawing Radiators

The common practice is to block off the air and run the engine with a retarded spark, depending upon the heat generated to do the work. This method is permissible if the freezing is slight, but not always effective. Best plan is to get into a warm garage as quickly as possible, or to pour hot water on bottom of radiator (see also page 154).

However, if the unit is frozen solid, damage to the radiator and engine may result long before the solid mass liquifies, for the reason that the water in the jackets very quickly boils away, leaving the engine dry.

If frozen solid remove the radiator and immerse it in hot water in the boiling tank, as shown in Fig. 101. See also pages 153, 150, 154.

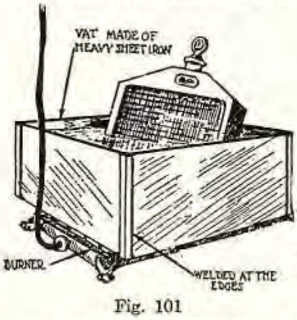

Fig. 101

Fig. 102

Fig. 101. To thaw out a solidly frozen radiator and test for leaks, place it in hot water in the testing tank. Do not have the water so hot that it will damage the finish.

Fig. 102. A device which is quickly and easily made for **elevating a radiator while soldering.** (*Motor Age.*)

NICKEL PLATING

The replating of nickeled parts of automobiles has been found to be quite a profitable business, particularly when conducted in connection with an automobile paint shop.

A plant for the plating of lamps, lamp reflectors, and other small parts, can be installed for approximately $425. A plant to handle small parts, and in addition, such large pieces as bumpers and radiator shells, would cost approximately $850.

Practical experience is of course a big aid in plating as in any other trade, and it would be of great assistance to anyone contemplating embarking in the plating business to obtain some plating-room experience, particularly to become familiar with the methods of cleaning, dipping, and the manipulation of the plating solutions.

An excellent book on the subject is *Principles of Electroplating and Electroforming,* by Dr. Wm. Blum and Geo. B. Hogaboom, who are authorities on this subject, and will be found to be a big help to the experienced plater, and almost indispensable to the novice. The price of this book is $4.00 net, plus postage. This book, also full information on plating equipment and supplies can be obtained from A. P. Munning & Co. of Matawan, N.J. manufacturers of electroplating and buffing apparatus and supplies. (Please mention *Dyke's Automobile Encyclopedia,* when writing.)

[1] **A free booklet** *Modern Cleaning Methods* dealing with cleaning radiators and metal parts is issued by Oakley Chemical Co., 22 Thames St., New York, N.Y.

[2] **A free illustrated catalogue,** listing tools and supplies for repairing radiators is issued by F. L. Curfman Mfg. Co., Maryville, Mo.

[3] **A book,** *A Manual of Automotive Radiator Construction and Repair,* by F. L. Curfman and T. H. Leet, containing 185 pages and 120 illustrations and of a practical nature, price $2.50 prepaid, can be obtained of Goodheart-Willcox Co., Inc., 2009 South Michigan Ave., Chicago, Ill.

INSTRUCTION No. 66

OXY-ACETYLENE WELDING AND CUTTING[1,2,3]

OXY-ACETYLENE WELDING

A successful welding process for joining metals depends upon a source of heat which can be accurately controlled and locally applied. Shortly before 1900 it was discovered that *acetylene when burned with oxygen* produced a flame temperature higher than any known to science before that time or since. In the early years of the twentieth century, efforts were made to apply this discovery commercially for the welding of metals. The success of these efforts is evidenced by the fact that the **oxy-acetylene welding process** has grown to tremendous commercial and industrial importance. Continuous research and experimentation with oxy-acetylene welding has progressed so rapidly that today procedures, equipment, and materials are available for the welding of practically all commercial metals.

The temperature of the oxy-acetylene flame, estimated to be in the neighborhood of 6,000° F., is so far above the melting point of all commercial metals[4] that it provides a means for localized melting of metals rapidly and under complete control.

Out of the oxy-acetylene welding process and the fact that iron or steel will burn in a remarkable way in the presence of pure oxygen **has grown the oxy-acetylene cutting process.** It seems curious at first thought to realize that by the proper combination and handling of two gases, oxygen and acetylene, metals can be *joined together or cut apart* with equal ease.

General Principles of Welding

In principle, oxy-acetylene welding is simplicity itself. Two pieces of metal are brought together and the edges in contact are melted, with or without the addition of filler metal in the form of welding rod, and the molten metal flows together until each edge is completely fused with the other. After the metal has cooled, there is, in effect, but a single piece of metal with no joint at all. The rules for practical application, of course, cannot be stated quite so easily, but the art of oxy-acetylene welding nevertheless retains this essential simplicity.

Welds made in the manner just described are known as fusion-welds because the base metal is actually melted and fused together with the metal added from the welding rod. In fusion-welding the base metal and welding rod generally have essentially the same composition, that is, in fusion-welding cast iron, for example, a cast-iron welding rod is used.

It is also possible to produce sound, strong joints in metal without actually melting the base metal. In bronze-welding, as this process is generally known, the edges of the joints are simply heated to a dull red by the oxy-acetylene blow-pipe flame. With the base metal at the proper temperature and with the aid of a suitable flux to clean the base-metal surfaces, molten bronze from a bronze-welding rod will unite with the base metal to form a strong bond. A properly made bronze-weld is quite comparable in strength to a true fusion-weld.

The oxy-acetylene welding flame lends itself to a number of other operations in addition to fusion-welding and bronze-welding; for example, **hard-facing materials** which may be welded onto metal surfaces to give increased wear resistance. In addition, there are innumerable applications in which the oxy-acetylene welding flame is used: **for heating** purposes, for **bending, straightening, or forming** operations, or for **preheating or postheating for welding.**

Welding Equipment

In its simplest form, an oxy-acetylene welding outfit consists of:

A cylinder of oxygen
A cylinder of acetylene
An oxygen regulator
An acetylene regulator
Oxygen hose and connections
Acetylene hose and connections
Necessary wrenches
Welding blow-pipe
Goggles and gloves
Friction lighter

To equip such an outfit for cutting operations as well, it is only necessary to add a cutting attachment which may be attached to the welding blow-pipe in the place of a welding head, or a full-size cutting blow-pipe. If such an outfit is mounted on a hand-truck as shown in Fig. 1, it becomes readily portable and can be taken to the work with ease.

Fig. 1. (*left*). **Welding and cutting unit.** This portable outfit is fully equipped to do oxy-acetylene welding, cutting, or local heating operations.

Fig. 2 (*center*). **Oxygen cylinder.** When made in accordance with various official regulations is a seamless drawn steel shell, which, when full, contains 220 cu. ft. of oxygen compressed to a pressure of 2,000 lb. per sq. in. at 70° F.

Fig. 3 (*right*). **Acetylene cylinder.** This is also made in accordance with official regulations. Contains a porous filler in which acetone is used to dissolve many times its own volume of acetylene. This cylinder is operated by a T-handle valve which should not be opened more than $1\frac{1}{2}$ turns.

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[1] **The subjects on pages 741–752 have been revised and consequently there may be some discrepancies between the Index and text.** See *Supplementary Index.*

[2] **A book entitled "*Welding Encyclopedia,*"** containing 638 pages and 645 illustrations, price $5.00, can be obtained of The Goodheart-Willcox Co., Inc., 2009 South Michigan Ave., Chicago, Ill. This book tells how to weld every weldable metal by each of the welding processes. See page 690 under "*Welding Encyclopedia,*" also, under "*Welding and Cutting by Oxy-Acetylene*" and "*Welding-Electric Arc Welders.*"

[3] **Attention is called to "*Dyke's Self-Starter*"** which has questions and answers pertaining to oxy-acetylene welding and cutting, also electric arc welding. See also pages 752, 690.

[4] **For melting points of some of the various metals** see p. 1048.

With the addition of the necessary welding rod and fluxes, this outfit can be used to weld practically all commercial metals or to cut steel, wrought iron, and cast iron within the range of thicknesses that can be handled by the cutting blow-pipe used. Hard-facing operations or local heating can also be performed.

For large-scale operations or for permanent setups in shops or plants, manifolded oxygen supply and an acetylene generator or a manifolded supply of cylinder acetylene can be used. From such main supply point the acetylene and oxygen are piped to welding or cutting stations located throughout the shop wherever they are needed.

Gases Used for Welding

Oxygen, supplied in portable steel cylinders, can be obtained from reliable manufacturers having conveniently located warehouses and distribution points throughout the country. The standard oxygen cylinders usually contain either 220 cu. ft. or 110 cu. ft. of oxygen (depending on the size) and are charged at a pressure of 2,000 lb. per sq. in. at 70° F. when full. Each cylinder is equipped with a *valve* especially designed to operate at high pressure. When the oxygen is being drawn off, after a suitable reducing *regulator* has been attached, the valve should always be opened as far as it will go.

Acetylene is available also in portable steel containers or cylinders and have rated capacities of either 300 cu. ft. or 100 cu. ft., depending on size. These cylinders are quite different in construction from oxygen cylinders, for free acetylene should never be stored at pressure above 15 lb. per sq. in. After much study, the problem of combining safety with capacity was solved by packing the cylinders with a porous material, the fine pores being then filled with acetone, a liquid chemical having the property of dissolving or absorbing many times its own volume of acetylene. In such cylinders, acetylene can be handled and shipped with perfect safety. The acetylene is produced in large stationary generators, purified carefully, and then dissolved into the cylinder. The acetylene *dissolved in acetone* will not change its nature. Acetylene is drawn off through a valve, which in Prest-O-Lite[5] cylinders is located in a recessed top, where it is protected from breakage. The valve is much simpler than an oxygen valve, not having to withstand as high pressure. It should be opened only one and one-half turns. Safety fuse plugs are provided to meet any fire emergencies, and the entire construction, as is the case also with oxygen cylinders, must satisfy the requirements of various governmental and regulatory bodies.

Stationary or portable acetylene generators of various capacities are available for the manufacture of acetylene directly from carbide, the preferable style and size of generator being dependent upon the amount of acetylene necessary and the conditions under which it is to be used. All *acetylene used commercially is made from calcium carbide,* or "carbide," as it is known in the trade.

In the *carbide-to-water type generator,* which is used almost exclusively in this country, small lumps of carbide are fed from the hopper into a comparatively large volume of water. The heat given off during the reaction is readily absorbed by the surrounding water. When the acetylene forms, it bubbles up through the water, being cooled and purified in this way. While all carbide-to-water generators operate according to the general method outlined, there is of course considerable variation in mechanical details. Modern acetylene generators for use in welding and

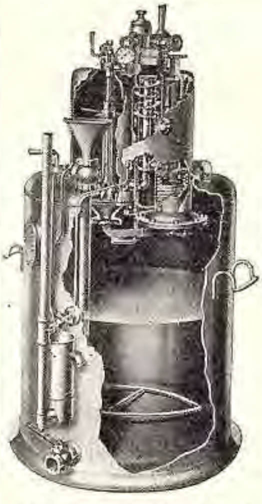

Fig. 4. Acetylene generators are manufactured so as to be as nearly foolproof in operation as possible. Before using an acetylene generator, the manufacturer's instructions should be carefully studied and followed exactly.

cutting are designed to be automatic in operation and as nearly foolproof as possible. When installing or operating acetylene generators, the manufacturer's instructions should be followed exactly.

Blow-Pipe Construction

Blow-pipes perform the essential function of mixing oxygen and acetylene to produce an oxy-acetylene flame under conditions of complete control as to size, characteristics, and ease of application. While blow-pipes vary rather widely in design, all types have certain fundamental and common characteristics.

Welding blow-pipes have a handle with *two inlet connections* for gases at one end. Each inlet has a *valve* that controls the volume of oxygen or acetylene passing through. By means of these valves, the desired proportions of oxygen and acetylene are allowed to flow through the blow-pipe, where they are thoroughly mixed before issuing from the blow-pipe at the tip or nozzle. The oxy-acetylene flame is produced by igniting the mixture at the blow-pipe tip.

Types of oxy-acetylene blow-pipes. Considered from the points of view of construction and operating principles, there are **two general types,** *low pressure* and *medium pressure.* The distinction refers to the acetylene pressure range required for operation. Acetylene at pressures less than 1 lb. per sq. in. is designated as low pressure; from 1 to 15 lb. per sq. in. as medium pressure. Low-pressure blow-pipes can use acetylene from low-pressure generators, medium-pressure generators, or cylinders. For pressure blow-pipes the acetylene pressure must be more than 1 lb. per sq. in. and can be supplied from cylinders or medium-pressure generators, but not from low-pressure generators.

A low-pressure blow-pipe which makes use of what is known as the injector principle is shown in Fig. 5. Oxygen passes through a small opening in the injector nozzle, producing a suction effect which draws acetylene into the oxygen stream. One advantage of this type of construction is that small changes in the amount of oxygen will produce a corresponding change in the amount of acetylene drawn into the gas mixture, so that the proportion of the two remains substantially constant while the blow-pipe is in operation. The blow-pipe shown in Fig. 5

[5] The words "*Prest-O-Lite*," "*Oxweld*," "*Prest-O-Weld*," "*Purox*," and "*Haynes Stellite*," are trade-marks of Units of Union Carbide and Carbon Corporation.

is known as the *type W-17 Oxweld blow-pipe* and is supplied with a series of welding heads, either one piece or two piece, for practically the complete range of welding work. There are thirteen of each type head in this series.

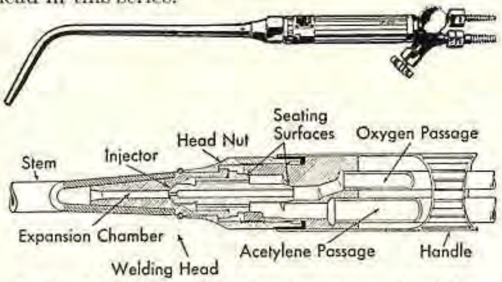

Fig. 5. **Low-pressure blow-pipes** operate on what is known as the injector principle, in which oxygen passing through the center orifice of the injector draws the proper amount of acetylene into the stream.

In medium-pressure type blow-pipes, oxygen and acetylene are fed at independent pressures to a mixing chamber, the construction of which varies considerably according to the ideas of different manufacturers. Medium-pressure blow-pipes which operate with equal pressures of oxygen and acetylene are also designated as the **balanced pressure type.** Fig. 6 shows a medium-pressure welding blow-pipe known as the *type W-105 Prest-O-Weld blow-pipe,* while Fig. 7 shows a typical balanced pressure welding torch, known as the *No. 35 Purox welding blow-pipe.*

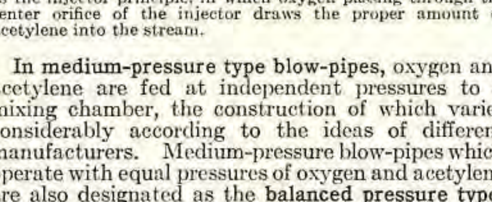

Fig. 6. **Medium-pressure blow-pipes** require more than 1-lb. pressure of acetylene. These may be operated on cylinders of dissolved acetylene or medium-pressure acetylene generators.

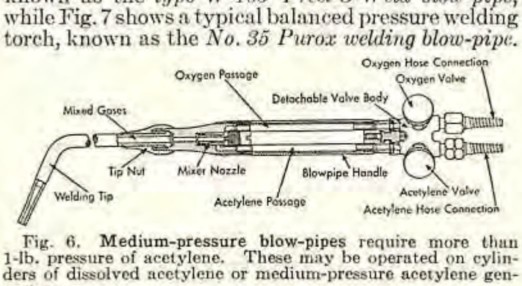

Fig. 7. **Balanced-pressure blow-pipes** operate on equal pressures of oxygen and acetylene. These may be operated on cylinders of dissolved acetylene or medium-pressure acetylene generators.

Practically all welding blow-pipes are provided with a series of interchangeable heads or tips of different sizes so that the same handle can be used on a wide variety of operations.

Cutting blow-pipes are so designed that the flame is divided into several small jets surrounding a central opening in the tip or nozzle. The central opening, connecting to the oxygen inlet through an independent tube and valve, supplies the *jet of oxygen that actually does the cutting.*

In cutting blow-pipes the same differences in principle regarding the method for mixing the preheat gases applies as in the welding blow-pipe. Cutting blow-pipes using the injector or low-pressure, medium-pressure, and balance-pressure principles are available. Fig. 8 shows a cutting blow-pipe in which the preheating gases are mixed by means of the injector or low-pressure principle. This blow-pipe is known as the *type C-31 Oxweld cutting blow-pipe.*

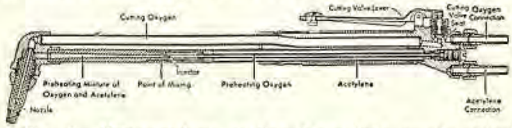

Fig. 8. **Oxy-acetylene cutting blow-pipes** supply mixed gases at the nozzle for preheating and a stream of pure oxygen which does the cutting. The blow-pipe shown here operates on the low-pressure injector principle, but blow-pipes are also manufactured which operate on the medium-pressure and balanced-pressure principles.

Cutting attachments. In addition to the full-size cutting blow-pipes, cutting attachments are manufactured which attach to the handle of the welding blow-pipe in the same manner as a welding head. In principle these cutting attachments operate in the same way as the cutting blow-pipe, but the design is considerably altered so that, when mounted on a welding blow-pipe handle, the unit becomes an easily manipulated hand equipment.

Regulators

Regulators are necessary to reduce the high pressure in the oxygen and acetylene cylinders to a working pressure at the blow-pipe, also to provide a steady and unfluctuating working pressure.

For example: Let us assume that we have a cylinder containing oxygen at 2,000 lb. per sq. in. and that we wish to do some welding that requires only 10 lb. oxygen pressure at the blow-pipe. We must have a regulator that can be set so as to deliver oxygen at 10 lb. pressure. That is, the regulator must function as a reducing valve, reducing 2,000-lb. pressure to 10 lb. But it must be more than a simple reducing valve, for the cylinder pressure does not remain constant while the blow-pipe is in operation. After welding several hours with that one cylinder, for example, half of the oxygen may be used, and the pressure in the cylinder will then be 1,000 lb. instead of the original 2,000 lb.; but we still need 10 lb. at the blow-pipe. Consequently, in order to maintain working pressure constant, regardless of

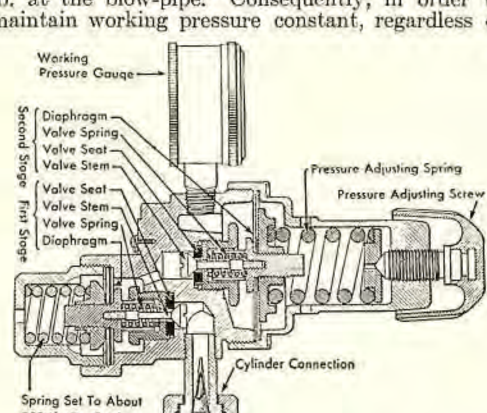

Fig. 9. **Cross-section of a two-stage regulator. Two-stage regulators are used for general oxy-acetylene welding and cutting work.** Regulators perform the double function of reducing the cylinder pressure to the desired working pressure and maintaining the working pressure constant until the cylinder contents are exhausted. There are two gauges on the body of the regulator, one showing pressure in the cylinder, the other the working pressure being supplied to the blow-pipe. Cylinder pressure gauge, safety release, and hose connection do not show in this view.

what the cylinder pressure may be, regulators must have a *sensitive regulating mechanism* in addition to a *reducing valve.*

Two-stage regulators. A number of different types of regulators have been developed to accomplish these functions. The regulator shown in the cross-sectional view in Fig. 9 operates on what is known as the two-stage principle. The gas enters directly from the cylinder into the *first-stage* or high-pressure chamber. By means of a diaphragm and valve coupled with a spring of previously determined tension, the gas pressure is reduced in this chamber to a lower pressure, say, 125 lb. per sq. in., the amount depending upon whether the regulator is to be used for welding or for cutting. Notice that the valve in the high-pressure valve closes with the pressure, thus eliminating leakage and making it possible to drain the cylinder completely even after the gas pressure has dropped below that set for the high-pressure stage.

In the *second stage* an adjusting screw adjusts the tension on the spring operating the valve and thus makes it possible to make the final reduction of pressure to the desired working pressure. The use of a spring in this stage to control the valve makes it possible for the regulator to maintain this working pressure at a constant value.

Oxygen regulators must be so designed that the high-pressure side of the regulating mechanism will take care of the full cylinder pressure, 2,000 lb. per sq. in. It is customary to provide a 3,000-lb. **cylinder pressure gauge** on oxygen regulators so there is an ample margin to prevent straining the gauge mechanism. The cylinder pressure gauge usually has a **second scale** which shows the contents of the cylinder in cubic feet at 70° F.

For welding, the regulator is designed to deliver a maximum of about 50 lb. and usually has a 100-lb. **working pressure gauge.**

For cutting, which requires higher pressure than for welding, the **working pressure gauges** are usually 400 lb. The maximum delivery capacity of the regulator may vary from 125 to 200 lb. per sq. in., according to type.

Note: Oxygen and acetylene cylinders are loaned by distributors, usually for a free period of thirty days, to purchasers of the contents. Users are billed for the oxygen or acetylene contained in the cylinders at time of delivery or shipment.

Regulators are not loaned, however, and must be used in all cases except when small-capacity acetylene tanks are used for air-acetylene work. Special regulators with gauge readings up to 400 lb. and 1,000 lb. are used with manifolds and occasionally for heavy oxygen lance operations.

Acetylene regulators for welding and cutting with dissolved acetylene have **cylinder pressure gauges** registering up to 350 lb. per sq. in. and usually 30-lb. **working pressure gauges** (graduated only to 15 lb., because acetylene should never be used at pressures above 15 lb. per sq. in.). Acetylene gauges all have vent holes in the side of the case to relieve any abnormal pressure.

Gauge dials are colored—green for oxygen and red for acetylene.

Connecting the Equipment

The steps in connecting an oxygen regulator to the oxygen cylinder are shown in Fig. 10. Oil or grease should never be allowed to come in contact with oxygen under any circumstances. Cylinders should be fastened so that they cannot be tipped over and damaged and so that the regulator will not be damaged.

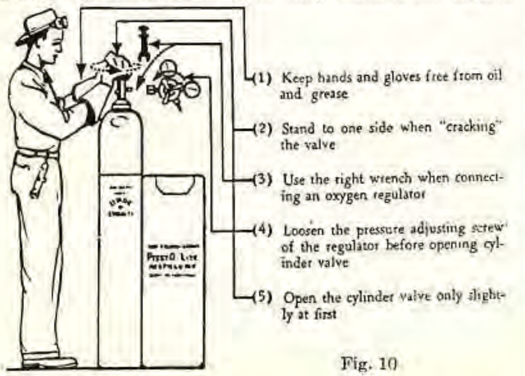

Fig. 10

Before attaching the oxygen regulator the cylinder valve should be "cracked" to blow out any dust or dirt in the cylinder valve opening. To do this, stand at the side or rear of the oxygen cylinder outlet, open the oxygen cylinder valve slightly for an instant, and then close it.

Connect the oxygen regulator which regulates the oxygen cylinder by means of the union nut, which should be tightened with the proper wrench. If the threads do not match exactly, a suitable adaptor should be used.

The pressure-adjusting screw of the regulator should be loosened until it is free and then the cylinder valve should be opened very slowly, while the operator stands at one side away from the face of the regulator. The oxygen cylinder valve should be opened all the way. The cylinder valve should never be opened suddenly, as the rush of high-pressure oxygen might strain the cylinder pressure gauge mechanism.

The acetylene regulator should be attached in a similar manner, although on Prest-O-Lite acetylene cylinders the valve is operated with a T-handle. This valve should not be opened more than one and one-half turns.

Connecting hose. Oxygen and acetylene hose should not be interchanged. The oxygen hose is green, while the acetylene hose is red. In Fig. 11 the standard forms of Oxweld hose and hose connections are shown. Notice that the acetylene hose connection has a left-hand thread, while that for oxygen is right-hand. All the equipment supplied by most oxy-acetylene equipment manufacturers have these distinguishing marks: *a red color and left-hand thread for acetylene connections and a green color and right-hand thread for oxygen connections.*

Hoses are connected to the regulator and to the blow-pipe as shown, and all connections are tightened with the proper wrench.

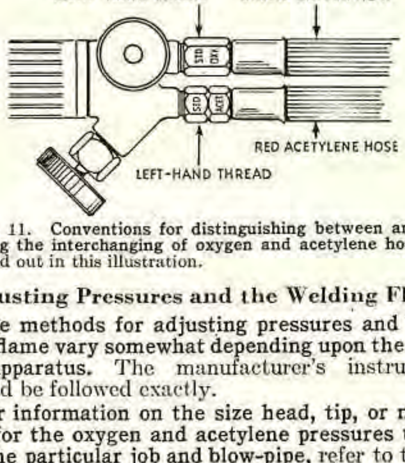

Fig. 11. Conventions for distinguishing between and preventing the interchanging of oxygen and acetylene hoses are pointed out in this illustration.

Adjusting Pressures and the Welding Flame

The methods for adjusting pressures and blow-pipe flame vary somewhat depending upon the make of apparatus. The manufacturer's instructions should be followed exactly.

For information on the size head, tip, or nozzle, and for the oxygen and acetylene pressures to use for the particular job and blow-pipe, refer to the instructions leaflet furnished with the blow-pipe by the manufacturer. After the proper head, tip, or nozzle has been attached to the blow-pipe, and with the *oxygen* cylinder valve opened as directed above, open the blow-pipe oxygen valve and then turn in the pressure-adjusting screw on the oxygen regulator until the desired pressure is registered on the low-pressure gauge. Then close the blow-pipe oxygen valve.

With the blow-pipe acetylene valve closed and the *acetylene* cylinder valve open, turn in the pressure-adjusting screw on the acetylene regulator to the desired pressure. Open the blow-pipe acetylene valve, light the flame and readjust the regulator to the correct pressure. Then close the blow-pipe acetylene valve.

Instructions accompanying the blow-pipe should be followed carefully in lighting and adjusting the flame. This is necessary for best results, since the procedure for operating one blow-pipe is not necessarily satisfactory for another. Before using any oxy-acetylene equipment make sure that the general safe practices for handling this blow-pipe are thoroughly understood.[6]

Adjusting the Flame

There are three types of oxy-acetylene flames which are used for welding work, known as the *neutral flame*, the *carburizing or excess acetylene flame*, and the *oxidizing flame*.

The neutral flame is probably the most widely used for welding work and is secured when equal quantities of oxygen and acetylene are being burned. The neutral flame is made up of two clearly defined zones or cones—a brilliant inner cone and an outer envelope. When the flame is adjusted with an **excess of acetylene,** a third cone appears surrounding the inner cone. If the acetylene is then shut down slowly by means of the blow-pipe acetylene valve, the flame becomes first a neutral flame and then an oxidizing flame. The **oxidizing flame** has two cones, but the inner cone has a purplish tint and is "necked in" when compared with the neutral flame. As a first part of his work in oxy-acetylene welding, an operator should practice adjusting to the three types of flame until he readily recognizes each one.

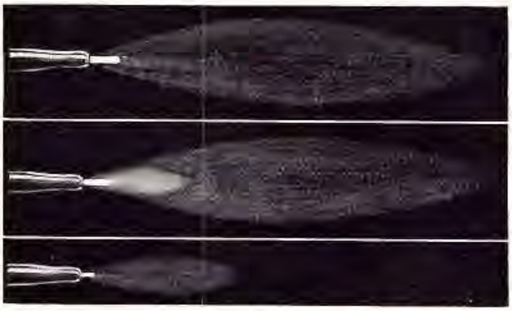

Fig. 12. **The oxy-acetylene flame.** Top illustration shows the *neutral flame* properly adjusted. Center illustration shows a *carburizing flame;* excess of acetylene. Lower illustration shows an *oxidizing flame;* excess of oxygen. All are required in oxy-acetylene welding work.

Identifying Metals[7]

Ability to recognize commercial metals and alloys is obviously an essential part of a welding operator's fund of practical information, for welding procedure varies with the different metals.

There are a number of simple tests that will aid the operator in identifying metals. **These are:**

Appearance. Observe the color, surface characteristics, and appearance of a fractured surface.

Chip test. Chip a narrow groove with a cold chisel and hammer. Observe the facility of chipping and the characteristics of the chips formed.

Spark test. Hold a piece of the metal against a power grinding wheel, preferably in a dark place. Observe the color, shape, length, and activity of the sparks produced.

Blow-pipe test. Melt the metal with the welding blow-pipe flame and observe its behavior.

Joint Designs

The fundamental joint designs for welding sheet metal are relatively few in number. These general types are shown in Fig. 13. By trade custom, metal up to 1/8″ in thickness is considered *sheet metal;* material thicker than 1/8″ is considered *plate*.

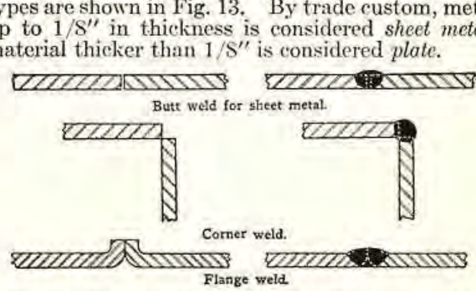

Fig. 13. **Standard joint designs for sheet-metal welding.** The black area indicates the weld.

The types of joints recommended for welding plate depend upon how the plates to be joined are disposed with relation to each other. The simplest case is, of course, the joining of plates in line with each other. The fundamental joint designs for plate is shown in Fig. 14. If the plate is more than 3/16″ in thickness, it should be *beveled* so that the included angle is between 50° and 90°, depending upon the welding method to be employed.

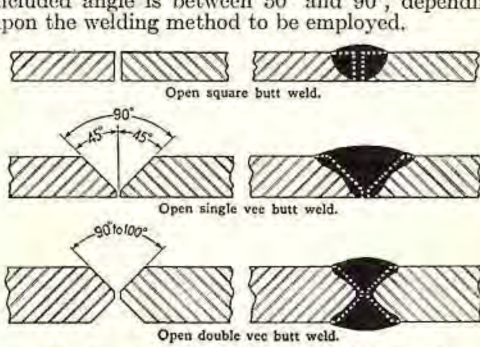

Fig. 14. **For material more than 3/16″ thick the edges are beveled before welding** to an included angle of between 50° and 90°, depending upon the welding process used. **For material more than 5/8″** in thickness a double-vee bevel is recommended.

Expansion and Contraction

Before getting into a discussion of the various techniques employed for welding the different types of metal, it would be well to discuss the subject of expansion and contraction briefly.

The theory of the expansion and contraction of metals with changes in temperature is based on facts which are easily understood. *Heat* causes metal to expand and the subsequent cooling necessarily means that the heated section will endeavor to contract into its original size and shape. *Uneven heating* will, therefore, cause uneven expansion, or uneven cooling will cause uneven contraction. Under such conditions, stresses are set up within the metal. These forces must be alleviated, and, unless precautions are taken, warping or buckling or even fracture of the metal takes place. Likewise, *on cooling*, if nothing is done to take up the stress set

[6] **A booklet** *outlining the precautions and safe practices in welding and cutting with oxy-acetylene equipment* is available from the nearest office of The Linde Air Products Company, or from General Publicity Department, 30 East 42d St., New York City. **Ask for** *booklet F-2035*.

[7] **A chart** *giving a number of simple tests for the identification of metals* is available from the nearest office of The Linde Air Products Company. See also footnotes 8, 9, 10. **Ask for** *chart F-2299*.

up by the contraction forces, further warping may result; or if the surrounding cool sections of the metal are too heavy to permit this change in shape, the stresses remain within the metal itself. Such stresses may cause cracking while cooling or may remain within the metal until further force is applied, such as when the metal is put into use.

Sheet metal has such a large surface area per unit of weight that heat stresses tend to produce warping or buckling of the sheet. This and the contraction effect which tends to draw together long seams are the principal points to be considered in sheet-metal welding. If the edges of a long seam are placed in contact throughout their entire length before welding starts, the far ends of the seam will actually overlap before the weld is completed. One way to overcome this effect is to set up the pieces to be welded so the edges are nearly in contact to one end of the seam and separated at the other end, a distance that varies according to the metal and the thickness. *Tack-welding* at various intervals along the seam also assists in holding pieces in alignment for welding. A properly made tack-weld need not be melted out but can be made a part of the finished weld.

Means of removing heat. The means most commonly employed to prevent buckling or warping of **sheet metal** during welding is to apply the principle of removing the heat from the base metal adjacent to the weld. In the case of flat seams, a heavy piece of metal such as a section of steel rail or heavy bar-stock placed on either side of the seam will effectively prevent the heat from spreading too far and will also tend to prevent movement of the parts by resisting the forces of expansion and contraction. Heat may also be removed from metal adjacent to the weld zone by the use of wet asbestos cement along either side of each seam.

Because of the frequently irregular shape and generally greater bulk of **castings**, a more careful consideration of expansion and contraction during welding is required than is the case with sheet metal or plate. *If the cast-iron casting is to be fusion-welded,* using cast-iron rod, the safest method to employ is to preheat the entire casting to a good red heat followed by slow cooling after welding. *If the casting is to be bronze-welded,* preheating to a black heat, or merely local preheating is all that is necessary. In any case, careful consideration of the casting should be made before welding to determine just how much and what parts of the casting should be preheated.

General preheating is best performed in a temporary brick furnace such as that shown in Fig. 15.

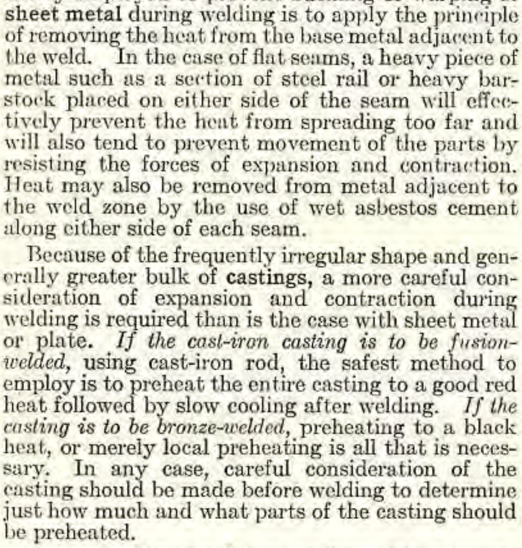

Fig. 15. The recommended method for constructing a temporary preheating furnace is shown in these four views. Such a furnace would preferably be fired with charcoal.

In this temporary furnace the fuel would be charcoal, oil, or gas. Care should be taken to see that the heating proceeds smoothly and regularly, so that uneven expansion stresses are not set up. The temporary furnace should be covered with a sheet of asbestos cloth, and the welding should be performed while the casting is still in the furnace. Holes in the asbestos covering provide ventilation for the fire, while sections of the covering may be turned back to permit welding to proceed. After the casting has been welded, the cover should be put back over the furnace and the entire casting allowed to cool to room temperature very slowly.

Nonferrous metals,[8] whether in the form of *sheet, plate, pipe, or castings,* require much the same consideration as outlined in the previous discussion, with such modifications as are made necessary by the specific characteristics of each metal.

The welding technique for joining various metals[9,10] differs from one to another to a certain extent, a factor which depends upon the different properties of the various metals. Furthermore, in certain cases the same metal is frequently joined by different processes or the process may differ depending upon the physical form of the part, for instance, whether it is sheet metal or a complicated casting.

Iron and Steel

Iron and steel being the most important industrial metals, a few lines will be devoted to them.[8,9,10] Quoting from "*The Oxwelder's Handbook*":

Cast iron is by no means pure iron; it is a rather complex mixture containing 91 to 94 per cent metallic iron and varying proportions of other elements, the more important of which are carbon, silicon, manganese, sulphur, and phosphorus. The *difference* in the properties of *steel* and *cast iron* is due mainly to the difference in carbon content. Steel contains less carbon than cast iron.

Wrought iron, the purest of commercial irons, contains very little carbon, less than 0.05 per cent. It is comparatively soft and ductile, having a tensile strength of about 45,000 lb. per sq. in., and it melts at a temperature of about 2,700° F. As the carbon content increases, the product becomes harder, but more brittle, the tensile strength increases up to a certain limit, and the melting temperature decreases. The products known as steel come within this range, beginning with "dead soft" steel (about 0.10 per cent carbon), passing through "mild," "medium," and "rail" steel up to the tool steels. Commercial steels stop in the very high-carbon tool steels, containing about 1.50 per cent carbon. Steel melts at from 2,400° to 2,700° F., approximately, depending upon its chemical composition.

Nature of cast iron. At about 2.50 per cent carbon, the products become so brittle that they cannot be rolled or worked like steel but must be cast to shape in molds. The range from about 2.50 to 3.50 per cent carbon includes the commercial cast irons, the characteristic properties of which are discussed in chapter 20 of "*The Oxwelder's Handbook.*"

Alloy steels. In addition to the carbon steels mentioned above, there are special steels or alloy steels which contain varying amounts of one or more other metallic elements, such as chromium, manganese, silicon, nickel, tungsten, vanadium, and molybdenum and whose special properties are produced only after a heat-treatment of more or less precision and complexity. These are considered in chapters 21 and 22.

Malleable iron. When white cast iron is heated under certain suitable conditions to about 1,400° F. for several days, the combined carbon separates not as flakes of graphite but as very fine rounded particles of carbon in the iron. This process tends to give castings more of the properties of pure iron; namely, high strength, ductility, toughness, and ability to resist shocks. Malleable iron must be bronze-welded. It cannot be

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[8] **Ferrous metals,** quoting from "*Dyke's Self-Starter,*" "are metals which contain iron such as cast iron, wrought iron and steel. **Non-ferrous metals** contain no iron (except in very small percentages) and include all metals except the ferrous metals." This book also includes information on the Brinell and Rockwell hardness test, meaning of tensile strength, etc. (See inside of back cover of this book explaining where the reader can obtain "*Dyke's Self-Starter.*")

[9] **A complete instruction handbook** *giving the procedures and techniques for welding practically all commercial metals* is available from the nearest office of The Linde Air Products Company, or from General Publicity Department, 30 East 42d St., New York City. This book, known as "*The Oxwelder's Handbook,*" contains over 300 pages of instructions and illustrations (price $1.00).

[10] **A booklet** *which lists essential automotive parts and gives the kind of metal they are composed of, and the recommended welding method of repairing,* is available from the nearest office of The Linde Air Products Company. **Ask for** *booklet Form 2336-D,* "*Repairing for Profit,*" also for *chart Form F-4464.*

fusion-welded, as the malleable properties are completely destroyed when the metal is melted.

Cast steel is frequently used to make parts of intricate shape when cast iron does not have the desired physical properties.

Welding Steel

In many ways the welding of steel by the oxy-acetylene process is similar to the steel-mill practice by which a great deal of our steel is made, a method known as the open-hearth process. In the oxy-acetylene welding of steel, the blow-pipe flame is used to melt a puddle of base metal and into this puddle is melted metal from a welding rod. The puddle is then moved progressively along the part by means of manipulation of the welding rod and welding flame. When this action is made to take place at the edges of two pieces of base material of the same composition, the continuously solidifying puddle made up from the base material itself and the welding rod results in what is, in effect, a single piece of metal.

In the practical application of fusion-welding of steel, the edges of the two pieces of metal to be joined are *thoroughly cleaned of any oxide or dirt.* This may be done by grinding, filing, chipping, or wire-brushing, depending upon the type of foreign matter present. If the edges are more than 3/16" in thickness, they are beveled as shown under Joint Designs, which beveling may be done by the oxy-acetylene cutting blow-pipe.

After the joint has been studied and it has been determined in what direction the welding will proceed and how the effects of expansion and contraction are to be cared for, the metal parts are spaced the distance of about 1/16" at the start of the weld and are then firmly held in this position either by means of jigs and fixtures or by means of tack-welding, short welds spaced at intervals along the edge to be welded. With the proper size head or tip attached to the blow-pipe and with the flame adjusted to neutral, an area about 2" in diameter at the start of the weld is then heated to a bright red temperature. The flame is then concentrated at the point at which the weld is to start and a puddle of molten metal formed. If the metal is not allowed to become too fluid, it will easily bridge the space between the edges of the base metal, aided by metal melted from the welding rod.

The puddle is then caused to progress the entire length of the weld, making sure that complete fusion takes place at all points between the puddle and the base metal. Some practice will be required before good-appearing welds which will develop full strength are secured.[11]

To a large extent, the strength of the weld depends upon the thorough union of all parts of the weld metal to itself and to the edges of the pieces being joined. A true fusion-weld is not produced in steel until it actually melts. In welding, care must be taken to work all oxides to the surface; otherwise it will be found that they weaken the weld metal considerably. The oxide or scale remaining on the surface of the completed weld can be easily removed by wire-brushing or hammering just before the weld gets cold.

Welding rod.[12] In fusion-welding it is most important to select only a high quality welding rod. Several good rods are on the market today, and welding supply manufacturers will be glad to advise which rod to use for a particular job.

Blow-pipe manipulation. In general, the welding blow-pipe will be held in the right hand and the welding rod in the left. These two should be inclined to each other at an angle of about 90° or slightly more and each should make an angle of about 45° with the weld. Depending upon the position of welding and the speed at which the weld is progressing, it may be necessary to vary these angles depending upon how fluid the puddle has become and certain other factors which will appear to the operator as he progresses. The tip of the inner cone of the welding flame should be held about 1/8" away from the top of the welding puddle and the welding rod should be held so that the metal as it melts will flow into the puddle, not so that it will drip.

As the rod melts, it should be moved from side to side in the puddle, the motion being just opposite to that of the blow-pipe. In this way the blow-pipe flame is allowed to play first upon one side of the vee and then upon the other, insuring complete fusion. Care must be taken not to flow the molten metal ahead under the relatively cold sides of the vee, since under these circumstances it will merely stick, but will not fuse.

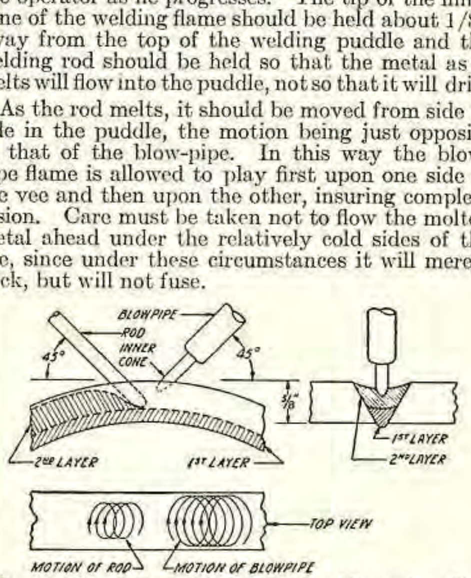

Fig. 16. **The motion of blow-pipe and welding rod** are illustrated. The upper views illustrate the method for building up the weld in layers when welding heavy walled pipe. A third layer is required which is not shown.

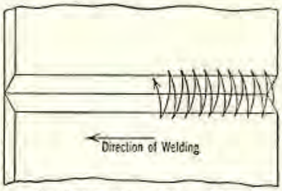

Fig. 17. **The swinging motion of the blow-pipe** is illustrated. The motion of the rod is opposite to but much less than the blow-pipe motion. This motion, employed in forehand welding, allows the blow-pipe flame to play first on one side of the vee and then on the other.

Welding can be carried on in practically any position, horizontal, vertical, overhead, or in a horizontal position with the work vertical. Considerable practice will be required before welding can be carried on successfully in the various positions, and it would be well to have more complete instructions than it is possible to give here.[11]

Bronze-Welding

As was mentioned earlier, bronze-welding differs considerably from fusion-welding in that fully comparable weld strengths can be secured without actually melting the base metal. This is because molten brass or bronze will flow evenly over a properly heated and chemically clean metal surface and form a bond or molecular union which has

[11] **More complete instructions** *for the welding of steel in the various forms in which it is commercially available today* will be found in "*The Oxwelder's Handbook,*" available from the nearest office of The Linde Air Products Company (price $1.00).

[12] **A booklet** *dealing with welding rods and fluxes* is available from the nearest office of The Linde Air Products Company. **Ask for** *booklet Form 2263A.*

See page 726 for **angle, channel, I-beam sections** formerly on this page.

admirable strength. In fact, bronze-welds having tensile strengths of 55,000 lb. per sq. in. or more are consistently made in steel.

Bronze-welding is used both in production and in repair for the joining of steel, cast iron, galvanized iron, copper, nickel, and alloys of copper and nickel. Practically any commercial metal can be bronze-welded successfully, but this is not done if it is necessary that the weld metal and base metal have the same appearance or the same corrosion-resistant properties. It is also not done in those few cases where the temperature of the part is to be at any time higher than 500° F., since bronze rapidly loses strength at temperatures above that point. **Bronze-surfacing** is the term used to describe the application of the bronze-welding process to the building-up of worn surfaces, such as pistons, shafts, etc. It is also used for building up worn or broken gear teeth, lugs, or bolt holes.

The fundamental technique of bronze-welding, or of bronze-surfacing (which are the same with few exceptions), **is as follows:**

First consideration is the preparation of the edges to be bronze-welded or the surfaces to be rebuilt. *Clean metal,* with complete absence of oxides, dirt, oil, or grease, is essential. If the edges to be joined are 1/4" in thickness or less, surface chipping or grinding to bright metal will suffice. If over 1/4" in thickness, the edges should be beveled to give about a 90° included vee. The beveling operation in itself will expose clean metal. Further than this, the metal for about 1/2" back from the top edges of the bevel should be thoroughly cleaned off. For parts that are to be bronze-surfaced a clean surface is equally essential. Machining, grinding, chipping, or sand-blasting is preferred for this work.

Second, it is important to determine before starting whether or not the part should be preheated. Then with the parts properly aligned and held in alignment either by tack-welds or by clamps, and with any necessary preheating done, the operator is ready to start the actual bronze-welding.

A blow-pipe head or tip one size larger than would be used for welding steel of a similar thickness should be selected. This recommendation applies generally to the various steels, cast iron, wrought iron, and malleable iron. For copper and certain other metals, and for certain special conditions, a different size head or tip may be required. Experience is the best dictator of this.

The flame is adjusted so as to be slightly oxidizing. The proper flame is obtained by first adjusting the flame to neutral and then closing the blow-pipe acetylene valve slowly until the inner cone has been reduced in length by about 1".

During welding it is necessary that a liberal amount of flux be supplied continuously to insure a chemically clean surface. If the rate of welding is to be rapid, this can be done best by coating the entire rod with the flux. Where welding takes place more slowly, as it will for heavier castings and heavier material, it is sufficient to dip the hot end of the rod in the can of flux and add to the puddle in this way as it is required.

Start the welding by heating the metal over a 2" diameter spot where the weld is to begin by means of a circular motion of the blow-pipe. As the metal gets hot, test its heat by applying a drop or two of rod. When at just the right temperature, the metal from the sufficiently flux bronze-rod will spread out evenly to produce a "tinning" coating on the base metal. The inner cone of the slightly oxidizing flame should be kept from 1/8" to 1/4" away from the surface of the metal.[13]

Welding Cast Iron

Cast iron may be either fusion-welded or bronze-welded, with the latter process offering the greater advantages and ease of operation. Although cast iron has relatively high resistance to compression, its tensile strength and resistance to shock are relatively low. The probems of expansion and contraction, therefore, assume greater importance in the welding of cast iron.

Bronze-welding assumes considerable importance in the welding of cast iron aside from the fact that it is considerably more rapid than the fusion-welding process. The lower heat required for bronze-welding minimizes the effects of expansion and contraction and often makes it possible to bronze-weld the cast-iron parts without dismantling and without anything but local preheating.

Malleable cast iron, which depends for its properties upon a lengthy and complicated heat treatment can be joined satisfactorily only by bronze-welding. The heat of fusion would destroy the malleability.

Fusion-welding cast iron. As mentioned above, the first factor to be considered when cast iron is to be welded is the effect of expansion from heating and contraction upon cooling upon the casting. If the casting is at all intricate with light sections joining heavy, or if the facture or part to be welded is in such a location that there is any restriction to free movement of the casting upon heating or cooling, it is probably better to preheat the entire casting to a bright red heat, making sure that the heating is even and that cooling after welding is slow and uniform.

In preparing the casting for welding, it is absolutely necessary that all foreign matter in the form of oil, grease, dirt, sand, or scale be completely removed. Usually this will be accomplished in the weld area itself by the chipping or grinding required for the preparation of the vee. A 90° included vee is recommended for fusion-welding, and care should be taken that this vee extends nearly through the part to be welded.

The welding of cast iron requires the use of *cast-iron welding rod,* a neutral flame, and a suitable flux. During the welding operation, which is conducted similar to that of steel, more manipulation of the welding rod is required to work any particles of sand or slag out of the weld.[14]

Bronze-welding cast iron. As was mentioned earlier under the subject of bronze-welding, this operation is performed without melting the base metal. The preparation of a casting for bronze-welding requires the same consideration as to the effects of expansion and contraction, but these are usually not nearly so great in their effect because of the lower temperature. If the casting does require preheating, this can be accomplished in a temporary or permanent furnace, with the preheating allowed to progress until the entire casting has been brought up to a good black heat. A convenient method to judge this temperature is to throw a few drops of water on the casting. If this water sizzles, the casting is at about the right temperature. This is similar to the housewife's test of a hot iron.

The preparation of the vee and the cleaning of the base metal should be done as described under

[13] **More complete information** *on bronze-welding* may be secured in a number of publications available from the nearest office of The Linde Air Products Company, or from General Publicity Department, 30 East 42d St., New York City.

[14] "*The Oxwelder's Handbook*" contains complete instructions for welding cast iron. See footnote 9, page 746.

fusion-welding cast iron, making certain that the entire surface is properly cleaned. If the vee is prepared by grinding, it is advisable to rub the surface briefly with a file afterward to remove the small grinding-wheel particles which adhere to the surface.

There are one or two precautions regarding the repair of fractures in castings which it is well to mention. In preparing a crack for welding, the preparation of the vee must extend to the limits of the crack. If a little oil is rubbed on the surface of the casting first and then wiped clean, chalk or other fine white power rubbed on the surface will pick up oil which has accumulated in the crack and will indicate its extent better than can be seen with the unaided eye. A small hole drilled at the extremity of the crack will aid in preventing it from "running" when heat is applied during welding.

To apply the bronze-welding technique, the point at which the weld is to start should be heated to a temperature at which it just begins to glow. Experience is necessary in determining the proper temperature for bronze-welding, and an operator will soon recognize the characteristic appearance of the casting when it is ready after practicing a little to determine how the bronze rod flows upon the surface. If the casting is *too hot,* the bronze will bubble and boil upon meeting the surface, whereas if it is *too cold,* the bronze will not adhere but will roll off. When the right temperature is reached, the bronze rod, previously heated and dipped in flux, when melted upon the surface will spread out evenly and properly tin the base-metal surface.

The *tinning action* is the most important part of the bronze-welding procedure, and care should be taken to see that it is done properly. After the surface has been tinned, the vee is filled up by melting in more bronze, making sure that the added metal is completely fused with the bronze which has been previously deposited.

Welding Galvanized Iron

Galvanized iron has a surface coating of zinc which volatilizes or turns into a vapor at a relatively low temperature. **Bronze-welding** is of particular advantage in welding galvanized iron, since the higher speed of welding and the lower temperature to which the base metal must be raised considerably reduces the amount of zinc which is burned off.

The technique for welding galvanized iron is the same as that outlined already, with a neutral flame being used for fusion-welding and a slightly oxidizing flame for bronze-welding. The corrosion resistance of the bronze-weld deposit compares very favorably with that of the zinc coating on the galvanized iron and usually requires no special care after welding. If the joint is **fusion-welded,** on the other hand, it is usually advisable to paint the surface of the weld and adjacent to the weld with aluminum paint or some other preparation which will increase its corrosion resistance.

Welding High-Carbon Steel and Alloy Steel

It is not possible to describe in the space that is available here the various techniques required to weld the large number of low and high alloy steels now commercially available any more than it has been possible to point out all the precautions or to describe the complete operations for other types of welding. For this additional information it is necessary that the operator consult the various publications which are available today giving complete instructions for the type of work in which he is interested. See footnotes 2 and 9, pages 741, 746.

Welding Aluminum

As the behavior of aluminum under the welding flame is quite different from that of steel, a distinctive welding method is required. Once the differences in behavior and technique are thoroughly understood, it will be found that aluminum is one of the easiest metals to weld.[15]

Characteristics. Aluminum has a relatively *low melting point,* 1,215° F. for the commercially pure metal. It *conducts heat* more than four times as fast as steel, which means that, when heat is applied to the metal at any point, it is carried away and dispersed rapidly throughout the body of the metal.

Because of its light color and low melting point, aluminum does not give any indication by changing color that the metal is approaching the welding heat. When the melting point is reached, the metal collapses suddenly. By observing the behavior of aluminum as it melts under the action of the blowpipe flame, the operator will quickly learn how to control the rate of fusion.

The surface of the molten puddle of aluminum oxidizes rapidly, forming aluminum oxide which has a higher melting point than aluminum. In order to make a sound weld, this *oxide must be removed.* It is customary to use for this purpose a suitable flux which combines chemically with the aluminum oxide to form a fusible slag that rises to the surface of the puddle where it is readily removed. Another property that must be considered is the fact that aluminum and many of its alloys are weak when hot; in other words, they are "hot-short." This means that due care must be taken to see that aluminum parts are adequately supported when hot.

Joint design. The only difference in the joint design for welding aluminum from that for welding steel is that it is often desirable to notch the edges to be welded with a cold chisel. These notches aid in obtaining full penetration and also make it less likely that holes will be melted through the sheet. The notches also act as small expansion joints to prevent local distortion.

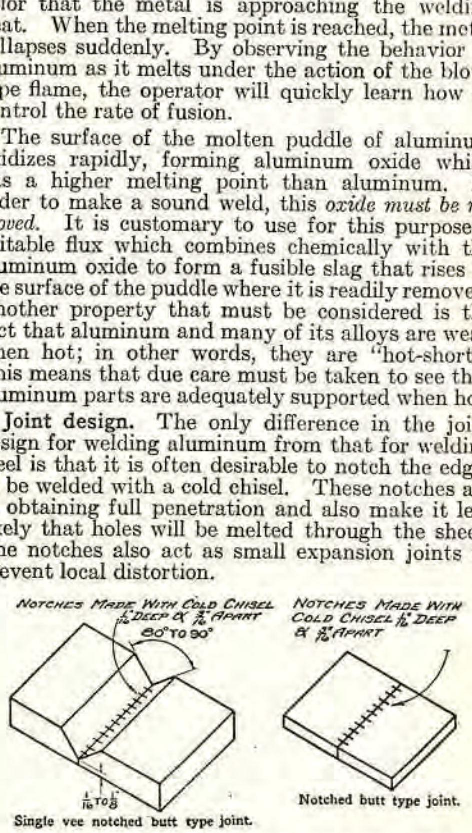

Fig. 18. **In welding aluminum** it is often found desirable to notch the edges to be welded to assist in securing thorough fusion.

Welding technique. There are so many weldable aluminum alloys on the market today that it is not possible to give a very complete description of the technique here. The *welding rod* should compare closely with the base metal and a good *aluminum flux* should be used.

The *blow-pipe flame* should be adjusted to have a very *slight excess of acetylene.* This is not because an excess of acetylene is needed, but because even the slightest oxidizing flame would make a very poor weld.

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[15] See also page 690 under "*Welding Aluminum.*"

See page 752 for oxy-hydrogen formerly on this page.

In welding aluminum it is advisable to use a *blow-pipe head or tip one size larger* than ordinarily used for welding steel of the same thickness. The *gases* should be adjusted so as to produce a soft flame. In welding, the *blow-pipe* should be held at an angle of about 30° to the plane of the weld with the inner cone of the flame about 1/8″ away from the metal. Metal from the welding rod should be fused thoroughly with the base metal as it is added. It is generally better to complete the weld in one operation. Should a section prove to be faulty and have to be replaced, chip out the old weld metal and re-weld with new metal. Care should be taken during the welding operation to make certain that any little particles of oxide or other foreign matter are worked out of the weld metal to the surface of the puddle.

Certain aluminum alloys depend for their properties upon *heat treatment*. These will require special precautions in welding, and more study and experience will be required of the operator in order to weld these materials.

Welding Copper

For many applications copper and its alloys can be joined by bronze-welding using the regular bronze-welding technique. Commercially pure copper contains a very small percentage of oxygen in the form of cuprous oxide which does not harm its properties in any way, except for the fact that it is not fusion-welded successfully. Completely deoxidized copper is now available from leading producers in a variety of forms, and in this form it can be successfully welded. Even if the copper does contain some cuprous oxide, it can be successfully bronze-welded as can also deoxidized copper.

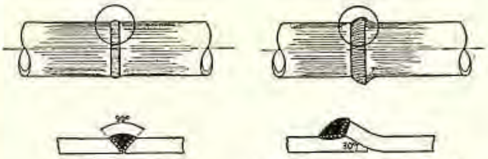
For fusion-welding copper, both the base metal and welding rod should be completely deoxidized. Joint designs for welds in copper are in general the same as for steel of similar thickness. A *neutral flame* is used and no flux is required. The welding head or tip should be one or two sizes larger than for similar thickness of steel because of the high heat conductivity of copper. Covering as much as possible of the work with asbestos paper during welding assists in reducing the heat losses. Large sections should always be preheated to a dull red before welding, and this practice is also advisable for small parts wherever practicable. After a few trials the welding operator will automatically make such minor modifications in technique as are made necessary by the relatively low melting point of copper and by the fact that the molten puddle is more fluid than is the case with steel.

Bronze-welding copper. For the large majority of copper-welding work the bronze-welding process offers distinct advantages. Where it is necessary that the color of the weld metal exactly match that of the base metal and in those cases in which the chemical composition of the two must be identical, however, bronze-welding should be replaced by fusion-welding.

Welding Brass and Bronze

In many cases a distinction between fusion-welding and bronze-welding brasses or bronzes is not possible because the melting points of these metals and the bronze-welding rod are so nearly alike.

When fusion-welding the bronzes which contain relatively high amounts of tin or lead, or both, it will be observed that these constituents start boiling out before the base metal is even at a red heat. By using a strongly *excess oxygen flame*, however, for both the preheating and the welding, the tendency for tin and lead to boil out is eliminated. After the base metal has melted and there is a noticeable film on the surface of the molten puddle, the amount of excess oxygen in the flame should be varied over a fairly wide range, during which it will be found that for one particular flame adjustment the film or coating tends to disappear and a bright surface is maintained on the metal. This is the correct flame adjustment necessary for good welding of the high-tin, high-lead, copper alloys. Usually a few preliminary trials will determine this adjustment, and, once found, welds free from holes or gas inclusions and with well-distributed tin and lead contents can be made. The same *fluxes* as for fusion-welding of brass are found to be satisfactory for welding alloys containing relatively large amounts of lead. The commercial fluxes which are used for bronze-welding or for welding the corrosion-resistant steels are usually found satisfactory for this work.



Single vee butt type joint.   Bell-and-spigot joint for brass pipe of less than ⅛ in. wall thickness.

Fig. 19. **For joining brass or copper pipe of less than 1/8″** wall thickness, use is often made of what is known as the bell-and-spigot joint.

As is the case with other metals, there are so many alloys of copper and also of nickel that considerable study is necessary, as well as practice, before the operator can be successful in welding these alloys.

Welding Nickel and Nickel Alloys

In general, the welding of nickel and the high-nickel alloys, including those containing copper, can be classed as a group. One of the problems associated with the high-nickel alloys is that they contain small amounts of certain deoxidizing elements which must not be allowed to boil out during the welding, as otherwise the hot metal will absorb gases and the result will be a porous weld. They also have a hot-short range, a condition of low strength, between the temperatures of 1,450° to 1,650° F. Care must be taken to see that the metal is adequately supported and that no stresses are present while the metal is passing through this range, both while being heated and while cooling.

For fusion-welding these alloys, it is advisable to use a *welding rod* of the same composition as the base metal. The commercial *flux* for bronze-welding is generally found satisfactory for use with these metals. Welding heads or tips for nickel and high-nickel alloys should be about one size larger than for the corresponding thickness of steel. The flame should be adjusted so as to have a **slight excess of acetylene.** The outer envelope of the flame should cover the weld during the whole operation so as to keep the molten metal from being exposed to the air and consequent oxidation. It is also advisable to keep the end of the welding rod well within the flame during welding. There should be little puddling of the weld metal and the tip of the inner cone should just about touch its surface. Nickel and high-nickel alloys can be easily **bronze-welded,** using the standard bronze-welding technique.

NOTE: **Repairing white-metal grilles (and chromium-plated automobile die castings) is explained in pamphlet,** *Form 4453.* Write The Linde Air Products Co., General Publicity Dept., 30 E. 42d St., New York City, and mention *Dyke's Auto Encyclopedia.*

Welding Lead

The welding of lead, called "lead burning" by the trade,[16] is considerably different from other welding processes. Because of its low melting point, only a very *small flame* is required, and it is consequently possible to use a *special blow-pipe*. Because lead has very little mechanical strength, care must be taken to support all large pieces or they will collapse under their own weight.

A very small flame should be used. It should be held so as to be almost perpendicular to the surface of the work with the inner cone almost touching the surface of the metal. Just as the lead begins to melt, the blow-pipe should be quickly lifted in order to prevent excess melting. The *welding rod*, or "burning stick," made by cutting sheet lead into strips or by melting it into suitable molds, should be added by playing the blow-pipe flame simultaneously on the rod and the base metal so that they will come to the fusion point at the same time.

In storage-battery work where the lead has been subjected to the action of a strong acid, the area to be welded should be scraped down to pure metal and then the welding may proceed as usual.

Hard-Facing

For parts which are subjected to excess wear, it is sometimes advisable to hard-face them with a material such as *Haynes stellite alloy*, a nonferrous alloy of cobalt, chromium, and tungsten. This alloy is applied to the base-metal surface without actually melting the base metal. Using an *excess acetylene flame* the base metal is brought to a sweating temperature, a point at which the metal just begins to glisten.[17]

Heating

Quite apart from its use in welding and cutting, the oxy-acetylene flame provides the most convenient source of intense localized heat for a wide variety of other applications. Although oxygen and acetylene would seem, on first thought, to constitute a more expensive fuel than coke, coal, city gas, or gasoline, the intensity of the oxy-acetylene flame and the ease with which it may be concentrated directly upon the parts to be worked make it possible to do the work with so much less fuel that the fuel cost with the oxy-acetylene process is, in most cases, actually less. In addition, there is a marked saving of time and labor. The oxy-acetylene blow-pipe saves time by making it unnecessary to dismantle a large structural machine in order to heat the particular part to be bent or straightened.

Heating applications involving forming and bending range all the way from the most delicate detail of ornamental ironwork to the straightening of the stern post on a giant ocean liner. The removal of dents is a most important heating application for such sheet-metal products as automobile bodies and fenders, streetcar and bus bodies, buckets, ladles, kettles, tanks, pots, and stills. Structural shapes such as angle iron, channels, tees, and other sections are frequently formed and shaped through the aid of local heating by the blow-pipe flame.

Other applications for the oxy-acetylene flame may be grouped under the headings of *preheating*, *welding*, *metallurgical*, and *wood-treating*.

Silver Soldering[18]

Silver soldering by the oxy-acetylene process is an operation quite similar to bronze-welding that has gained considerable industrial importance.

The two principal reasons for silver soldering instead of bronze-welding in certain cases are that silver solder has a lower melting point than bronze and a range of lighter colors can be obtained with this type of joint. Silver solders are now available having melting points as low as 1,200° to 1,300° F. Silver solder *will stand up under conditions of constant vibration*, a fact which is demonstrated by its use on delicate vibrating parts of radio loud-speakers and in many other ways where excessive vibration is a factor. Joints silver-soldered by the oxy-acetylene process have a tensile strength ranging from 40,000 to 60,000 lb. per sq. in. The *high resistance to corrosion* of silver solder is another important property recommending its use for certain chemical equipment.

Technique. The parts to be soldered should first be cleaned thoroughly either mechanically or chemically. For general soldering, a saturated solution of borax makes a good flux and may be effectively applied with a brush. The edges to be joined should fit tightly, since only a film of silver solder is needed.

A *small oxy-acetylene flame* should be used to preheat the joint and surrounding metal after fluxing, taking care that the base metal does not reach the melting point. When sufficient preheat has been applied, the flame should be moved away and the silver solder brought to the joint where it will melt and flow quickly if the parts have been properly fluxed and preheated. The knack of heating to the proper temperature is quickly developed with a little practice. The silver solder should be melted simply by the heat of the base metal; the flame should never touch the solder or a porous joint might result.

The Air-Acetylene Flame

The air-acetylene flame, produced by burning a properly proportioned mixture of acetylene and air to produce a temperature considerably below that of the oxy-acetylene flame, provides a source of heating which has literally hundreds of applications.

Equipment is available to utilize this flame in torches, soldering irons, for paint burning and a maze of other special applications.[19] Complete information regarding the forms of torch available and suggestions regarding the application of this flame may be secured from the manufacturers.

Oxy-Acetylene Cutting

Oxy-acetylene cutting is based upon the fact that ferrous metals[20] **when heated to a bright red temperature will actually burn rapidly in the presence of pure oxygen.** As described earlier the cutting blow-pipe consists of a device for providing a mixture of oxygen and acetylene which can be burned as a preheating medium and also supplies a stream of pure oxygen which does the actual cutting.

The operation of the cutting blow-pipe is in itself rather simple, although mechanical dexterity in making smooth cuts depends upon the amount of practice the operator has had.

In cutting steel or wrought iron the preheating flames are held on one edge of the piece of metal to be cut until it reaches a bright red temperature when the cutting lever is depressed to turn on the oxygen stream. If the metal has been properly *preheated*, cutting will immediately start with sparks and slag being given off.

Cutting Cast Iron

Cast iron can be easily cut with the oxy-acetylene cutting blow-pipe, although the resulting edges will be less smooth than they are when steel is cut. The method for cutting cast iron differs slightly from that for steel in that the cutting blow-pipe is moved

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[16] See page 752 and page 581.

[17] **Complete instructions** *for applying a number of hard-facing materials as well as suggestions as to parts which are effectively hard-faced*, consult *"Hard-Facing with Haynes Stellite Products,"* a booklet available from Haynes Stellite Company, Kokomo, Indiana.

[18] See page 690 under *"Silver Soldering"* where to obtain literature.

[19] **A booklet entitled** *"101 Uses for the Prest-O-Lite Air-Acetylene Flame," Form F-2708-A*, also pamphlet *"Prest-O-Lite 5 in 1 Outfit," Form 2709-b* are available from nearest office of The Linde Air Products Company, or from General Publicity Department, 30 East 42d St., New York City. See also page 690 under *"Soldering, Brazing, Lead Burning."* See also pages 581, 582, 585 and 751.

[20] **See footnote 8, page 746, giving a definition.**

slightly from side to side as the cutting progresses. As in the operation of other oxy-acetylene processes, some practice is required on the part of the operator before cast-iron cutting can be done most efficiently. The operator will soon learn the speed at which the cutting operation may progress and the amount of sidewise motion that is required in order not to lose the cut.

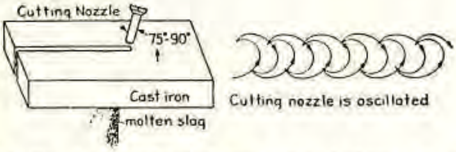

Fig. 20. A successful cast-iron cutting technique requires a slight side-to-side motion of the blow-pipe.

There are a number of special cutting techniques, such as *rivet removal, oxygen lance cutting, flux cutting, and grooving.* Since there is not sufficient space here to describe these operations adequately, it is felt more desirable to refer the operator to the supply manufacturing companies or to the organizations distributing literature on these subjects.

Flame Hardening

Although the method of heating and quenching for hardening relatively low-carbon ferrous material is a comparatively old process, developments and equipment for controlling the oxy-acetylene flame have made this process of tremendous commercial importance. The application of the oxy-acetylene flame hardening process to commercial jobs requires a rather careful consideration of the metallurgical factors involved. The carbon content is of considerable importance as is the rather close control of the temperature range through which the surface of the part is carried.[21]

Flame hardening may be defined as a process whereby the surface of a quench-hardening ferrous material is locally heated by means of an oxy-acetylene flame followed by a suitable quench. In other words, the surface of the part to be hardened is rapidly raised to the required temperature with the intense heat of the oxy-acetylene flame and then just as rapidly cooled, usually by a stream of water.

Welding Precautions[22]

1. Always shut off the gas at the cylinder valves when the work is finished.
2. Never leave pressure in the regulators when not in use. The pressure gauges will indicate.
3. Never clean out a blow-pipe tip with a sharp, hard tool.
4. Before attaching rubber hose to a blow-pipe or regulator, make sure that the inside of the hose is free from dust or powder (used as a preservative), which is apt to choke the blow-pipe.
5. Never let oil or grease come in contact with oxygen or any of the equipment through which oxygen passes.
6. Always see that the hose is clamped securely to the blow-pipe and regulators before using.
7. Always turn on the cylinder valves slowly.
8. Never open the acetylene cylinder valve more than one and one-half turns of the spindle.
9. In case the flame goes out at the tip or burns back of the tip, shut off first the oxygen, then the acetylene, at the blow-pipe.
10. If the flame is not blue and the part being welded is smoked black, then the oxygen line is likely to be stopped up or the tank is empty.
11. In disconnecting an empty acetylene cylinder from the welding outfit, remember to close the cylinder valve tightly. Remember that the acetone in an empty cylinder is inflammable, and that, should the temperature in the room increase, an open valve would permit vapor to escape, as well as any slight quantity of gas which might yet remain in the cylinder. For these same reasons, the railroads require that valves be closed before shipping.

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[21] **A booklet,** "*Flame Hardening,*" *describing the flame hardening process* is available from the nearest office of The Linde Air Products Company, or from General Publicity Department, 30 East 42d St., New York City, N.Y. **Ask for** *booklet F-3813.*

[22] **See footnote 6, page 745.**

MISCELLANEOUS INFORMATION

Welding Literature

In addition to the literature and booklets mentioned at the bottom of some of the preceding pages, the reader's attention is called to the paragraphs on page 690 under "*Welding.*"

Lead Burning

Lead burning of connectors and other parts on storage batteries, etc., with acetylene alone is not altogether satisfactory and is generally used in conjunction with oxygen. Illuminating gas with oxygen is sometimes used. See pages 581, 582, 585. See also page 690 under "*Lead Burning.*"

Light Brazing and Soldering Outfit

An outfit which can be used to advantage for light brazing, soldering, sweating together metal parts, annealing, drawing, tempering, melting metals, thawing pipes, sealing batteries, burning cable lugs, light preheating work, radiator repairing, etc., is the Prest-O-Lite "5-in-1" outfit mentioned in footnote 19, page 751. This outfit is used with Prest-O-Lite acetylene gas tanks, style B and MC, containing 40 and 10 cu. ft. of gas, respectively. They are the same tanks that are used for truck lighting. No oxygen is required. Another popular outfit is the Imperial No. 32 brazing and soldering outfit made by The Imperial Brass Mfg. Co., Chicago, Ill. The torch burns acetylene and the tip draws in the necessary oxygen from the atmosphere, making it economical to use. The tank connection fits the small automobile acetylene lighting (Prest-O-Lite) tank, but the outfit can be used on large-size acetylene cylinders fitted with regulators. See also page 690 under "*Brazing*" and "*Soldering.*"

For general brazing work, oxy-acetylene with the size torch suitable for the work to be done is considered best.

Oxygen Decarbonizing or Carbon Burning

Carbon can be removed from the cylinder head and pistons of an automobile engine by burning it out with oxygen. This process was formerly used to a great extent on engines of the nondetachable cylinder head type as explained on page 764.

Electric Arc Welding

Electric arc welding is another form of welding. The principle, quoting from "*Dyke's Self-Starter,*" is as follows: "When an arc is formed across a gap in an electric circuit, an intense heat is generated. The employment of this heat is the general principle of arc welding. The metal parts to be welded form one of the electrodes of the circuit. The other electrode is movable and is placed in a special holder which is held and controlled by the operator. The movable electrode can be made of carbon, in which case the porcess is known as *carbon arc welding.* The movable electrode can consist of the welding rod itself, in which case the process is known as *metallic arc welding.*" See p. 690 under "*Welding*" where to obtain literature.

Spot Welding

Spot welding is the fusing of two metals together by the electric contact resistance method without the use of filler material and is widely used in sheet-metal shops on light gauge material. The process is electric and usually employs pressure between the electrodes but requires a different type of machine from the regular electric arc equipment. See page 690 under "*Welding-Spot Welders*" where to obtain literature.

Oxy-Hydrogen

Hydrogen gas in connection with oxygen gas is sometimes used for cutting and lead burning, but is very seldom used for general welding. Hydrogen is not in as general or universal use as is the oxy-acetylene process.

When it is desired to equip for oxy-hydrogen, a hydrogen regulator and a set of hydrogen tips for welding and cutting will be necessary. The Imperial Brass Mfg. Co., Chicago, Ill., supply such equipment, also oxy-acetylene equipment. See also page 690 under "*Welding.*"

See page 115 for oil-vac gasoline fuel-feed system formerly on this page.

INSTRUCTION No. 67

TOP REPAIRING.[1] LACQUER FINISHING: Equipment and Application

Any repair shop, by the investment of a small amount of money in equipment, and the exertion of reasonable care, can develop a profitable top repair department. It is as essential a part of the trade as is the machine shop or the vulcanizing shop.

Only a **small amount of equipment is necessary in a top repair shop,** and this, with the exception of the sewing machines, may be made by the repairman himself.

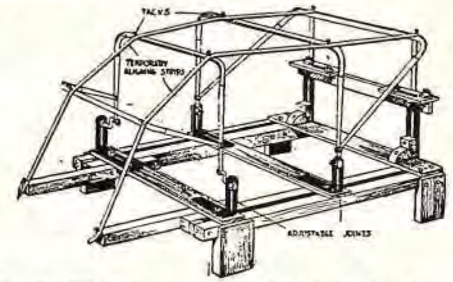

Fig. 1. When the car cannot be left in the shop, this adjustable frame enables the mechanic to duplicate the method of holding used on the car.

The top building frame is shown in Fig. 1, and it is used only when the car for which the top is being repaired cannot be left during the work. It is simply an adjustable framework upon which the top may be placed in exactly the position it occupies when up, and on the car. For each car the frame is set to duplicate the measurements of the top-supporting irons and the car body. Then the workman can repair or rebuild the top with assurance that it will fit when returned to the car. When possible, the top should be left on the car during the repair.

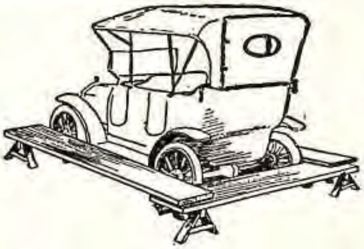

Fig. 2. Most tops are repaired right on the car, and a framework on three sides of the car renders all parts accessible.

In order to render all parts of the top accessible, when left on the car, a framework shown in Fig. 2 is set up around three sides of the car. This framework is about 18″ high, and comprises three planks resting on four small wooden horses.

Another method of accomplishing the same result, yet one which the author has never seen, would be to construct a pit below the floor level. This would permit the workman to work directly from the floor and save the time lost in stepping to and from the platform.

All work is laid out and cut on the laying-out table shown in Fig. 3. This table is about 6 ft. wide, 12 ft. long, and 28 in. high. A notched rack at one end supports the rolls of top material and enables the workman to obtain or replace the top material readily when desired. Rolls may be easily removed from the frame, or as many as three rolls of material may be carried at one time.

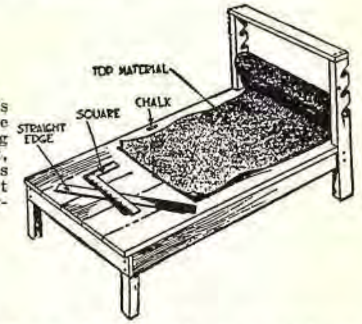

Fig. 3. The rolls of top material are carried on rods hung in a notched upright, and the material is marked out and cut to form on the laying-out table.

The tools[2] of the workman are few, comprising a light cross-peen **hammer,** with a tack puller fitted to the end of the handle; a heavy pair of **shears,** a small **cold chisel,** and a **nail set or punch.** These are carried in a special apron, made of top material, as shown in Fig. 4. In addition, **a carpenter's square,** a 10-ft. **straight edge, a yardstick,** and a **plumb bob** are required. The plumb bob is used to plumb up the edges of the back curtain, when fitting, to make certain that they are hung straight.

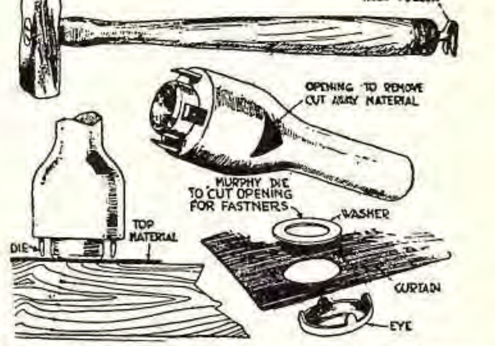

Fig. 5. The other end of the hammer (at top of illustration) is fitted with a tack puller, thus combining the two tools. Special dies are required to cut openings for fasteners. The most common type is shown in lower part of the illustration.

In addition, several special punches and dies will be necessary for cutting the openings for the curtain fasteners. One of these—styled the **Murphy die**—is shown in Fig. 5, and corresponding dies are used for each type of fastener.

The sewing machine used in this work is of extra heavy construction, and is similar to those used by harness makers. These machines should be motor-driven, and may be purchased from almost any reliable sewing-machine manufacturer. See p. 755.

A portable drill of the type shown on page 700 is a very serviceable tool for top work.

So much for the equipment. Now for **the method of doing the work.** Briefly this consists of removing the top material, part by part, using the parts as patterns to cut the new parts by; fitting the parts to the top frame; removing the parts; sewing them

[1] From *Motor World* (pages 753, 754). [2] Trimmers' tools can be obtained of concerns mentioned on page 755.

together, and then placing them again on the frame. Careful work is essential, and after carefulness has become a habit, speed may be developed. Carefulness, then speed, are the only two requirements for a successful top repairman.

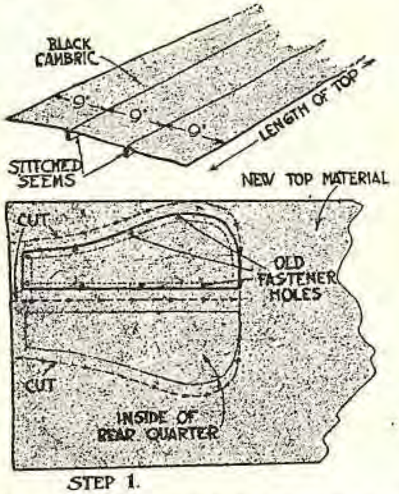

Fig. 6. The side pads are a single strip of cambric 9" wide and sewed as shown.

The following is a typical example of the method used in re-covering an automobile top. Though it specifically applies to a Ford top, it may, in general, be applied to any car.

1. **Remove the top covering from the frame,** part by part, using the hammer and cold chisel as tools. Note how each part is fastened, as the rebuilding must be exactly the reverse of the tearing down.

2. **Using each part as a pattern, one by one, mark out the new parts on the top material.** Care must be taken to allow extra material at the edges for fastening the material to the frame. The method of constructing the rear quarter is shown in Fig. 7 (lower half), and this method applies in general to each of the top parts.

All metal fastener holes should be punched, using the holes in the old parts as guides, and all square corners should be checked up by means of the square. The parts are then sent to the machine, and the necessary sewing is done. The celluloid windows are also placed in the rear curtain at this time.

In the meantime, the top frame should be placed in good condition. If any bows are broken, new bows should be fitted. Ordinarily, new wrapping should be tacked around the bows, but if this wrapping is only faded, it may be dyed to conform to the inside of the top material.

3. **The side-pad covers should now be made,** according to the pattern shown in Fig. 6. On the Ford, black cambric is used, but in every case the material should conform in color and quality to that used in the top material.

4. **Line up the top bows.** The method of doing this is shown in Fig. 1. Heavy canvas straps are passed over each side of the bows, drawn tight, and tacked in place. The front bow should fit down over the windshield; the two middle bows should be vertical, and the position of the rear bow can be gauged by the length of the straps holding it down to the body back.

5. **The side-pad liners are next tacked in place,** and the burlap strips are tacked tightly in place. After this the curled hair, or cotton packing, is replaced, and the side-pad flaps are pasted into place. If desired, the edges of the pad may be

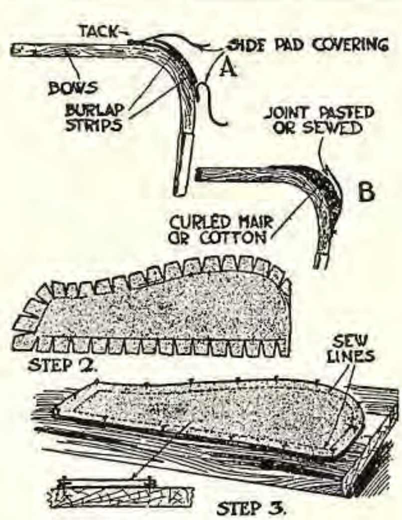

Fig. 7. In the upper half of the illustration is shown the method of building up the side pads.

The lower half of the illustration shows the various steps in laying out and cutting a rear quarter. It is then taken to the machine and sewed.

sewed together. These operations are shown in detail in Fig. 7 (upper part).

6. **The rear quarters and back curtain are now fitted and tacked in place,** after the metal fasteners have been applied, as shown in Fig. 5. All vertical edges are plumbed up with a plumb bob, as any edge out of the vertical here is particularly noticeable.

7. **The two side quarters are now temporarily tacked in place,** beginning at the front and working to the back. These quarters should be drawn tight, without wrinkling. The edges of the deck are then turned under, and the deck is temporarily tacked in place.

8. **By carefully fitting and changing, the top may be fitted to the bows in exactly the position it is to occupy.** When everything appears to fit correctly, the side curtains should be placed in position, and if necessary, the tacks should be removed and the top pieces shifted until the side curtains fit. (In most cases new side curtains do not have to be made; but if so, the new curtains should be fitted at this point.)

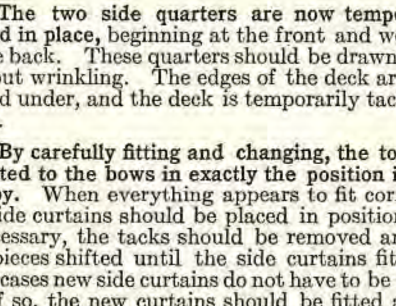

Fig. 8. After all parts of the top are made, they are temporarily tacked to the bows and fitted. When a perfect fit is secured, the edges are marked, and the parts removed and sewed. They may then be replaced on the frame, and permanently fastened in place.

9. **When everything is right, the mating edges of the top pieces should be marked with chalk,** and these marks should be crossmarked, as shown in

Fig. 8. Then, by joining the corresponding marks together, the sewing-machine operator can sew the parts together correctly. Chalk marks should also be placed at the points where the edge of the top crosses the bows. This permits the top to be correctly replaced after a sewing.

10. The parts of the top are then removed, and the flaps on the edges that are to be sewed are trimmed down to a width of about 2 in. The parts are then sent to the machine and sewed together.

11. To complete the work it is only necessary to replace the top covering and tack it securely in place. All extending edges are removed and the joints covered by a narrow strip of cloth material fastened by black upholstering tacks.

The foregoing covers the method of completely replacing the top covering, with the exception of the side curtains. As stated, this is rarely necessary, as the side curtains are little used. If desired, any one part of the top may be replaced with new material, providing the other parts are in good condition. However, if either the deck or side-quarters must be replaced, it is necessary to tear the top completely down in order to sew it together again.

In cases where it is necessary to replace some parts of the top covering, it will usually be found advisable to renovate the interior and exterior of the rest of the covering to make it conform to the appearance of the new part. Or this renovating may be done at any time to improve the appearance of the top.

After applying any patches that are necessary, replacing broken windows, and tacking on new binding at the edges where required, the top should be thoroughly brushed and cleaned. Gasoline should never be used for this purpose if rubber is used in the top material construction, as its action tends to destroy the rubber. Soap, warm water, and a brush are all that are usually required.

When the top is thoroughly cleaned and dried, top dressing may be applied to the outer surfaces, and the faded inner surfaces may be dyed black. There are many brands of top dressing on the market for this purpose, and any well-known brand should prove entirely satisfactory. By exercising a little care, the appearance of a shabby top may be greatly improved by this simple cleaning, patching up of loose ends, and application of top dressing.

Top roof patching strips adapted for mending tops can be cut to fit any repair needed in roof, side or back curtains and are permanent and waterproof; they are convenient for all repair shops, and are made of different material to meet different requirements. They can be secured of supply houses.



Fig. 9. Top roof patching material.

Fig. 10. **Celluloid windows,** bound with suitable material to match different curtains.

Fig. 11. **Glass curtain lights.** The glass is beveled and comes with a frame ready to place in the curtain. Glass and celluloid curtain lights can be secured of auto supply houses.

Fig. 12. **"Lift-the-dot fastener"**: a popular curtain fastener. To unlock and remove, lift the dotted end of the socket which is placed nearest the edge of the curtain. Manufactured by Carr Fastener Co., 31 Ames St., Cambridge, Mass.

Where to Obtain Top Equipment and Material

Trimmers' tools: C. S. Osborne & Co., Newark, N.J. (trimmers' and upholsters' tools); H. D. Shields, Grand Rapids, Mich.; J. M. Waterson, Detroit, Mich.; Sligo Iron Store Co., St. Louis, Mo.

Top material, such as top dressing, top patches, celluloid for curtains, glass curtain lights, visors for windshields, seat covers, tire covers, etc., can be obtained of Sligo Iron Store Co., St. Louis, Mo.; The Faeth Co., Kansas City, Mo.; Beck & Corbitt Iron Co., St. Louis, Mo.; Campbell Iron Co., St. Louis, Mo.; The Cincinnati Auto Specialty Co., Cincinnati, Ohio; The Ero Mfg. Co., Chicago, Ill.; Nathan Novelty Mfg. Co., New York, N.Y.; Cray Auto Supply Co., Cleveland, Ohio; The Landers Bros. Co., Toledo, Ohio; The Toledo Auto Fabrics Co., Toledo, Ohio. J. C. Haartz Co., New Haven Conn. and many of the auto supply houses listed on page 686.

Sewing machines: The Singer Sewing Machine Co., Singer Bldg., New York, N.Y., manufactures a sewing machine especially designed for top and curtain work and also seat covers, etc. It is known as Class "16-188." Other classes are "16-141" and "42-5."

Miscellaneous

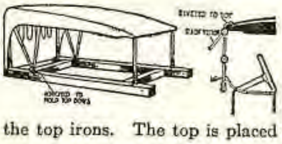

Fig. 13. It is often desired to paint or repair a top without leaving the car in the repair shop. A simple support that permits this is a rectangular wooden framework notched to hold the top irons. The top is placed on this framework.

Fig. 14. **Rain vision windshields (visors)** are a simple matter to add. The upper section of a windshield is mounted on the front of the top, two specially made brackets being used to hold it in place. It catches the rain and the regular windshield protects the driver from the wind. **Windshield cleaners** (page 649) are very necessary.

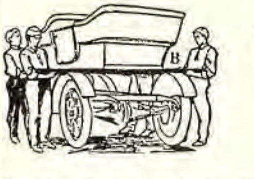


Fig. 15. **Removing a body.** Showing how the body of a car can be lifted easily from or on to the chassis, and conveniently transported about the garage or shop.

Fig. 16. **Closed bodies may be removed** without strain by the aid of the hoisting cradle illustrated. Two cross-pieces are attached to separate chain hoists and are so spaced that they hang 2 ft. from the ends of the body to be removed. First one end of the body is pried up, and a lower cross-member slipped beneath it. Then the other end is raised, and the other lower member put in place. The steel stirrups are then used to attach the lower and upper cross-pieces, after which the body may be raised and the chassis rolled from under.

Vulcanizing Small Holes in Tops

Dr. S. A. Peake's method of **vulcanizing small holes** as large as ½" in tops is as follows: First clean both sides of the surface with gasoline; then use "Mastic" or "Tire-Doh" and work it to a point, and insert in the hole, so as to fill it completely. Cut off on each side. Then place a hot sad-iron underneath and on top. This will vulcanize the Mastic in the hole. (The Boyer Chemical Co., Chicago, Ill., supplies top-mending outfits.)

Department for Renewing the Body of a Car

This department is usually conducted with the painting department, and equipment is divided into departments as follows:

Painting: truck for moving bodies; paint removing machine (alkali type); electric drill; room for finishing with forced ventilation and air filter. (See also "Nitro-Cellulose Lacquer Enamel Finish," page 756.)

Enameling: a room should be provided for this and the equipment as follows: enameling ovens; drain board; flowing machines; drop tanks; tanks for cleaning fenders in; air compressor. (For concerns supplying enameling equipment see page 728.)

Trimming: This department is used for upholstery and top work. Top work is described on page 753 and should consist of: sewing machine (see page 755) with table; cutting table; rack for material and shelves; hammers, shears, tools, etc.

Electroplating: This department is for replating parts such as nickel, etc., and equipment should consist of: motor-generator designed for plating; tanks for copper and nickel plating; acid stripping tank; tank for cleaning parts (see pages 474, 761); lathe with motor for buffing; book of instructions on plating (see page 740).

Cleaning Car, Tops, Upholstering, Etc.

On this subject see pages 643–649 under "Care of a car."

LACQUER FINISHING NITRO-CELLULOSE: EQUIPMENT AND APPLICATION

The reader is requested to turn to page 648 and first read how nitro-cellulose lacquer finish differs from paint and varnish and its advantages.

The major equipment[1] necessary for this work consists of an air compressor, together with a motor to drive it, an air-regulating device which takes all oil, water, and dirt out of the compressed air, and about 25 ft. of hose for the spray gun.

Spray outfits for small shop use, suitable for operating one spray gun would cost approximately $275.00.

If a person going into this business already has an air compressor which would supply about 6 cubic feet of air per minute, the cost of the small equipment could be cut to about $100.00.

It is not absolutely necessary to have an exhaust fan to draw off the spray dust, but it is a mighty good thing to have, since it makes better work and better working conditions; this costs approximately, from $50 to $135, according to the size.

Method of Finishing over Cleaned Surfaces; Paint Removed[2]

This subject is dealt with briefly here. To those interested, we suggest writing the different manufacturers per footnote page 648, and below.[2]

If old paint is to be removed, clean all parts thoroughly. Then remove the old varnish and paint with **a paint and varnish remover,** such as "Taxite," made by Sherwin-Williams Co. This can be applied with a brush and allow to stand for ten or fifteen minutes, then scrape off with a putty knife and clean surface either with benzine or denatured alcohol.

The booklet[2] explains five methods for finishing from the base metal to the polished surface when all paint and varnish is removed. **The undercoatings** are, first a primer, then a putty glaze, then a surfacer.

Briefly, the first method consists of spraying on the primer coat which is left to dry for 12 hours, or if forced drying is used it can be dried in 4 to 5 hours at 150° F.

The primer is then sanded lightly with No. 7-0 grade of fine sandpaper, then glazing putty thinned with turpentine is sprayed on, usually two or three coats.

When this is dry (8 hours, or 6 forced), it is then water sanded (sandpaper wet with water and all rough spots rubbed smooth—use plenty of water), then another coat of primer is applied and left to dry (12 hours, or 4 forced), which seals in the porosity of the surfacing material from the action of the lacquer.

After drying, this is sanded with fine sandpaper (No. 280). Then a thin coat of lacquer enamel is sprayed on and after drying (1 hour), a second, and a third coat is applied.

Some operators put on as many as five coats of enamel, although three coats of "Opex" enamel gives satisfactory results. The last coat is left to dry overnight. A light coat of thinner will tend to flow out the finish if applied after the last coat of enamel.

The finish of these applications will be a satin finish, not a high luster or gloss. There are several methods of obtaining gloss, such as to sand out just prior to the last coat, or by using grade 3 F pumice stone, and some operators sand with high-test gasoline, as this evaporates fast. Opex polishing compound is then used to polish with.

Finishing over Old Paint

The booklet[2] explains three methods under this heading. The success of the application of the lacquer enamel over the old paint and varnish depends entirely on the method of application, the condition of the old paint and varnish, and the care of the operator. Many cars have been successfully finished, but of course if the lacquer enamel is applied to paint which is almost ready to fall off, it cannot be expected to hold on.

First clean and sand off car thoroughly. All loose paint, grease, oil and dirt must be eliminated. Many refinishers use ammonia to clean off the varnish and then sand off the remaining color varnish.

Next, apply one coat of primer and when dry, sand lightly to knock off the nibs. Then apply a light coat of binder surfacer gray, light or dark. This dries within one hour. Successive coats are then applied, depending upon the condition of the original finish. Usually two or three coats are sufficient to give a foundation, which, when sanded out, leaves a smooth finish for the lacquer enamel. **The enamel is then applied and the gloss obtained** as mentioned in the foregoing method.

Like anything else worth while, the work must be done right. For example, if the wrong pressure is used on the spray gun, or unsatisfactory ventilation, "spray dust," as it is termed will form over the finish. There is another, termed "orange peel" effect, caused by not keeping the spray gun at proper distance—all of this can be remedied as explained in booklet.[2]

Miscellaneous

On fenders, if finished in a hard baked-on high-quality enamel, the old finish will not have to be removed but cleaned and sanded well, followed with a rubbing of alcohol; then apply a coat of metal primer and spray on the lacquer enamel.

If it is desirable to remove the baked enamel from fenders, bumpers, etc., so that lacquer enamel can be applied, dip them into a tank of hot lye, then wash in clean hot water and blow out seams. Then apply lacquer with a spray as for body (never subject aluminum to lye baths).

When fenders, bumpers, etc., are painted and varnished instead of baked enamel, the paint and varnish can be removed with a paint remover. **On chassis frame, axles, springs, etc.,** apply oil enamel chassis black with brush spray reduced 45 per cent with turpentine. It would be better if a coat of primer was applied first. **Wheels, bumpers, lamps, etc.,** can also be treated with lacquer enamel with spray.

Special polishes can be obtained which will clean and polish a lacquer finish. Opex polishing compound and Duco polish No. 7 are two popular brands.

Refinishing a Lacquered Car

After a long time the surface of lacquer finish will wear thin. This condition can be improved by rubbing off all spots with No. 0 steel wool or No. 7-0 sandpaper, then clean thoroughly and spray on a surfacer thinned with good thinner, then when this is dry and has been thoroughly sanded, spray on lacquer enamel and finish as mentioned before. **The only** condition that would necessitate removal of old lacquer would be if old finish were flaking off or cracking.

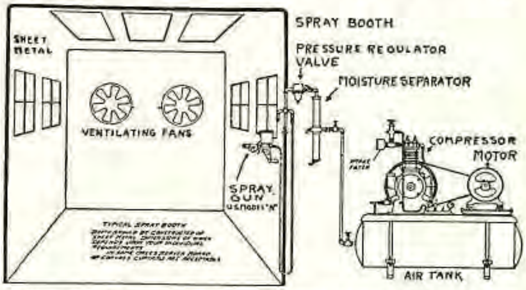

Fig. 17. **Example of equipment necessary for lacquer spray work.** The spray booth should be constructed of sheet metal. In some cases beaver board or canvas curtains are acceptable. (From catalogue of U.S. Air Compressor Co., Cleveland, Ohio.)

Brushing Lacquer

The foregoing applies to lacquer to be applied with a spray gun and which cannot be used with a brush due to the rapid evaporation of the solvents used. **Lacquer which can be applied with a brush** can be obtained of most lacquer manufacturers (see list, page 648). Usually two coats are given and can be applied with about one hour's time between coats.

[1] **Some of the concerns who supply complete equipment for** spray painting for use in finishing, refinishing and touching up work and also issue instructive literature on this subject are: Binks Spray Equipment Co., Chicago, Ill.; Brunner Mfg. Co., Utica, N.Y.; De Vilbiss Mfg. Co., Toledo, Ohio; Eclipse Air Brush Co., Newark, N.J.; Egyptian Lacquer Mfg. Co., 90 West St., N.Y.; Paasche Air Brush Co., Chicago, Ill.; Spray Painting and Finishing Equipment Sales Co., Boston, Mass.; U.S. Air Compressor Co., Cleveland, Ohio.

[2] **Credit is extended for most of the information under this subject to a very instructive booklet,** *Modern Automobile Finishing Methods,* published by The Sherwin-Williams Co., Cleveland, Ohio, manufacturers of "Opex" lacquer enamel. This booklet will be mailed free to readers of this book.

INSTRUCTION No. 68

REPAIRING AND ADJUSTING A CAR: Overhauling a Car; Cleaning Engine and Chassis; Greasing a Car; Lubricating; Removing Carbon; Causes of Loss of Power; Compression Tests; Testing for Engine Knocks; Grinding Valves; Refacing and Reseating Valves

WHAT CONSTITUTES A CAR OVERHAUL

Automobile overhauling is essentially a process of general cleaning, inspection, tightening-up and re-adjusting, involving, perhaps, some minor replacements, all of which will be taken up in their respective order.

Tuning up car is essentially a process of adjusting and checking the various parts of entire car to see if they function properly.

Tuning up engine is likewise a process of adjusting and checking the various parts of the engine, such as ignition, carburetion, and valves.

A complete overhaul would consist of first inspecting and checking all units. All such parts as are shown by the inspection to be at fault should be adjusted, repaired or replaced, **providing car is worth completely overhauling.**

Before doing any work at all on a car, place covers over seats, upholstery, doors, fenders, etc., to protect the parts from grease, dents and scratches. See page 662 for "car overalls."

Engine[1]

Test compression: Test for knocks; clean carbon; grind valves; adjust valve clearance; fit new rings if necessary; re-bore cylinders if necessary; take up on bearings; check the valve timing; examine valve springs; examine gaskets.

Ignition and wiring: Check the ignition timing; test battery and electrical apparatus; clean spark plugs and adjust gaps, clean and adjust ignition breaker points, also clean, oil, adjust and tighten the generator and starter, nuts, etc., clean and adjust cut-out point, and see that all ground connections are tight. Clean generator commutator and commutator segments, adjust generator charging rate.

Clean engine: Flush out old oil as explained on page 167, and clean oil strainer. Refill oil pan with a good grade of oil. If of long standing, remove and clean oil pan and refill and replace.

Miscellaneous engine parts: Examine water pump; see if water hose requires replacement; examine intake and exhaust manifolds and see that gaskets and joints are tight; tighten all cylinder and cylinder head bolts and nuts.

Front end chain. Adjust but not too tight.

Radiator

The radiator should be disconnected and a **stream of water forced through it. If scale exists,** cleaning can be done with a solution of soda and water, as explained on pages 739, 740.

Carburetion

The carburetor should be removed and thoroughly **cleaned and tested for float or needle valve leak.** Examine the gasoline line and see that all joints are tight. Drain and clean vacuum tank.

Clutch and Transmission

The clutch is one part that should receive attention, and here the repairman should resort to the maker's instruction book, if it is still at hand.

The cone clutches are usually faced with leather or fabric. The leather can be cleaned with a dry cloth and can then be painted very lightly and evenly with neatsfoot oil. The fabric facing can be given a squirt-gunful of kerosene. Be free with oil on all the clutch connections, and take especial care that the clutch thrust bearing is properly fed. Oil all connections from the clutch pedal lever to the clutch proper. Do not take up on the clutch spring unless you are certain that it is needed.

With wet-plate clutches the housing should be flushed with kerosene and the engine turned over a number of times. At the same time that the engine is turned over someone should push the clutch pedal in and out. This works the kerosene around the plates and tends to remove any gummy deposits. Then drain the housing, and repeat the operation. That finished, fill to the required level with oil. Usually 1 pint is used with ½ pint of kerosene (follow manufacturer's instructions on this).

With a dry-plate clutch the only thing that may be needed is a cleaning with kerosene, to remove gum. However, use a squirt gun in this case. No matter what the type of clutch, be free with oil at all the various connections.

Look for small oil holes which are clogged with dirt. Oil the clutch cross-shaft, the clutch collar, and all the parts which move.

Clutch pedal: see that it has free play; see Figs. 7, 7A, page 841.

Universal joint: Back of the clutch or transmission there may be a universal. Clean it thoroughly with kerosene, whether it is exposed or housed. Allow this to dry, and then pack with graphite or grease.

Next, proceed to the transmission. Drain the old lubricant, replace the drain plug, and remove the cover if there is one and clean it out.

Fill the case half-full of kerosene, and with a clean cloth mop it. This is a dirty job, but it will be worth your while, because the gear-set usually is neglected throughout the year and is required to give efficient service with oil that is perhaps a year old. With the case clean, add a grade of oil as recommended by the manufacturers. See also pages 171, 762. Do not put too much oil in the case. There usually is a level-plug, but if there is none, allow the level to be about up to the shaft of the highest or upper gears.

After draining and cleaning clutch, transmission, and rear axle, fill with fresh lubricants of proper consistency for summer or winter. See pages 644, 762.

Running-Gear Parts

Wheels: First in order come the wheels. The car has been jacked up, and the next step is to see that the wheels run true on their bearings.

There are many ways of doing this. A good way is to sight with one eye closed, while the wheel is revolving. Any irregularity in wheel movement is easily detected. However, sometimes the rim is bent a little and one will imagine the wheel is running untrue. Grip the wheel firmly with both hands and test for side play and up-and-down play by pushing and pulling on the wheel in all directions. A loose bearing usually causes this trouble, and in many cases the looseness can be overcome by tightening the nut slightly.

Sometimes **new bearings** are needed, because they are worn excessively. This subject is more fully treated farther on, under discussion of the cause of "wobbly wheels," etc. **Remove, examine, clean bearings and reinstall wheels. Align the wheels,** as explained farther on.

Brakes: clean, equalize and adjust.

The steering assembly, brakes, and other parts require the same sort of attention and will be taken up in their separate order farther on. Adjust steering gear and front axle steering linkage.

Springs: Tighten spring clips and shackle bolt.

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[1] See pages 663–664 on inspection of engine and car, and page 766 on testing compression. See also page 641.

The rear axle should be cleaned and lubricated, and the drive pinion tested as to its relation with the drive gear on the differential. If noisy, it is probably loose and requires adjustment, as will be explained under "Adjustment of rear-axle gears."

Inspection after Repairing (see also page 663)

See that the following are in proper condition:

1. Cylinder head tight.
2. All spark plugs firing, and tight.
3. Fan belt tight.
4. Fan bracket bolt and cotter pins tight.
5. Adjust carburetor properly.
6. Water connections tight and no leaks.
7. Hood fits properly.
8. Head lamps burn, properly focused; connections tight.
9. Front wheels adjusted, lubricated, and lined up.
10. Fenders and running board bolts and nuts tight.
11. Doors work properly.
12. Brakes adjusted.
13. Transmission bands adjusted (on Ford car).
14. Floor boards fit properly.
15. Grease in rear axle.
16. Grease in all cups.
17. Oil in engine.
18. Water in radiator.
19. Tires properly inflated.
20. Examine tool kit.
21. Curtains fit.
22. Horn in working condition.
23. Starting motor and generator is in working condition.
24. Battery fully charged.

A SUGGESTED METHOD OF OPERATING A REPAIR SHOP ON A FLAT-RATE PRICE BASIS FOR LABOR; ALSO A GUIDE FOR OVERHAULING A CAR

Note the **flat-rate system of charging for the work,** as shown in column A, and the flat-rate **to pay the mechanic,** as listed in column B. This method of "selling service," as it is termed, is meeting with success. The list below refers to the Ford, but can be worked out for other popular cars.

The idea involves dividing the shop into divisions for doing a certain class of work; to charge for the work done, as enumerated, and to pay the mechanics accordingly. Note each job of work is numbered.

These prices[1] are not given as a fixed standard. This would depend to some extent upon the locality and other conditions; for instance, for a shop to make money at these prices would necessitate a shop equipment of a number of labor-saving devices and tools. See page 700 explaining the **importance of proper shop equipment,** and pages 714, 789–794, 803, 823, 1095, 1137, showing various labor-saving devices.

The following data give information covering the overhauling of the entire Ford car, so far as labor cost is concerned, and the average schedule of prices charged for doing the work as shown under column A. This is **worked out on the piece-work basis,** as shown in column B. Therefore, as you will note, the repair shops get practically 60 cents out of every dollar taken in, and the mechanic gets approximately **40 cents.**

Engine Division

		A	B
1A.	Remove motor from car	$3.00	$1.10
1B.	Overhaul motor and transmission out of car	20.00	8.00
1C.	Replace motor in car	7.00	3.00
2.	Overhaul motor only—out of car	15.00	6.00
3.	Overhaul transmission only, or repair, replace magneto out of car	5.00	2.00
4.	Braze crank-case arms; support or repair leak in case by taking out the motor	12.00	5.00
5.	Install or refit one piston or one connecting rod	3.00	1.20
6.	Install or refit two or more pistons or connecting rods	5.00	2.00
8.	Tighten two or more connecting-rod bearings	4.00	1.50
9.	Replace transmission bands without starter	2.50	1.00
9A.	Replace transmission bands on cars equipped with starter	3.50	1.40
15.	Grind valves and clean carbon	3.00	1.10
20.	Replace cylinder-head gasket	1.00	.40
21.	Replace radiator or all three hose connections	.75	.30
22.	Replace one hose connection only	.40	.15
23.	Replace crank-shaft starting pin, or pulley	1.50	.50
24.	Tighten motor to frame	$ 1.25	$.45
25.	Clean crank case or install gasket under lower cover	.50	.15
26.	Replace carburetor or manifold; repair leak in manifold	.75	25
27.	Install new butterfly spring	.75	25
28.	Overhaul carburetor	1.50	.50
32.	Replace commutator pull-rod joint	.60	.20
33.	Replace or rebush fan-pulley assembly	.60	.20
34.	Adjust clutch fingers and transmission bands	.60	.20
35.	Adjust transmission bands only	.40	.15
40.	Tune and adjust motor, regular, only	1.25	.40
41.	Tune and adjust motor, special, only	1.75	.60
42.	Tune and adjust motor, regular, with operation No. 15	1.00	.40

Parts Brought in or Shipped in for Repairs

		A	B
57B.	Overhaul transmission, only	4.00	1.60
58B.	Rebore cylinder only	3.50	.80
59B.	Rebore cylinder only, including fitting of pistons	4.50	.90
60B.	Rebore and re-babbitt cylinder, including fitting pistons	6.50	1.30
61B.	Re-babbitt cylinder only	2.75	.40
62B.	Re-babbitt cylinder, fit crankshaft, and run in	4.50	1.50
63B.	Rebore and re-babbitt cylinder, fitting of pistons, crankshaft, connecting rods, and running in	8.00	3.00
64B.	Rebore and re-babbitt cylinder, fit pistons, valves, push-rods, cam shaft, crankshaft, connecting rods, and run in	11.00	4.00
66B.	Rebore and fit pistons, valves, and push-rods, and straighten and fit cam shaft	6.50	2.40
68.	Rebush three transmission drums	1.50	.50
69B.	Rebush transmission drums, each	.60	.20
70B.	Rebush and re-rivet three triple gear assemblies	1.50	.50
77B.	Straighten cam shaft and fit bearings	1.25	.50

Rear System Division

Model "T" Passenger Car Chassis

		A	B
96.	Overhaul rear axle and re-bush springs and perches when necessary	7.00	2.75
96A.	Overhaul rear axle when car has shock absorbers, truss rods, or special hub brakes	8.00	3.25
98.	Repair or replace one rear radius rod	1.50	.60
99.	Replace rear spring; tie bolt or new leaf, including polishing and graphiting or leaves and lining up of body	3.00	1.20
102.	Pad rear spring to line up body or replace rear spring tie bolt only	2.00	.80
107A.	Install felt and steel washers—both sides	1.25	.50
108.	Install brake shoes and equalize emergency brakes—one shoe	.75	.30
108A.	Install brake shoes and equalize emergency brake—both shoes	1.00	.40
116.	Adjust pull rods or replace one	.75	.30

Model "TT" Truck Chassis

		A	B
96T.	Overhaul rear axle and re-bush springs and perches where necessary	15.00	6.00
97T.	Repair or replace drive-shaft tube	7.00	2.80
98T.	Repair or replace one rear radius rod	3.00	1.20
99T.	Replace rear spring (one)	3.00	1.20
99TA.	Replace rear spring (both)	5.00	2.00

[1] These prices have not been revised lately. Refers to model "T" Ford.

		A	B
100T.	Remove front and rear springs, polish and graphite only	$7.00	$2.80
101T.	Replace spring perches—one	1.50	.60
101TA.	Replace spring perches—both	2.50	1.00
104T.	Install universal joint	5.50	2.20
106T.	Tighten rear radius rod	1.75	.70
107T.	Install felt and steel washers (one side)	1.25	.50
107TA.	Install felt and steel washers (both sides)	2.25	.90
108T.	Install brake shoes and equalize emergency brakes—one	1.25	.50
108TA.	Install brake shoes and equalize emergency brakes—both	2.25	.90
109T.	Tighten universal ball-cap bolts	.75	.30
110T.	Install or tighten rear-spring clips	1.50	.60
111T.	Tighten rear hub lock nut—one side	.50	.20
111TA.	Tighten rear hub lock nut—both sides	1.00	.40
112T.	Fit new hub keys—one side	1.00	.40
112TA.	Fit new hub keys—both sides	1.75	.70
113T.	Replace pull-rod supports—one	.50	.20
113TA.	Replace pull-rod supports—both	.75	.30
114T.	Replace or re-bush hub-brake cam—each side	2.50	1.00
115T.	Replace rear axle assembly	5.00	2.00
117T.	Straighten radius rod in car	1.50	.60
118T.	Install outer roller bearing—each	2.00	.80

Front System Division

167.	Overhaul front axle, including re-bushing of springs and perches when necessary, straightening and lining up and readjusting of wheels	5.00	2.00
167A.	Overhaul front axle when car has shock absorbers, special front radius rod, etc.	6.00	2.40
168.	Rebush spindle bodies and arms—each side	1.50	.60
169.	Replace or straighten front axle (no other repair)	2.50	1.00
171.	Rebush spindle arm—each	.75	.30
173.	Replace front spring tie bolt or new leaf, including polishing and graphiting of leaves	2.50	1.00
174.	Replace front spring or tie bolt only	1.50	.60
177.	Replace radius rod	.75	.30
179.	Replace spindle arm or body, and line up assembly	.75	.30
181.	Tighten all sockets and joints of front end	1.25	.50
182.	Replace or straighten spindle or steering-gear connecting rod	.60	.25

Chassis Division

Front End and Frame

228.	Replace front cross-member	6.50	2.50
230.	Straighten front cross-member without removing from car	2.50	1.00
232.	Replace side member of frame	20.00	8.00
242.	Repair hand-brake lever assembly, including replacing of pawl	1.00	.40
243.	Replace hand-brake lever quadrant without removing running-board shield	1.25	.50

Fenders and Running Boards

258.	Replace one fender or running board	1.00	.40
259.	Replace one fender or running board and straighten iron or bracket	1.25	.50
260.	Remove fender or running board and straighten	1.00	.40
261.	Replace running board shield—one	1.25	.50
264.	Replace rear fender iron	.75	.30
265.	Replace truss rod—one rod	.40	.15

Dash

276.	Replace dash	4.50	1.80
279.	Replace coil box, install new switch, or repair the box	.60	.25

Steering Gear

291.	Overhaul steering gear, including replacing of quadrant or gear case, and re-bushing of bracket	3.50	1.40
292.	Overhaul steering gear when motor is out	2.50	1.00
298.	Re-bush steering-gear bracket only	2.00	.80

Muffler

310	Change long exhaust pipe	.75	.30
311.	Replace muffler	.60	.25
312.	Repair muffler	1.00	.40
313.	Repack exhaust pipe pack nut	.40	.15

Gas Tank and Line

324.	Clean sediment bulb and gasoline feed line, and clean carburetor	.75	.30

Radiator

		A	B
350.	Repair radiator, solder one or two tubes, and replace one or both sides	$3.00	$ .90
352.	Solder casting to lower or top tank when necessary to remove radiator	1.50	.50

Wheels

365.	Change hub, rear or front	1.00	.40
366.	Replace wheel and tire—each	.75	.30
367.	Adjust and dope front wheels	.60	25
368.	Remove front wheels and replace bearing parts—one wheel	.75	.30
369.	Line up front wheels	.40	.15
370.	Oil and dope car (including material)	.75	25

Body Division

412.	Install new lock—Touring or Runabout—each	1.00	.40
413.	Replace Town Car or Sedan door lock	1.50	.60
415.	Install new leather on door panel—one	.60	.25
418.	Re-upholster Touring body—using new materials	10.00	4.00
419.	Re-upholster Runabout body—using new materials	6.00	2.40
420.	Change closed body	10.00	4.00
421.	Change Touring or Runabout body	6.00	2.40

For removing dents and other general repairs to bodies make contract price, according to amount of work necessary, using operation No. 2000.

Paint Division

Make contract price according to quality of job desired and condition of car when brought in. Consult paint foreman. Use operation No. "P."

Top and Windshield Division

455.	Overhaul Touring car on Torpedo Top, including re-covering, lining up, and fitting of curtains	7.50	3.00
456.	Replace top deck or side quarters—each or both	3.00	1.20
458.	Install and fit top	2.00	.80
464.	Replace back curtain	1.50	.60
465	Install celluloid lights in side curtains, per light	.60	.25
469.	Replace windshield and line up windshield frame	1.00	.40
470.	Replace upper windshield glass	1.00	.40
471.	Replace lower windshield glass	1.00	.40

Special

530.	Trouble calls (from any point within city limits)	1.50	.60
531.	Tow-in (from any point within city limits)	3.00	1.20
536.	Inspect and prepare new cars for delivery, including stamping identification number, pasting sticker on windshield, and installing or adjusting any minor parts when necessary, each	3.00	1.20
537.	Deliver car to purchaser's address	1.50	.60
538.	Wash and polish Touring car or Runabout	1.50	.60
539.	Wash and polish Touring Car or Runabout—wire wheels	2.00	.80
540.	Wash and polish Coupé or Sedan	2.00	.80
541.	Wash and polish Coupé or Sedan—wire wheels	2.50	1.00
545.	Clean car for placing on show floor, each	1.00	.40
533.	Teach car purchaser to drive, each lesson	2.00	.80

Commercial Bodies

605.	Install slip-on body	2.00	.80
B.	Install any new commercial body	CONTRACT	

Electrical Accessories

650.	Install Ford alarm	.50	.20
654.	Remove battery from car for recharging and install rental battery, including recharging of battery	.75	.25
655.	Remove rental battery from car and install customer's recharged battery	.25	.10
656.	Install electric horn	.50	.20
660.	Install electric tail light on dry cells and magneto	2.00	.80
661.	Install electric dash light	1.00	.40
662.	Install electric dome light	2.00	.80
663.	Install electric spot light	1.00	.40
664.	Install headlight lens	.40	.15
667.	Install standard Ford electric starter, complete	7.50	3.00

Wheels and Tires

702.	Change tires, each	.30	.15
703.	Install side-tire carrier	.75	.30

		A	B
704.	Install rear-tire carrier	$1.50	$ .60
705.	Install rear holder for wire wheels	1.50	.60
706.	Install 30" x 3½" Ford wheels or demountables in front only	3.00	1.10
707.	Install complete set of demountable rim wheels	4.00	1.60
708.	Install complete set of wire wheels, not including holder	5.00	2.00

Miscellaneous Accessories

		A	B
751.	Install Ford fan belt	.25	.10
752.	Install leather starter belt	.75	.30
753.	Install tool box	.50	.20
754.	Install front and rear license plates when brackets are in place	.25	.10
755.	Install front license brackets and license plates	.40	.15
756.	Install bumper (front)	1.00	.40
757.	Install rear bumper	1.50	.60
758.	Install set of three pedal pads	.25	.10

		A	B
761.	Install cut-out	$1.50	$ .60
762.	Install exhaust deflector	.25	10
763.	Install set of C. & M. oil retainers (model "T")	1.50	.60
764.	Install set of C. & M. oil retainers (model "TT")	1.50	.60
766.	Install Buffalo oil gauge	1.00	.40
767.	Install foot accelerator	.75	.30
768.	Install steering-gear lock	1.00	.40
769.	Install Yale lock on one door, catch on other door, Sedan or Coupé	2.00	.80
770.	Install Yale lock on both doors, Sedan or Coupé	2.50	1.00
771.	Install mirror	.25	.10
772.	Install rubber step mats (two)	.50	.20
773.	Install odometer	.50	.20
778.	Install carburetor control	.75	.30
777.	Install speedometer	2.50	1.00
1500.	Charge for work according to actual time spent on job.		
2000.	Special contract-price jobs.		

CLEANING ENGINE AND CHASSIS

We will now take up the usual and common work required on all engines. We will first start with cleaning and lubricating the engine and greasing a car. About every nine cars out of ten require cleaning and greasing.

Cleaning Inside of Engine

Clean old oil from the engine as explained in the illustrations, Figs. 1, 2, and 3.

The best time to drain oil is after engine has been run and is heated up and oil thinned.

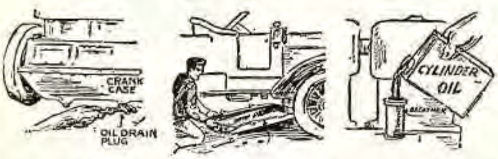

Fig. 1 (left). Remove the drain plug at bottom of oil pan and drain out the oil.

Fig. 2 (center). Remove oil pan and clean it thoroughly with gasoline; also clean oil strainer screen.

Fig. 3. Replace oil pan, and pour fresh cylinder oil into engine. **Note:** On some engines the oil pan should not be removed and instead, an **oil-pan drain flange** can be removed and oil strainer drawn out.

Flushing. If oil pan is not removed and oil is drained through the drain plug, or drain flange is removed, the engine should be flushed out with a very light grade of engine oil.

Procedure: After draining replace the drain plug. It is not screwed tightly home, as it is soon to be removed again. Now **pour some light engine oil into the breather pipe** (Fig. 3) and run engine for about 15 seconds; then drain this out. It is better to flush out the parts with light cylinder oil in this manner, than to use kerosene for reasons stated on page 167. Replace drain plug and draw it tight, or if oil pan drain flange is removed see that the gasket is replaced properly and does not leak. **Refill with good cylinder oil.** A gauge alongside of the engine is usually provided to show how much oil to place in the engine.

If the engine is not in running condition, after replacing the drain plug as directed above, open the compression cocks on the cylinder and spin it rapidly by hand. The longer this is done the better, but it is an arduous task and if kept up for a minute or so it will be all that is necessary.

If the drain cock does not permit the oil to flow freely, when draining, run a wire through it to open it up.

Cleaning Outside of Engine

The outside of the engine can be cleaned with kerosene or gasoline. A stiff brush dipped in gasoline to reach inaccessible places, and also an oil gun to shoot gasoline in inaccessible places, will suffice. The lighting of a match while cleaning should be prohibited.

Another method of cleaning engine is with kerosene applied with a water tool brush (an oval shaped brush) about 1½" diameter, after which it should be washed with water in which linseed oil soap has been dissolved, then rinsed off with clear water, flushing at low pressure from a hose without a nozzle; use a sponge to facilitate the operation. Any excess water should be taken up with a sponge, and engine allowed to dry.

The spray method is used extensively for cleaning engine and chassis of grease where compressed air is available. A kerosene spray[1] under air pressure is sprayed on engine, wheels, spindles, springs, steering knuckles, under fenders, etc. After the kerosene has had time to loosen up the grease and dirt it is then hosed off at low pressure, then sponged off with soap suds (linseed oil soap); then the soap is rinsed off with clear water, then sponged off dry.

If any parts are rusty, sand off and touch up with black.

Suggestions for making home-made sprayer for cleaning engine are given below.

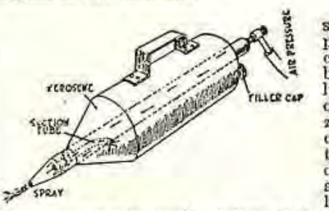

Fig. 4. **Home-made spray gun:** A copper pipe passes through the center of tank, one end being connected to air line and the other being drawn down into a nozzle. A small copper tube connects this pipe, so that the solution is drawn from the tank and forced into a spray by the passing air. A foot pump can be used to inject air if pressure is not available.

Fig. 5. This spray[1] comprises copper tubing, about ¼" in diameter, having a piece of 1/16" brass tubing soldered to its side. Air line is connected to larger tube, and smaller tube is connected to gasoline supply. When air is turned on, suction is created in smaller tube, drawing gasoline from the can, and forcing it onto the part to be cleaned. (*Motor World.*)

Cleaning Engine Exhaust System

This cleaning should include the exhaust manifold, pipe, and muffler.

The latter should be taken apart and the **parts soaked in kerosene** over night. The pipe and manifold may be cleaned by drawing through a pack of kerosene-soaked waste attached to a long wire.

Keeping Oil off the Radiator Hose

To prevent oil from rotting the inlet hose from the radiato to the engine, give the hose a **coat of shellac** and then a **couple of layers of tape** and shellac over that. This will assist in preventing leaks. The shellac keeps the oil away from the rubber and makes a good joint.

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[1] **Air brushes or spray guns for spraying liquids,** such as kerosene for cleaning engine and under parts of car of grease, etc., can be obtained of concerns listed on page 645 and footnote 1, page 756, and of auto supply houses.

Cleaning Parts of a Car[3]

A few **home-made devices** which can easily be constructed for cleaning other parts of car are shown.

In large shops vats are provided in which engines are dipped into a potash cleaning solution, by means of a chain hoist. For cleaning brass and other metal parts see pages 474, 1039.

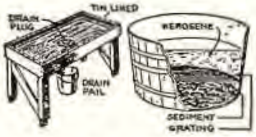


Fig. 6. **A washing table for parts.** This is large enough to permit any part of the car to be cleaned. But, more important, it may be moved to the job. A wooden basin, or sink, 5 ft. long, 2 ft. wide, and 6 in. deep is mounted on legs, and lined with tin. A drain plug is placed in the center, permitting the dirty cleaning solution to be drawn off into a pail hanging beneath the stand. Gasoline may be used for cleaning parts, but kerosene is cheaper and safer.

Fig. 7. **Kerosene tub:** A large tube of kerosene will be found convenient for washing parts. The tub should have a metal grating 4″ or 5″ from the bottom, so that whatever sediment settles is not stirred up each time a part is washed. The presence of the grating insures clean liquid for a considerable length of time, for just as soon as a part is washed the grit and dirt settles below the grating, leaving the liquid clean.

Fig. 8. **Combination cleaning tub and drainboard for** removing the dirt from parts. It is usual to make the tub and drainboard separate, but by installing a screen in the tank whose height may be readily raised or lowered, all the advantages of a drainboard are obtained, together with considerable economy of space and some added conveniences. A **wire basket** is handy for dipping small parts.

Fig. 8

Fig. 9

Fig. 9. **Gasoline or kerosene, forced by air pressure on to the parts to be cleaned,** quickly removes all dirt and grease. A system for doing this is illustrated. The cleaning liquid is held in a metal tank placed beneath the inclined clean'ng troughs in the manner shown. An injector type nozzle, connected to the air line and to the liquid, permits the liquid to be drawn from the tank and forced on to the part to be cleaned after which it drains back to the tank, to be used over and over again. When the cleaning outfit is not in use the dirt settles to the bottom and may be scraped out.

GREASING A CAR[1]

The lubrication of a car can be divided into five parts: (1) engine lubrication; (2) chassis lubrication; (3) rear axle and differential; (4) transmission; (5) universal joint.

Lubrication of the chassis (those parts other than the engine and its component parts and accessories) includes parts such as springs, spring bolts, steering connections, brake shafts, toggle joints, wheel bearings, steering spindles, transmission, differential, rear axle, wheels, universal joints, etc.

Lubrication systems can be classified as low-pressure **grease cups** which are screwed down by hand to force the grease into bearings and **high-pressure systems,** by which a band or power compressor is used to force the lubricant into the bearing under high pressure, such as the Alemite, Alemite-Zerk grease compressors

Another method is known as the **centralized system.** With this system oil can be injected into all of the various bearings on the chassis by means of a plunger pump operated by hand or foot. Some of the systems of this type are made by Bijur Lubricating Corp., Bowen Products Corp.,

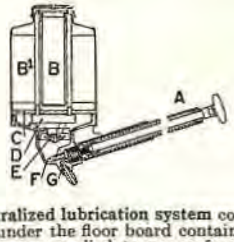


Fig. 9A. **The Bowen centralized lubrication system** consists of an oil reservoir installed under the floor board containing a foot-operated pump. A pressure applied to pump forces oil under pressure, in measured quantities through copper pipes to all chassis bearings. Under normal operating conditions heavy cylinder oil, such as Mobile B, is recommended.

Fig. 9B. **The Bijur centralized lubrication system** as used on the Packard utilizes a hand pump (A) which forces measured quantities of oil from a reservoir (B) on the dash to chassis bearings through control outlets. The kind of oil used is new filtered medium oil that in cold weather stays fluid, about the quality of Mobile A.

The Alemite centralized lubrication system (not illustrated) is automatic. Vibration of car actuates a delicately balanced weight which works a pump developing pressure up to 150 lbs. per sq. in.

With the centralized lubrication method it is a simple matter to lubricate a car. The supply lines can be cleaned by flushing with kerosene if clogged. The centralized systems are so constructed that the tank cannot be emptied or the feed through any other supply line be disturbed by the breakage of one or more lines.

To grease a car by means of high-pressure grease compressors, such as the Alemite is an improvement over the old method of screwing down individual grease cups.[2]

One of the fundamentals of this system is that because of the high pressure developed, all old lubricant as well as any grit or other foreign matter is entirely removed and the bearing is completely packed with fresh lubricant.

In most cases it is advisable to force lubricant into bearing until the old lubricant is forced out and new

[1] **printed matter** on this subject can be obtained by writing Alemite products, Chicago, Ill.

[2] **manufacturers of Alemite products** Chicago, Ill., supplies a **booklet** on the grease lubrication business.

[3] **For cleaning radiators,** see page 740. Oakley Chemical Co., 22 Thames St., New York, N.Y., supplies a free and instructive booklet, *Modern Cleaning Methods.*

lubricant appears. There are **exceptions** to this, however. For example, too much lubricant on the **fan** bearing would cause fan belt to slip. Too much on ignition **distributor shaft** may cause trouble. Care should also be used as to not to over-lubricate the **wheel hubs** and **universal joints** which tend to "throw" grease.

There are two very important essentials in greasing a car.

One is to not overlook any of the parts to be lubricated. There are 17 to 60 vital bearings on the chassis of every car. If one or more bearings are overlooked it may cost the owner a repair bill.

Second, use good lubricants. A good lubricant functions in hot weather or below zero weather. Inferior lubricants get too thin in summer or freeze in winter. For example, many greases and compounds that are put into the transmission, rear axle and steering device contain a kind of soap fibre "fillers" that congeal above zero (some of the fillers of good grade lubricants are tallow and fish oil). Those of poor grade lubricants are garbage renderings, resin, talc, etc. which at low temperature freeze and cause difficult steering and gear shifting. To function satisfactorily they must also be made of low cold test mineral oil. One leading concern recommends a lubricant with a cold test under 25° F.

The kind of lubricants to use varies with different makes of cars. It is best to follow the car manufacturer's chart from the instruction book in determining the parts to lubricate and the kind of lubricant to use.

*The **rear axle, differential and transmission** usually require a semi-flowing lubricant graded according to seasons, thick or thin, made of low cold test oils of high viscosity and containing only the best oil and filler.

The **universal joints** require a good sticky compound slightly heavier than No. 2.

Note: If grease cups are used, screw down on the grease cups, which forces out all grease therein. The cap is then unscrewed, the grease cup refilled, and the cap placed back, but do not cross-thread the caps or they will work loose and be lost.

Lubrication of Springs[1]

The oiling of those parts of the springs upon which the leaves move gives easy riding qualities by permitting the leaves to slide one upon another and prevents rust forming, which not only prevents the proper movement of springs, but causes mysterious squeaks as well. The spring shackles should also be lubricated.

Fig. 10

Fig. 11

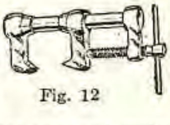


Fig. 12

Fig. 10. Lubricating the surface of the separated spring blades. Fig. 11. The same tool used as a temporary clamp to secure a broken spring. Fig. 12. The spring tool.

To lubricate: The best plan is to have springs lubricated at a service station where compressed air is used to force a spray of penetrating oil between the spring leaves, or place a jack underneath the spring bolt at the extreme front end of the frame for the front springs, or rear of frame for rear springs and raise sufficiently to relieve spring of its load, then spread the leaves with a spring tool as shown in Fig. 12 (a putty knife could be used), and lubricate with a penetrating graphite oil.[1]

If a car is overloaded much beyond its normal capacity, extra work will be thrown on the springs which may give rise to breakage when the car is being driven over bad roads. **An extra leaf added** to the springs is advisable **for overloads.** Considerable advantage to the life of the springs is obtained by having shock absorbers. See also Index under "Spring repairs."

Other parts of a car to lubricate and grease are shown on pages 172 to 174.

A Spring Lubricant

A spring lubricant is applied to the sides of the springs with a brush and chemically accomplishes that which by mechanical or other means is either an arduous or impossible task, in that it **penetrates** between the leaves without the necessity of spreading; it disintegrates and eliminates rust; it deposits a lubricant, and causes the springs to perform their function properly, without squeaking about it. In the same manner its application makes the removal of "rust-frozen" nuts, bolts, screws, spark plugs, valve caps, etc., a simple matter.

Spring Covers

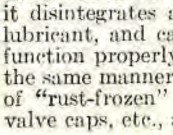


Fig. 13. **A spring cover and lubricator** which laces over the spring, preventing any danger of moisture or dirt getting between the leaves. The cover is lined with a felt wicking which is saturated with oil before the cover is put on, and will hold enough oil to lubricate the springs for 10,000 miles. The smooth gliding effect is obtained which is so noticeable in a new car with perfectly lubricated springs.

Tightening Springs

When lubricating the springs, it is a timely opportunity for observing defects of loose nuts or broken leaves in the springs.

The nuts belonging to the **clips** which hold the spring on to the axle often display a tendency to work loose, and if this is not remedied the axle will be thrown out of line, with more or less serious consequences to tires and driving gear generally; or, if the front axle is in question, the steering may be affected, thus causing "wobbly wheels."

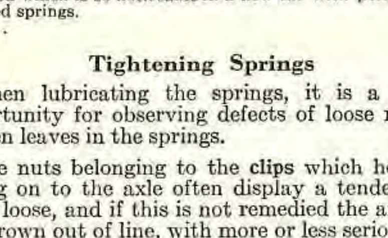


Fig. 14 Fig. 15

The springs, like the engine bearings, have to take a sort of set before they are permanently tight. Hence it is desirable to tighten up the spring bolt nuts at the end of the first one hundred miles of

[1] The method of lubricating springs is done by using graphite penetrating oil and a compressed air brush, or stiff hand brush. The penetrating oil should have a base of graphite and turpentine and not kerosene, and crank-drainings should not be used.

*See page 1062B for viscosity of lubricants now generally used in **transmission and rear axles.** See also page 867. See pages 1104-1106 for **wheel bearing lubrication,** and pages 900-909 for **steering gear lubrication.** See also footnote 3 page 1062B.

running and then to inspect them occasionally until they remain tight.

The breakage of a spring is usually caused, **not by the downward movement,** but by the **rebound.** Spring breakage **mostly occurs with loose spring clips.**

Spring Shackles

Many of the makers now are putting on **adjustable** spring shackles, so that wear can easily be taken up. This is especially desirable in cars using a Hotchkiss drive, where a great deal of stress and wear is put on the shackles of the rear spring at its rear end and on the spring bolt attaching the front of the rear spring to the bracket on the frame.

With the Hotchkiss drive the rear spring supports have to take not only much of the weight of the car, but also the driving and braking strains. Hence, the better the design of the shackles and bolts at this point, the longer the life of the parts.

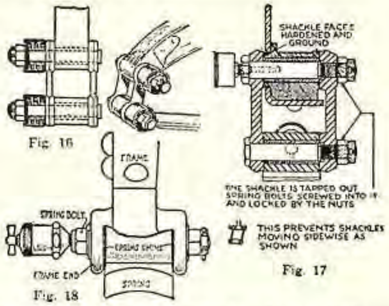


Fig. 16 Fig. 17 Fig. 18

Fig. 16. **Automatic shackle bolts** in which end play is taken up by coil springs. Fig. 17. **Adjustable shackle bolts;** wear taken up by turning nuts. Fig. 18. **Taking up side play with** shims.

Rubber cored shackles, requiring no lubrication, are frequently used. The rubber core can be replaced.

Threaded shackle bushings are used on several cars to withstand side thrust. They are adjustable.

REMOVING CARBON FROM CYLINDER, COMBUSTION CHAMBER AND PISTONS

Before taking up this subject, refer to pages 169, 170, and read the explanation of the **cause of carbon** and the **relation of carbon to lubricating oils.**

This is a job usually attended to before valves are re-ground. The frequency with which the job should be done depends upon the service, and quality and quantity of lubricating oil used.

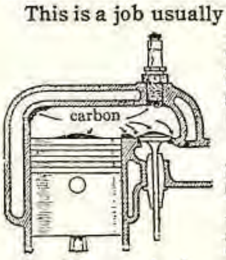


Fig. 19. Carbon usually accumulates at the points shown and ill effects of same are given on page 170. When carbon collects on valve head, the head is unable to dissipate heat and in time it burns and warps. Carbon also gets between valve and seat and impact of valve causes pits in seat. Result is loss of compression, reduced power and greater gasoline consumption.

Methods of Removing Carbon

There are three general methods employed in removing carbon.

1. **To scrape** by hand as shown in Figs. 20, 21, 22, or use special wire brushes in a portable drill (Fig. 21A.) (See also, pages 776**D** and 700.)
2. To use the **oxygen decarbonizing** process.
3. To use **chemicals.**

Scraping Methods[1]

Fig. 20 Fig. 21 Fig. 21A.

Fig. 20. **To scrape carbon from a piston** in the manner shown it is necessary to remove the piston from the cylinder which is sometimes an expensive job.

Fig. 21. **Remove the cylinder head, if it is a detachable type.** Access can then be had to the tops of the pistons and to the walls of the combustion chamber in the head.

Fig. 21A. **Carbon removing brushes in the chuck of an electric portable drill** remove carbon quickly. Special wire brushes can also be obtained for cleaning valve guides, valve stems, etc. (see also pages 700 and 776D).

[1] **Avoid scratching or nicking the surfaces of aluminum cylinder head or pistons** in any way at all when removing carbon. After removing carbon and cleaning, feel for burrs, and if any, rub down with fine sand paper. **A smooth surface is also advised on cast iron,** as it will gather carbon if rough.

[2] **Nearly all engines are now equipped with detachable cylinder heads.** Most of the concerns listed on page 833 **supply carbon removing tools.**

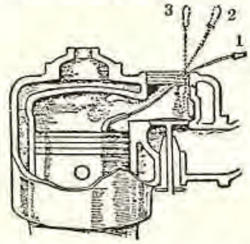


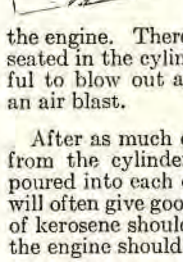
Fig. 22. **Scraping tools of special design** are necessary for scraping the inside of combustion chamber and the head of a piston when the **cylinder head is not detachable** and where the pistons are not removed. The work can be done through the valve cap or plug holes.[2]

Tool No. 1 is for scraping the piston head; **No. 2,** for the cylinder head, as shown by dotted lines, and **No. 3** is for the cavities over and around the valves and such other surfaces as have considerable curvature.

Scraper No. 1 should be used first, and worked back and forth with considerable pressure across the piston head until the scratching sensation disappears and the tool seems to glide over the surface. Care should be taken not to gouge grooves in the metal.

After scraping, blow out the free carbon, using a hand bellows as shown in Fig. 23,[3] if compressed air is not available. Continue scraping until the blast of air does not blow out any more carbon dust. Be sure to scrape the entire surface, for if jagged patches are left, they will become incandescent from the heat of explosion and cause pre-ignition.

Fig. 23



It is important that none of the carbon gets into the cylinders, valves, or other parts of the engine. Therefore be sure that the valve is well seated in the cylinder you are cleaning, and be careful to blow out all carbon deposit thoroughly with an air blast.

After as much carbon as possible has been taken from the cylinders, a half-tumblerful of kerosene poured into each cylinder with the air blast applied, will often give good results. Another half-tumblerful of kerosene should be poured into the cylinders, and the engine should be turned over a few times.

The oil reservoir should then be drained and cleaned thoroughly with a clean cloth previously soaked in gasoline, and fresh oil should be put into the oil pan (after cleaning and using kerosene), as

[3] Illustration from *Popular Mechanics.*

kerosene will thin the oil and cause it to lose its lubricating qualities and is liable to cause the bearings to score or cut. If any of the kerosene is left in the engine combustion chamber, it will eventually work into the crank case.

It is customary to grind the valves after having scraped carbon, and after grinding, to adjust valve clearance.

Oxygen-Decarbonizing Method[1]

The oxygen-decarbonizing method is a process of removing carbon from inside the cylinder and head of piston, without removing the cylinder head, by means of an oxygen flame, as shown in Fig. 24. This process is particularly favored on engines of the non-detachable cylinder-head type, where the removal of carbon by scraping (commonly recognized as best practice) would necessitate the removal of the cylinder block and taking out of the pistons.

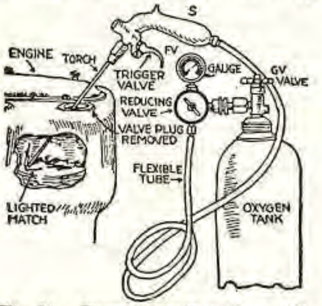


Fig. 24. Oxygen-decarbonizing outfit.

The outfit (see also p. 751) consists of an oxygen tank, at an initial pressure of about 1,800 lb. per square inch, fitted with an adjustable reducing valve that brings the pressure down to 10–20 pounds.

The oxygen is applied through a torch or copper tube about 18" long, with a rather fine, flexible delivery jet, connected to the reducing valve by a flexible tube and fitted with a trigger valve (FV). The delivery jet of the torch, when inserted through a valve-plug orifice or spark-plug hole, can be manipulated to reach all parts of the combustion space if it is slightly bent and cleverly turned and twisted by the operator. **The carbon is completely burned away by the oxygen.**

To Operate Oxygen Decarbonizer

Note. **In using oxygen for carbon removal,** the piston should be placed at the extreme top of the cylinder, as the intense heat tends to roughen the cylinder walls. Both inlet and exhaust valves should be closed to prevent pitting of valve seats. The flames should not be directed so as to strike the threads of the spark-plug hole. See that the water system is kept full of water. The torch should be moved constantly, to cover as large an area as possible.

1. **Turn off the gasoline at the tank,** and let the engine run until it uses up all the gasoline in the carburetor. If the pan is greasy, remove it, to avoid the possibility of a fire.
2. **Remove the hood and cover the air intake of the carburetor** with sheet asbestos, so that no spark can drop into it.
3. **Remove the large plugs into which the spark plugs are screwed,** and clean the cylinders, one at a time, being sure that the **piston is at its extreme height in each cylinder** and that both intake and exhaust valves are closed before starting to clean it.
4. **Start on the valve chamber,** first putting a few drops of kerosene oil or alcohol into it; ignite with a match or wax taper; insert tip of torch and direct a jet of oxygen against the carbonized surface. The jet of oxygen almost instantly consumes the carbon where it strikes, so move the tip around until the incandescence dies out, when it will be necessary to inject more kerosene or alcohol, and to repeat the operation until the chamber is thoroughly cleaned. When the burning starts the carbon will burn with a whitish flame and a shower of sparks will come out of the spark-plug hole.
5. **Clean the piston head.** When it is impossible to see portions being cleaned, continue the operation until the series of sparks stop blowing out, as sparks will cease as soon as the carbon is entirely consumed.

To clean the top and sides of the cylinder combustion chamber it is necessary to bend the flexible copper tip of the torch so as to direct the jet of oxygen upwards. To inject the kerosene or alcohol, use an oil gun or ordinary oil can with a curved nozzle.

Alcohol leaves the surfaces much lighter than kerosene, but when the oxygen strikes it there is quite a sharp report. **Kerosene** is rather more quiet than alcohol.

Some operators simply **drop in a lighted match** and then turn the jet upon it, but this method requires much more frequent igniting than when kerosene or alcohol is used.

It is important that **kerosene should not be mixed with the lubricating oil** as it will lose its lubricating qualities. The crank case should be wiped out before putting in fresh oil. When using the method described above, the flame must be handled cautiously, otherwise the parts inside of the cylinder combustion chamber will be overheated.

Q. Where can oxy-decarbonizing outfits be obtained?

A. Linde Air Products Co., 205 E. 42nd St., New York; Bastian-Blessing Co., Chicago, Ill., Imperial Brass Mfg. Co., Chicago. Can also be obtained of auto supply dealers.

Chemical Method for Removing Carbon

There are several preparations on the market for this purpose. It comes in powder, also tablet form, which, the markers claim, if placed in the cylinder (some are mixed with the gasoline), will loosen the carbon formation. There are other preparations to prevent carbon formation.

Another agent is known as **a liquid decarbonizer.** This chemical, the manufacturers claim, will dissolve the carbon accumulation in the combustion chamber and on the piston, and will also loosen the rings if they are gummed and stuck to one side of the piston.

Liquid carbon removers can be obtained of auto supply houses; some are poured into the cylinders, others **fed to the air opening of carburetor** or to the **intake manifold** from time to time and others **mixed with the gasoline.**

The printed matter of one concern reads: "It does not dissolve carbon—it loosens it by attacking the charred oil that holds it to the metal. The loose flakes of carbon are then blown out through the exhaust." **To minimize carbon formation,** see page 171.

WHY AN ENGINE LOSES POWER

There are four main causes for this. When an engine fails to develop its usual power the cause is frequently one of the following:

(1) Loss of compression.

(2) Improper valve action.

(3) Faulty ignition.

(4) Improper carburetion mixture.

1. **Loss of compression** means more than simply failure to compress the charge to a specific extent; it is a common name for a condition which not only means low initial compression and consequent weak explosion, but also that a smaller charge is taken into the cylinder, that a portion of the diminished charge escapes during the compression stroke without doing even a small amount of work, and that a part of the explosive force (the only source of power that an engine has) escapes through unauthorized channels —altogether a threefold loss. **The power of an engine is in direct proportion to its compression.**[2]

Faulty compression comes from a variety of causes: Cylinders may be worn, scored or cracked; pistons may sometimes crack, or rings become gummed, worn or broken; valves need grinding when pitted or warped; their stems are sometimes bent so that the valves cannot seat perfectly, or the stems and guides considerably worn. Valve stems become gummed and the springs sometimes weaken, so that a portion of the charge escapes before the valve shuts it in.

[1] **Caution is advised, especially with aluminum pistons and cylinder heads,** to allow the combustion to proceed slowly, keep the torch moving constantly and administer at regular intervals short, quick shots of oxygen to sustain the combustion without overheating the metal. **Also applies to any kind of pistons and head.** See also footnote, page 763.

[2] See also page 44 Addenda.

Leaks occur around spark plugs, spark plug porcelains, and valve caps, but are readily found by applying a little oil, while engine is running and noting if it bubbles.

2. **Valve action is disturbed by wear.** Usually this results from the valve tappets not having been given sufficient opening, or having been set to give too much opening, or from the valves not being properly timed. Valves that do not seat come of course under the subject of loss of compression.

If the clearance or gap between valve stem and tappet is not enough, the heat, especially during a long continuous run, may be sufficient to cause the valve stem to expand enough to hold the valve open and prevent it from properly seating. This will burn and warp the valve, causing a loss of compression, which of course results in a loss of power, sluggish pick up, missing of explosion, and inability of engine to idle properly. See also pages 57, 58. When touring, give valves maximum and not minimum clearance.

If the clearance between valve stem and tappet is too great, it not only produces noise but lessens the power of the engine, due to the valve lift being lessened to such an extent that the inlet valve does not open wide enough to take in a full charge of gas, and that the exhaust valve does not fully discharge all of the burned gas. See also pages 59, 61, 1105.

3. **Faulty ignition** is occasioned by numerous causes (see page 462B), or by incorrect timing (page 301), or by a weak battery, or by demagnetization or some other trouble if a magneto.

The ignition interrupter should be examined for proper gap clearance, clean points and worn parts, such as a worn and wobbly arm, shaft, etc. (see pages 462B–462G). **Incorrect timing** means loss of power, and it is plain that missed explosions are fatal to efficiency. It is not always easy to detect missing or weak explosions, and no doubt they pass unnoticed many times. If vibrator coils are used they probably need adjusting, or their contacts need dressing.

4. See pages 117 and 462A for suggestions regarding the **carburetion mixture.**

Other Causes of Loss of Power

Air leaks around the inlet valve stems make it impossible for even the best carburetor and the most careful regulation to supply a right mixture, as the leakage fluctuates and is greatest at the very time when the volume of gas used is the smallest, because there is stronger suction when the throttle is nearly closed. This completely upsets the right proportions at all throttle openings except the one adjusted. This is true also of air leaks around the carburetor or intake connections.

Weak valve springs will also cause loss of power, as explained farther on.

The muffler may have become clogged by soot and charred oil, thus preventing a free exhaust and consequently a full charge, besides causing back pressure and undue heating.

Gasoline passages may have become clogged.

The oiling system may fail to supply the needed amount of oil, or the oil used may not be of the former good quality.

Carbon may have accumulated in the cylinders; the air valve in the carburetor may be working badly because of dirt or wear.

Dragging brakes will consume a lot of power.

In conclusion, it is suggested that **if an engine does not run with its former power, the major cause is lack of compression** and factors in engine up-keep which have considerable to do with **maintenance of compression are: 1,** proper fit and condition of piston and cylinder walls; **2,** proper fit of piston rings; **3,** use of correct oil to establish and maintain proper piston ring seal; **4,** proper seating of valves; **5,** absence of leaks and further, the cause is probably not the result of any one thing, but of a number, each contributing in proportion to its importance.

MEANING OF COMPRESSION, EXPANSION, AND MEAN EFFECTIVE PRESSURE

Compression pressure is the pressure of the gas after being drawn into the cylinder and **compressed in the combustion chamber** by the up compression stroke of the piston. This varies with the quantity of gas drawn into the cylinder, the speed of the piston, the size of the combustion chamber, and the condition of the valves and rings, and the tightness of the parts. See also, page 116.

The expansion pressure (often termed explosion pressure) would be the maximum or the **greatest pressure immediately following the combustion** or burning of the gases. This pressure is many times greater than compression pressure. This expansion pressure (gas expands when ignited and heated) continues, but diminishes throughout the entire power stroke.

The explosion pressure runs from three to five times that of compression pressure. If the compression drops one-half, then the explosion pressure drops, but the loss is in more than direct proportion. It would seem that if the explosion pressure was one-half, the power developed would be one-half. But one must realize that it takes a certain amount of power merely to keep the engine moving, that is, to overcome the inertia and friction of the moving parts. This amount is constant. All power developed beyond this amount is available to run the car. If the compression and power drop to one-half, just as much power is required to run the engine, so that the available power drops in much greater degree.

Mean effective pressure (M.E.P.): During the entire cycle of a gas engine, the cylinder is subjected to many variations of pressure. We have seen that during the power stroke, the pressure **decreases** as the piston proceeds along its stroke. All of this pressure causes the engine to deliver power. In the same way, during compression stroke the pressure gradually **increases** as the piston travels upward. All of this pressure hinders the engine from delivering power, and should therefore be considered as a negative power.

Now, if we average up all the pressures during a cycle and subtract those which hinder the engine from those which help it (the power stroke is the only stroke which helps), we shall arrive at the M.E. P., that is, the **average or mean pressure which is effective in producing power.**

The advantages of high compression are: greater engine efficiency at high speeds and greater economy in fuel.

The disadvantages are lack of flexibility at low speeds, greater strain on bearings, and greater tendency to burn valves and plugs, as well as a tendency to over-heat.

A greater compression can be carried in an overhead-valve engine, regardless of stroke or bore; therefore larger valve openings are permissible.

Naturally this increases the heat, but as the valves are in the head, the discharge is rapid. The explosion pressure is generated directly above the piston center, which receives no side thrusts.

The spark plugs in an "L"-head type are usually over the inlet valves where the inrushing gas keeps them cool and where the fire is most certain—since they are in the most perfectly scavenged part of the cylinder, i.e., the direct path of the fresh charge.

In the overhead type, on the contrary, they are exposed to the full heat of the explosion. In a high-compression engine, therefore, only well-made plugs should be used. One method of protection is to surround plug with a water jacket as much as possible.

Abnormal compression is prone to cause overheating. Results however can be obtained with high-compression ratio which cannot be approached with average compression.

If a high compression is desired in an"L" or "T"-head engine, in order to take advantage of the high compression, the cylinders must be designed with a sufficiently long stroke, to enable the desired ratio to be obtained without raising piston appreciably above the floor of valve pockets, as at (L) (Fig. 26).

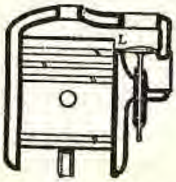


Fig. 26. This illustration shows the type of piston referred to. It will be obvious that the explosion will develop in the valve pocket (L), and that part of its expansion or pressure value is lost when the piston projects above the top of the cylinder to any great extent.

See page 806 for the principle of the Ricardo cylinder head.

Average Compression of Engines

The usual compression pressure for passenger-car engines is about 60 to 75 lbs. per square inch. **The maximum compression is obtained with wide-open throttle and engine warm.** The compression on a Marmon six-cylinder engine, for an example, which has been in service should average approximately 65 to 70 lbs. when measured with a compressometer.

A six, eight, or twelve-cylinder engine, having a much more continuous torque than a single-cylinder engine, will obviously stand a higher ratio of compression. The tendency is to decrease compression as the diameter of bore increases.

Compression in all cylinders should be equal and up to standard. If the compression varies greatly between the various cylinders, the cause should be determined and remedied.

Compression at the time of the explosion, at the instant when the piston is at top of stroke, is very hard to determine. Factors which would have to be taken into consideration are: character of fuel, degree of mixture, and speed of engine. **An example follows.**

In the average engine, with a compression pressure of 60 lbs. per sq. in., in a cylinder with a piston 3⅝" dia., whose area is 10 sq. inches, **the total force on compression would be 10 x 60=600 lbs.,** and **the total force of the explosion pressure** would be about five times as much, or 3,000 lbs. This means that the piston is being forced down as if a weight of 3,000 pounds were resting on it, and this force is turning the crankshaft.

Therefore with a loss of 10 lbs. compression pressure (50 instead of 60) **the total force on compression would be 500 lbs. and total force of the explosion pressure** would be 2,500 lbs., or a loss of 500 lbs. in turning the crankshaft. The engine would therefore suffer a loss of 3000÷500, or one sixth of its pulling ability, **showing the importance of maintaining compression.**

As a rule the explosion pressure is three to five times the absolute compression pressure based on the assumption that the cylinder is filled with the charge to atmospheric pressure at the beginning of the compression stroke.

The compression on a motorcycle engine, as a general rule, is often rather high where speed is desired, but on the U.S.A. motorcycle engine, used during the war, the compression was slightly lower than the average. This somewhat depresses the power curve, but **the engine will run better on a wide-open throttle at lower speed,** enabling the machine to "hang-on" with great tenacity and to pull with power through sand, mud, etc. **The compression of airplane engines** is somewhat greater than on automobile engines.

An open throttle fills the cylinder with gas, which of course increases the compression pressure. Therefore some engines may knock at low speeds with a wide-open throttle, as when climbing a hill slowly (see also bottom of pages 115, 806).

At higher speeds of the engine a slight compression leak is not so noticeable as at low-engine speed. If it is desirable to have the engine throttle down to a very slow speed, then be sure that there are no compression leaks in any part of engine, including valves or rings.

Increasing Compression in an Engine

This means that by **reducing the space in the combustion chamber** from the head of the piston to the inside top of the compression chamber of the cylinder—when the piston is in its uppermost position—the gas would be compressed tighter, therefore there is more explosive or expansion force on the piston when combustion takes place.

High compression gives more power, but it is harder on bearings and makes engine more liable to knock (termed **pinging or detonation**: see pages 806, 1136 for a relief) and produce heating, and is less flexible at low speeds. See page 1075 for detonation.

It is true that different compressions affect the power of explosions, and that an **uneven compression ratio in different cylinders will consequently cause an engine to jerk.** If the compression is excessively high, it can keep the spark from jumping gap in spark plug, unless gap is closed up slightly.

Decreasing compression; see page 780, and page 1044 for expansion and compression pressure.

TESTING THE ENGINE COMPRESSION

The compression is much easier to test than the carburetor or ignition apparatus. Test should be made while **engine is warmed up** as the parts are then expanded to normal working conditions.

There are two kinds of test: by hand, called the **feel-test,** and by means of a **compression gauge.**

To test the compression of the engine by hand, test by cranking slowly (with ignition switch off, and throttle open) and note the comparative **resistance** of each cylinder.

If the resistance of the compression of one or more cylinders is less than in the others (when on compression stroke) then this particular cylinder is leaking compression through one of the many causes previously enumerated.

If the resistance of all of the cylinders is below the regular standard, then, perhaps, all are leaking.

A cylinder with good compression cranks with a rocking, bouncing, or springy resistance.

If it cranks very freely, it may be considered an evidence of poor compression and this is usually due to leaky valves.

If the pressure is slight or fairly good as the piston goes up on compression stroke, but begins to leak as the piston nears the top of stroke, the probabilities are the compression is leaking past the piston and rings, and by testing as shown in Fig. 30, page 769, the hissing may be heard (test with engine warm).

How to distinguish between piston-ring leakage and valve leakage, and to determine the rate of leakage is explained on next page. See also page 779.

To test the compression of the engine with a compression gauge, proceed as follows: With engine warm remove spark plug from cylinder to be tested and leave others in place; screw compressometer gauge into the spark plug hole of cylinder to be tested; open throttle wide; place ignition switch in "off" position.

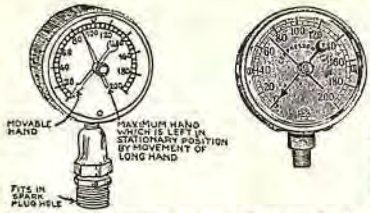


Fig. 27A. A special gauge designed for testing the comparative pressure of each cylinder, called a compressometer.[1] Tells whether compression is uniform in all cylinders—whether piston rings are leaking—whether valves are leaking—whether valves are correctly set, etc.

The compressometer is mounted in place of the spark plug, and may be had with spark plug threadings, as follows: ½-inch tap, ⅞-inch straight, and metric.

Note the two hands: the short red one (maximum) remains fixed at the highest point reached during the test of each cylinder. The black long one is an indicating hand.

The test can then be made by using the starting motor to crank the engine, but only for a few turns. This is preferable, because it will give a uniform number of revolutions which should be the same on each cylinder tested, in order to make the relative **comparison.**

As each cylinder is tested separately, enter the reading on a slip of paper, and then compare the results. If one cylinder tests higher than others, a variance of 2 to 3 lbs. less in the others is satisfactory; a variance of 4 to 6 lbs. less is permissible; a variance of 10 lbs. less indicates a cylinder with low compression, and the cause should be found and remedied.

Example: On a certain eight-cylinder car, all cylinders tested 65 to 70 lbs. except No. 1 which tested 25 lbs.; No. 4, 35 lbs. and No. 8, 45 lbs. It was found that No. 1 and No. 4 exhaust valves were badly burned, due to the valve clearance having been set too close, and during a long run the heat expanded the valve stems and valves remained open. No. 8's low compression was found to be due to leaky piston rings.

With the gauge just described one should be able to obtain the following information:

1. Whether the compression is uniform in all cylinders.
2. Whether piston rings are leaking.
3. Whether valves are leaking.
4. Whether valves are correctly set.
5. The rate of leakage in each cylinder.

To distinguish between piston-ring leakage and valve leakage, after taking the reading, remove the gauge and pour a spoonful of heavy oil on top of the piston and replace the gauge. The oil will temporarily seal leakage past the piston rings.

Turn over the engine again, and note whether the compression is approximately the same as before, or whether it is higher.

If the same, it shows that the rings are tight and the **valves are leaking.**

If the compression has gone up, it indicates that there is leakage at the **piston rings.**

To determine the rate of leakage in a cylinder, turn the engine to dead center (compression), and watch the black hand (long one).

The black hand indicates the pressure at any instant. If there is leakage, you will see the black hand gradually return to zero (although the red hand—short one—which indicates the maximum pressure attained, will remain at maximum compression). Note the time required for the black hand to return to zero.

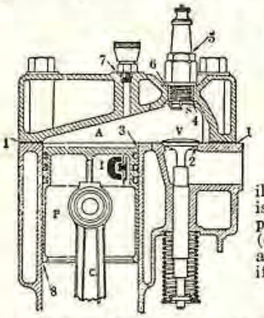
Repeat this for each cylinder and you have a **comparison of the rate of leakage** in each cylinder.

Poor Compression: Effect and Cause

The subject of compression is one of the most **important** subjects connected with a gasoline engine. If an engine **lacks power,** nine times out of ten it will be traced to **poor compression.**

The compression space in an engine is the space between the end of the piston and the top of the inside of the cylinder as at (A), Fig. 28. In drawing in a charge of gas into the cylinder, the piston (P) travels downward, but after drawing in the gas through the intake valve (V), the valve closes and the piston on its up-stroke pushes the gas up into the head of the cylinder and **compresses** it (see page 32). When the gas is compressed to the highest point, the spark (S) ignites the compressed gas and forces the piston down with great force. If the compression pressure is **low the force will be less.** If compression pressure is **high the force will be greater.**

If there is a leak then the gas will not be compressed to as high a pressure as if there was no leak. Therefore **power of an engine depends on good compression,** which must be maintained.



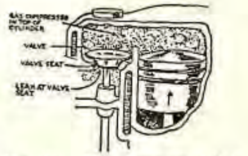


Fig. 29. The purpose of this illustration is to point out what is meant by the gas being compressed in the top of cylinder (combustion chamber) and how **a leak can occur at valve seat** if valve is not tight in its seat.

Fig. 28. Transverse section of an engine cylinder. **Figures show where compression leaks may exist in an engine: 1,** cylinder head gasket; **2,** valve seat; **3,** piston rings; **4,** spark plug threads; **5,** spark plug bushing or porcelain; **6,** spark plug gasket; **7,** relief cocks; **8,** cylinder wall scored, tapered or out of round; **(A)** compression space; **(C)** connecting rod; **(I)** insert shows how the gases escape past the piston and rings. When the rings are worn the gases have an unobstructed path back of the ring as indicated by the arrow; **(P)** piston; **(S)** spark plug gap; **(V)** valve head shown seated in its seat (2). (Illustration from *Automobile Digest*).

A frequent cause of leakage is through the valves (see also page 769), which, by not closing tightly, leak at the seat (2) and permit the pressure to escape.

This may be caused by the valve being held open by a piece of carbon between valve face and seat, or valve **clearance set so close** that valve was held open and burned, and warped, due to excessive heat, or **valve may stick in guide,** due to gummy condition and warpage of valve stem in guide, or weak or broken valve spring, or a "flame lick" against valve stem at top near valve head.*

A leak through one or more valve seats is generally accompanied by misfiring, loss of power and poor idling. A slight leak through all valves is accompanied by loss of power, but often without misfiring.

Grinding the valves in the seats will usually remedy leaky valves, but sometimes they will have to be refaced first, especially if burned or warped.

Leaky piston rings are often the cause of compression leaks and may be due to the rings being gummed in the grooves and not expanding properly.

Note that the arrow in (I), Fig. 28, **shows how the gases escape past the piston and rings.** When rings are worn the gases have an unobstructed path back of the ring as indicated by arrow and leak occurs between ring and piston at the groove.

[1] See also pages 40–44 of ADDENDA for **engine checking and testing devices.** *One test for a sticking valve: Missing will be more noticeable when running at low speed and hard pull after engine has been raced.

Compression leaks in valve caps, spark plugs, and priming cups (relief or pet cocks) are usually due to a failure to draw them down tight in the threads.

These parts may be made tight by the use of copper washers, that metal being soft enough to be forced into the rough places. If the small gasket in the spark plug, or the spark plug itself, is not tight, gas will leak out and cause loss of compression and lack of power.

In addition to compression being lost through leaky valve seats, piston rings, valve caps, spark plugs, relief cocks, cylinder-head gaskets, etc., there are other causes, such as **incorrect valve clearance adjustment** (set too close) **and incorrect valve timing** (which opens or closes the valve at the wrong time). Leaks have also been known to occur through a small sand hole in the end of the piston.

To test for a leak at the valve cap, spark plug, or relief cock: Pour oil over the cap on top of the cylinder block, and if bubbles occur when the piston is moving upward, it is an indication that there is a leak. It can be corrected by simply tightening, or it may be necessary to renew the gaskets. Pour water into the valve cap to detect an air leak, if the spark plug or relief cock is screwed into a valve cap with a depression in it. If there is a leak, it will bubble through the water when the engine is being cranked. This can be remedied by merely tightening up or by fitting new gaskets.

A leak in the gasket connecting the intake pipe is a very common cause for missing at low speeds. It can be detected by allowing the engine to run at the missing speed. Take a squirt-can full of gasoline and squirt around all the intake pipe joints. If you detect any difference whatsoever in the running of the engine, there is a leak. The remedy is obvious.

Cylinder-head gaskets, if not properly tightened and fitted, will permit a compression leak, and will also admit water to the cylinder on those cylinders fitted with detachable heads. Tighten cylinder head nuts.

Asbestos gaskets, when replaced, are first coated with shellac or soaked in linseed oil (not used on automobile engines). Copper gaskets are soft and give; therefore they do not require this treatment. See Index under "Gaskets."

Where cylinder-head gaskets are replaced without thoroughly cleaning them, as well as the surfaces on which they are fitted, or if they are not drawn down tight after the engine is warmed up (second tightening), a compression leak is likely to occur. See page 733.

When cylinders are **not cast en-bloc,** care must be taken that gaskets are of exactly the same thickness, otherwise the cylinder with the thickest gasket will be raised higher than the others and will consequently have larger combustion space. As a result it will have lower compression. This in turn disturbs the running balance.

In two-cycle engines conditions would be even worse, for here we not only increase the combustion space and enlarge the lower space (which in two-cycle engines is an important feature), but we also change the port timing, as a little thought will prove.

If the cylinder wall, the cylinder head, or the piston head is cracked, compression will be affected.

A crack in the cylinder wall will admit water to the cylinder from the water jacket. If a hole is suspected, a test can be made on the cylinder to see if there is a leak by putting a foot-pump connection to the water jacket of the cylinder. Fill the water jacket with water and apply the air pressure, and see if bubbles of water ooze through, inside of the cylinder. If this is the case, then these holes must be made tight.

If water is found in the crank case, it results from one of three general causes: (1) water in the gasoline or lubricating oil; (2) loose cylinder-head gasket; (3) a cracked cylinder, or a sand hole in the cylinder from the water jacket. It is possible, sometimes, to stop a cylinder sand hole leak with salammoniac. See Index for this subject.

To detect a crack in the piston head, the latter must first be scraped clean of the carbon deposit and examined carefully.

Sometimes there will be a discharge back into the carburetor; this indicates a leaky intake valve, providing it is not first found to be the result of faulty carburetor adjustment, due to lack of sufficient gasoline, or to too much air, termed a "lean mixture."

Sometimes a discharge in the muffler indicates a leaky exhaust valve, but not always. It will require an experienced ear to detect the difference between an unfired charge being exploded in the muffler, due to carburetor adjustment and that of a leaky exhaust valve.

A compression leak between the piston and cylinder walls is rather difficult to test. Probably the best way is first to correct compression leaks as described above; then, if the compression is still poor, the leak must be between the piston and the cylinder wall. See Fig. 30 for one method of testing.

The remedy for leaks past the piston rings is to put in new rings, if they are not merely gummed and cannot be loosened with a little kerosene. Usually they are worn or out of round. See also the subject "Piston rings."

Piston and Rings Cause of Leaks

When the piston rings or cylinders have been cut and scratched by long use, or running without oil, the compression leak will be into the crank case, and when the crank case heats so that it is uncomfortable to touch, it is an indication that the leak exists. The only remedy is reboring of cylinders, and fitting of oversize pistons and rings, or, if pistons are not too badly scratched, new piston rings may suffice.

When piston rings work around in their grooves so that their split ends are in line (or if the **gap is too great:** see pages 169, 827, 828), this will often give the compression an opportunity to escape.

A worn ring either permits ring to expand and enlarge the gap, or if it has lost its expansion, the oil will pass between ring and cylinder wall, in addition to a compression leak. See also, Fig. 28, page 767, and note the insert (I) where the leak is between the piston ring and the piston at the groove.

If the piston rings are in good condition, they will be smooth and shiny, as will also be the cylinder walls. If the rings are dull and dirty in spots and streaks, it will indicate that the flame passes between them and the walls, leaving a sooty deposit.

Badly fitting piston rings may be caused by the rings sticking in their grooves, because of gummy deposit from the lubricating oil; rings that are stuck in their grooves will not press against the cylinder walls and will cause loss of compression. If this is suspected, just a little kerosene poured into cylinder and distributed by cranking may free rings.

To test for piston-ring leaks: Place the hose at the breather pipe; with throttle wide open, have someone crank the engine with switch off; if a **hissing sound** is heard as the piston moves up on compression, the pressure is escaping past the piston ring, down the wall of the cylinder into the crank case. In this case new rings are required, or maybe a little kerosene to loosen up the ring will suffice. Often this is also due to a **scored cylinder,** and if so, replacement of rings will not effect a complete remedy. See also pages 829 and 779.

If no hissing sound is heard, and you are still losing compression, the trouble is probably a leaky valve.

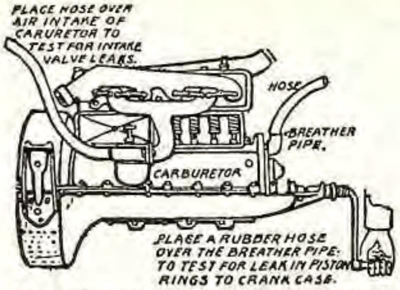


Fig. 30. One method of testing for piston-ring and valve leaks.

A test can be made to determine if the leak is in the rings or valves by removing spark plug and injecting a small quantity of heavy cylinder oil on top of pistons. This oil should seal the piston rings and temporarily stop the hissing; if not, then the leak is probably in the valves. (It is best to test with engine warm in order that parts will be expanded to normal working conditions.)

If you are able to hold against the compression of a cylinder for half a minute without perceptible loss of compression, the **compression is probably good** in this cylinder. Test each cylinder. See pp. 767, 779.

To test for inlet-valve leak: Knowing that the minor leaks above referred to are corrected and that all the parts are tight, the next step is to test for leaks of the inlet valves, if any. Place a piece of garden hose over the carburetor air intake, as in Fig. 30. With throttle wide open, have someone crank the engine with switch off. Place the hose to the ear; if a **hissing sound** is heard when the piston is on compression stroke, the inlet valve may be leaking and needs reseating. See also page 779 on testing with an air pump.

Prussian Blue for a Valve Leak Test

To test a valve-head seat: Buy a small tube of Prussian blue at any paint store. Remove the valve spring, and **blue the face of the valve.** Then turn it one-quarter around in the valve seat. If the seat shows a clear clean line of blue, you have a perfectly fitting valve. If there are points where the blue does not touch, you have a worn or warped valve or a faulty seat. (See also tester, p. 776D.)

If, after these tests and repairs, compression is not restored, the trouble is a serious one, requiring removal of the cylinders or cylinder head. The piston rings may be broken, scored, or badly worn, or the cylinders may be scored also. To remedy such troubles as scored cylinders requires special machinery, and this sort of repair is done by those who specialize in this class of work. Such work as fitting rings and grinding valves, etc., can easily be done in any shop.

Keep in touch, so to speak, with the **compression** in your engine if you wish to obtain best results.

Compression leaks may be caused by small holes in piston head or ring groove, resulting from a sand hole or caused by tool cutting through when machining. See page 829 for a test.

Compression leaks are sometimes in gaskets, caused by warped cylinder block or head. This leak may be from one cylinder to another and can be heard through spark-plug hole of adjoining cylinder. If gasket leaks into water jacket, water will bubble in radiator.

Spark Plugs Indicate Condition of Valves and Piston Rings

When spark plugs are constantly oily, this is an indication that oil is passing from crank case to combustion chamber and is usually due to carrying **too high an oil pressure, or an excessive amount of oil, worn piston rings, or too wide a ring gap, scored cylinder, or too great a piston clearance.** These causes will also frequently permit excessive quantity of lubricating oil to pass out of the exhaust in the form of blue smoke.

If spark plugs are coated with black soft soot, like that which accumulates in a lamp chimney, this indicates too much gasoline, or too rich a mixture being fed to cylinder from carburetor, due either to adjustment, or to excessive use of choker valve, or to an air leak in the intake manifold.

Sooty spark plugs could also be caused by leaky valves, as this permits burned gases to be drawn into the mixture, with the result of poor combustion.

Causes of Leaky Valves (Poppet Type)

A valve and its parts, as used on engines with valves on the side, is shown in Fig. 31.

If engine does not idle well, does not pick up speed as formerly, and there is sluggishness and loss of power, then **test the compression** (see page 767).

If the test indicates leaky valves, then remove cylinder head and look for the causes, some of which are mentioned below:

Carbon or some other substance may get between valve-head face[1] and valve-seat,[1] thus holding valve open. Wide seats are more apt to retain carbon flakes. Valve-seat may be covered with carbon and pitted. Carbon may also have collected on valve-stem under head, preventing valve from properly seating.

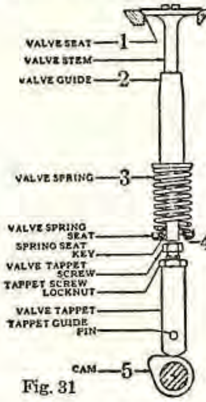


Fig. 31

Valve-seat in cylinder block may be worn down too deep, due to constant hammering or tapping.

Valve-seat, also valve-face may be burned and scale may have formed (more common with the exhaust valve).

The scale flakes off and gets between valve-face and valve-seat and holds valve open at this point, which of course causes a compression leak and continued burning of valve, forming grooves and holes.

The cause may have been due to carbon or some other foreign substance getting between valve-face and seat, or to valve-stem clearance being set so close that the heat-expanded stem caused valve to be held open, which permitted red-hot gases continuously to pass between face and seat; sometimes the gas shoots through like a flame from a blow torch and cuts holes.

Ordinarily carbon particles will pass out through the exhaust valve, being carried out with the exhaust gases, but sometimes red-hot particles of carbon instead of passing out, will weld to the valve-head face or valve-seat, and thus cause pitting.

It is said that exhaust gases raise valve temperatures to as high as 1600° F. or more at times. Improper carburetion mixtures cause carbon troubles. On some valves the material is such that the high temperatures to which it is subjected will harden the valve-head to a point where it becomes brittle, causing cracking, which permits leaks.

Valve burning is also due to **bouncing** at high speeds, that is, the valve practically remains open and the **flame-lick** constantly playing on the upper part of stem and head causes burning. Bouncing is caused by insufficient spring tension and gummed or sticky valves.

Valve-head may be warped, due to being held open and permitting the hot gases to pass continually under head, thereby burning the head where attached to stem (more common with the exhaust). Extreme temperature on a poor grade of valve will

[1] "Valve-head face" refers to the face of the valve-head, and "valve-seat" refers to the surface with which the valve-face comes in contact when closed, as shown in Fig. 32.

often distort and warp the head. Excessive heat is sometimes due to low water or lack of oil or running on a retarded spark.

Valve may be held open due to clearance (4) between valve stem and tappet being set too close (see page 57 under "valve-stem clearance" for ill effects of this).

Valve-spring (3) may have lost its temper due to excessive heat and thus be **weak**, which results in valve holding open at seat (more common with exhaust), or spring may be **broken.** Valve-springs, when too stiff, will cause excessive wear and noise.

Valve-stem may be stuck in its guide (2) despite the pull of the spring (3), due to lack of lubrication, or carbon deposit on stem; or because of warped or bent stems; all cause a lagging action. See also page 767.

Valve-timing may be incorrect, or contour on cam (5) may be worn and thus not close or open valve at the proper time.

Valve-guide or valve-stem may be worn, permitting air to be drawn through inlet-valve-guide when the inlet valve is open, thus admitting more air to mix with the carburetion mixture, which causes missing and poor idling.

Examine the various parts mentioned above until the cause is located. **The most common valve troubles are** burned valves, sticking valves, and noisy valves.

In most instances the valves may be ground or lapped to their seats in the cylinder head or block.

If the valve-head is badly pitted, burned, warped, or out of line with its seat, or if shoulders or grooves appear on the valve-head face or ridges around the valve-seat, due to constant hammering, it is advisable to reface the valve-head (or install a new one) and recut the valve-seat, then lap or grind to a smooth seat by hand or with one of the valve-grinding tools that has an oscillating motion.

Valves that are warped or burned badly are often replaced with **new** ones which also must be ground to a tight seat.

If the valve-seat in the cylinder block is excessively wide, which in many cases is wider than valve-face, or if pitted and crystallized with scale, it should be reseated and valve-head refaced and then ground to seat. If a **new** valve-head is installed, the valve-seat in cylinder block should be reseated before the new valve-head is ground to a seat.

Valve-stem should fit the guides. This subject is discussed on page **776A.**

Valve-stem clearance is **very** important. This subject is treated on pages **776B** and 57.

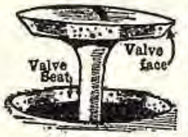


Fig. 32. **A pitted valve-head and valve-seat.** Note the black spots on the valve-face and valve-seat. This permits escape of gas. If the seat is pitted it may or may not leak. If the valves are ground or reseated, the spots will be removed and the valve will seat tightly provided the pitting is not too deep and the valve spring is not too weak.

Where a valve is deeply pitted, it is a mistake to attempt to grind out all of the pits, and it is not necessary, so long as good line contact is obtained between the pits as shown in Fig. 47. Of course, if a pit cuts through the line of contact, there will be a leak. Pits, also carbon deposit, may be removed with a valve refacer, valve-seat reamer, or cutter.

Fig. 33 (left). **Exhaust-valve-stems often become carbon-coated,** and when the engine is driven at high speeds for long periods of time the temperature increases, causing expansion, with the result that the valve will be given a taper or warped effect which will not permit it to seat properly. Often this is the cause of a leaky valve, and the stem should be cleaned thoroughly and sufficient clearance allowed between the valve-stem and the valve-guide. **Clean** by placing the valve between wood blocks in a vise (Fig. 33A), and use a strip of emery cloth.

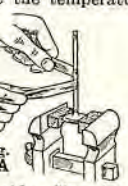


Fig. 33A

The exhaust valve has a tendency to leak more than an inlet valve because it is more exposed to heat, due to the outlet of hot gases.

The exhaust valve-stem expands more than the inlet valve, as it is exposed to a greater temperature. It is usually given a slightly greater clearance between valve-stem and tappet than is given to inlet valve.

The exhaust valve-seats in the cylinder block do not suffer as much from heat as the exhaust valve-head because the seats are usually water-jacketed. The valve-seats, both exhaust and inlet, **wear** down in time from constant hammering or tapping and thus make too broad or too **wide a seat.**

The valve-face on exhaust or inlet valve also wears in time from the same cause, and shoulders and grooves will appear.

The inlet valves usually require only grinding or lapping, as the cool gases from carburetor tend to keep them cooler than the exhaust valve.

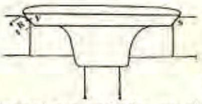


Fig. 33B. **A valve-seat** should never be wider than the face of valve, but should be narrower. A narrow radial seat (R) is theoretically preferable to a staight seat (S) because it will not wear to a wide contact as quickly as the conventional straight seat. An[1] instruction book says "a tight valve should show a smooth bright bearing about $\frac{1}{32}''$ wide in the valve and seat."

Too narrow a seat will not wear, and too wide a one tends to catch carbon. Valve-seats that are too wide may be reduced with reseating cutters or reamers. Heavy-duty engines require wider seats, owing to heavier spring tension and continual hammering.

Valve Reconditioning Methods

1. **Grinding or lapping** engine valves to a tight seat with valve-grinding compound and tool.
2. **Refacing a valve-head** on a valve-face grinding or cutting machine. It is essential that the valve-head be faced true or centered with relation to the valve-stem and valve-seat.
3. **Reseating the valve-seat** with a reamer or cutter, using with it a pilot, in order that the valve-seat in the cylinder block be true or centered in relation to the valve-stem guide and that seat has the correct width.
4. **Trueing up, and beveling valve-stem ends** by grinding.
5. **Reaming valve-stem-guides for oversize valve-stems** and reaming valve-tappet-guides for oversize valve-tappets when excessively worn.
6. **Testing valve-spring** tension.

GRINDING OR LAPPING ENGINE VALVES (POPPET TYPE)

The purpose of valve grinding is to make a tight seat which will prevent the escape of the compressed gas through the valve-face and valve-seat of the inlet or exhaust valve. See also page 56.

Before grinding valves be sure the valves leak. Make the compression test. If there is a loss of

[1] **On modern high speed, high compression engines** (heat increases with compression), tendency is toward wider seats. Wide seats dissipate heat from valve heads better but narrow seats give better sealing; if too wide, carbon particles may be caught between the valve and valve seat causing blow-by that will soon burn valve and seat. Seat width depends upon characteristics of engine rather than there being a standard for all engines. **Follow manufacturers' recommendations.** See *Supplementary Index* under "Valves."

compression, bear in mind that it may be elsewhere than in the valves. Weak compression can also result from leaky piston rings; therefore be sure that the leak is in the valve and not in the rings or elsewhere. The blue test for a valve leak (page 769) (or with tester, page 776D) can be tried if in doubt.

On some engines the valves are on the side and cylinder head is cast integral with cylinder block making it necessary to remove the valve-cap to get to the valve as in Fig. 108, page 56.

On others, the valves are on the side and in cylinder block and cylinder head is detachable as in Fig. 111, page 56.

On others, the valves are in the detachable cylinder head as in Figs. 112–115, page 57.

On others, the valves are in cages as in Fig. 93, page 53.

But no matter where or how the valves are arranged, they serve the same purpose and are ground in very much the same manner.

Valve-Grinding Procedure

As an example, we will use an engine with valves-on-the-side and in a cylinder block which has a detachable cylinder head.

First drain the water from radiator, disconnect upper hose from cylinder block (loosen flange), disconnect spark plugs, and remove the cylinder-head bolts and lift off cylinder head, then the gasket. Hang the gasket on a nail.

Removing carbon is an operation that should be done at this time: temporarily replacing bolts in holes will prevent carbon falling in. Turn crank until the pistons 1 and 4 are up; then scrape carbon from the heads of these pistons, valves, etc.; be sure and put cloth into No. 2 and 3 cylinders. Then blow off all carbon with air and repeat the operation with No. 2 and 3 pistons. Be sure to remove any carbon collected under head on stem, as this is what usually causes valve to **stick** in guide.

Also loosen any dirt or **carbon in bolt holes,** otherwise cylinder head could not be drawn down tight and water would leak out around gasket when head and parts are replaced. Trying to force bolts may break them off.

Be sure carbon does not get into cylinders. Also remove carbon from the inside of cylinder head and clean well, so that there are no loose particles. See also, pages 776D, 763.

Next remove valve-cover and gasket, as shown below.

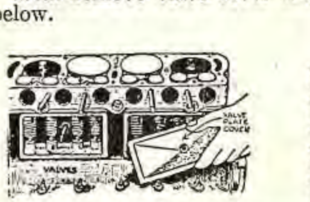
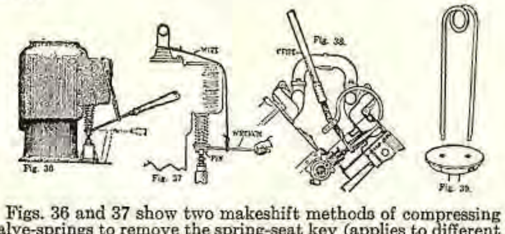


Fig. 34. Valve cover and detachable cylinder head removed on an engine with valves on the side exposing the valve-springs and valve-stems. **Note:** It is not usually necessary to remove manifolds in order to grind valves.

Next, remove the valve-springs. There are various methods and devices for doing this. Methods are shown in Figs. 36 to 39B. The idea is to compress the valve spring (when valve is fully seated), so that the spring-seat-pin, or valve-seat-pin can be withdrawn from the stem.

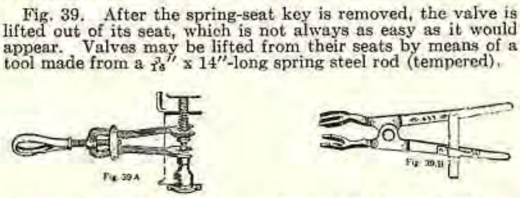
The valve can then be removed, but before doing so it is a good idea to remove with a fine file any burr which may have formed on the end of the valve-stem, so that it will pass through the valve-guide easily.



Figs. 36 and 37 show two makeshift methods of compressing valve-springs to remove the spring-seat key (applies to different kinds of engines).

Fig. 38. A device sometimes used on V-type cylinder-block engines for compressing valve-springs.

Fig. 39. After the spring-seat key is removed, the valve is lifted out of its seat, which is not always as easy as it would appear. Valves may be lifted from their seats by means of a tool made from a $\frac{3}{16}''$ x 14''-long spring steel rod (tempered).



Figs. 39A, 39B. Two of several types of valve-spring lifters: the Vlechek (39A) and the Mossberg (39B).

If more than one valve is removed, be sure to arrange or **mark them** so that the same valve will be replaced into the same valve-guide from which it was removed. Light punch marks can be made on the head.

Place cloth into the opening of the cylinder to prevent the grinding powder and dirt from getting in; and be sure and take it out when through.

Bear in mind that a valve-stem can be easily bent; therefore be careful to not allow tool or spring to bear sideways against valve-stem.

Examine valve. If burned, warped or deeply pitted or badly worn on the stem it should be discarded and a new valve installed.

If you are equipped with a valve refacing machine it may be possible to **recondition** it.

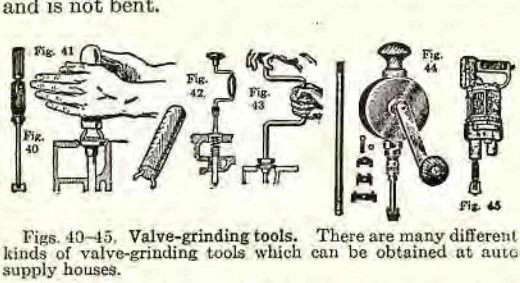
If valve-guide and stem are worn (.008'' clearance or over), it is best to ream valve-guide with an **oversize reamer** and put in a new valve with **oversize valve-stem.** (See page 776A, "to check valve-stem-guide wear.")

If valve-seats in cylinder block are pitted or burned (scale on it) or if valve has a very wide seat, it should be reseated with a reseating reamer (see pages 775–776). If the valve-stem guides have been reamed oversize, the reseating tool should be used with an oversize pilot. The valve is then ground to a seat.

Another point to observe is the lower part of valve-stem. If badly worn, the clearance will be too great. If there is no provision for adjustment of valve clearance, as on the Ford, a new valve will be necessary.

If the valves and seats are in good or fairly good condition, likewise the valve stem and guide, the valves can be ground, but before doing so clean the stem (Fig. 33A) and all parts thoroughly.

Before grinding an old valve, it should be tested by revolving between centers to see if it runs true and is not bent.



Figs. 40–45. **Valve-grinding tools.** There are many different kinds of valve-grinding tools which can be obtained at auto supply houses.

If a **slot** is cut in the head of the valve an ordinary screwdriver or brace and screwdriver bit (Fig. 42) will serve the purpose.

If there are **holes** in the head of the valve, a special tool such as shown in Fig. 40 and Fig. 41 is

NOTE: Text was **changed** from page 769 to and including page 780 (since the General Index was prepared), consequently there may be some **discrepancies between the index and the text. See** p. 690 under "Valves" for literature and booklets on valves.

required. (The one in Fig. 41 can be made of a broom handle and two nails.)

The one in Fig. 40 has a double handle, one of large diameter for speed and the other for slow speed. Fig. 43 is a valve-grinding tool made by some of the wrench manufacturers, such as Walden.

Fig. 44 is a hand-oscillating type. It has an extension which is handy for reaching some of the rear valves. (Made by Albertson & Co., Sioux City, Ia.). Fig. 45 is an electric oscillating type. Then there is another type not shown, operated by air.

Fig. 46

After removing valve and cleaning it, apply some valve-grinding compound[1] **on the face of the valve** (Fig. 46). The usual procedure is to dip the finger into the compound (coarse grade first) and apply this to the face. Put on an even coat and do not plaster it all around the surrounding metal parts, a thin coating is sufficient.

There are specially prepared grinding compounds[2] which can be secured at supply houses. They usually come in two grades: coarse and fine. The first cuts heavily; the second does not cut so much, and is for finishing.

Place the valve back into its seat; then take a valve-grinding tool (see Figs. 40–45), placing the point in the recess, and bear down on the valve with slight pressure, and **oscillate** the valve back and forth in its seat for a few seconds. (Make sure end of valve stem is clear of tappet.)

Then, with your free hand, reach under the valve-stem, push the valve up and off its seat, revolve it a quarter turn and let it fall back in its seat once more. Then begin oscillating the valve back and forth again for another few seconds, and again raise the valve, turn it in the same direction another quarter turn, drop it back on its seat, and proceed again the same way.

A pressure of about 3½ lbs. is sufficient. More pressure than this will cause grinding compound to cut rings in the valve-seat.

The reason why a valve should not be turned round and round, or continuously in one direction when grinding, is that it is liable to result in an annular cut in the seat which would be hard to grind out.

A spring should be placed under the valve head as shown in Fig. 42. This will allow the valve to be raised from its seat occasionally for inspection.

After you have gone completely around twice with the valve in the above manner, remove valve, wipe off compound, and pass the finger over face to make sure it is clean. Then carefully wipe the compound off the valve-seat, and pass the finger over this surface also.

Examine the two seats carefully, and see if they seem to be ground evenly all over. If not, repeat operation, using again the "coarse" grade of compound.

When you believe that you have a uniform looking seat, clean both seats carefully and apply a small quantity of "fine" grade grinding compound and once again go through the same operations, using the fine instead of the coarse grade.

Caution: The usual mistake which is made, is to carry the grinding operation too far. The average valve requires but little grinding to make it tight, but it should have this little grinding often, say every 5,000 miles; also ream carbon from valve-seats and reface valve-head when necessary.

The idea is more to clean and resurface to a clean tight seat than to remove very much metal, unless worn, with ridges or grooves, and then often a new valve should be installed. The carbon should always be removed at the same time, not only from valve-head, seat, and stem, but surrounding it, to prevent particles getting under valve. Always **blow out all loose particles with air.**

After you are through with your two grinding operations—the "roughing and finishing," as it is called—clean all surfaces with the greatest care, and then apply a thin film of clean **oil** to the seat of the valve and drop it back into place once more.

This time apply all pressure you can to your valve tool and oscillate valve a number of times in its several positions, just as if you were grinding it, only with **oil instead of compound,** and using more pressure.

Now take the valve out, wipe off the oil carefully and get a reflected light on the surface of the seat of the valve, by holding it at the proper angle between your eye and the light.

A test to see if valves are tight: Turn the valve slowly, keeping your eye fixed at the same point of reflected light and you will see some fine, very bright or polished lines, which run around the seat. These lines represent the points of contact.

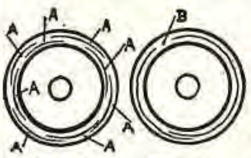


Fig. 47 Fig. 48

Refer now to Fig. 47 and you will note that these bright lines (A) are not necessarily continuous all around the seat.

One line will run part way around and then stop, and another will then start, go farther along and run out, and so on; usually not so short as these shown, but rarely a continuous line.

If all these lines **overlap,** as shown in Fig. 47, the valve is tight on its seat, but if they **fail to overlap** as shown at **(B)**, Fig. 48, then there will be a leak at **(B)**, and it is necessary to commence all over again and grind the valve some more, beginning with the coarse compound and finishing with the fine, then testing its tightness by rubbing in with oil as before.

An ideal valve seat is a very fine, narrow edge, as it will last longer than a wide one, and, furthermore, a wide seat tends to permit carbon to collect in the seat, and thus heat the valve, while a narrow valve seat cuts the carbon, thus assisting in keeping the seat clean.

Fig. 49

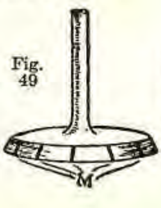


Fig. 49. **Another method to test the finish of a valve-face after grinding:** Mark it with a lead pencil as shown about ⅛" apart or less. If, after putting the valve in place and after oscillating it about a quarter turn, all marks are erased, the job is satisfactory. The marks (M) on valve are the pencil marks to be erased.

[1] This method of valve grinding is taken from *Compression Leaks.*

[2] **Valve-grinding compounds are of two kinds, carborundum compound and water-mix-compound.** The carborundum compound cuts under the action of oil, and water-mix compound cuts only with water.

"Clover valve-grinding compound," a mixture of abrasive and hard petroleum-cutting oil containing no emery or grit for grinding valves, lapping cylinders, fitting piston rings, etc., is manufactured by the Clover Mfg. Co., Norwalk, Conn. For valve grinding, this company recommends its valve-grinding compound which comes in a duplex can and contains a coarse grade (E) for roughing and a fine grade (A) for finishing. They also supply a water-mix valve-grinding compound known as "Just Rite." They state that it will cut very fast, but recommend the slower process of using their compound which has an oil base.

Some mechanics prefer the oil-base compound, while others prefer the water-mix compound.

There are a number of other good valve-grinding compounds on the market, such as "Zip" (The Zip Abrasive Co., Cleveland Ohio), "Pep" (Pep Mfg. Co., 33 W. 42 St., New York), and many others—all of which can be obtained at automobile supply houses.

After grinding valves and they are found to be tight, they should be cleaned with gasoline or kerosene. Also clean valve-seat, and be sure that no abrasive substance gets into cylinder or valve-guides, and don't overlook cleaning the valve-stem.

When replacing valve, place a little oil on the stem and place it in the valve-guide and in its seat. Be sure that the valve-stem is free in its guide. Before replacing valve-stem, be sure the end of the stem is ground true.

A valve that is properly seated will bounce back when dropped into its seat. If it stops with a dull thud, either the grinding is not perfect or the valve-stem is bent.

The valve-spring is then compressed and placed back, and other parts assembled.

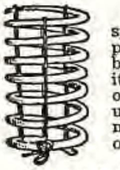


Fig. 50. **One method of replacing a valve-spring:** Tie the valve-spring before trying to replace it. A simple method is to compress spring between the jaws of a vise. While compressed, it is tied up with a loop of wire or string in two or three places. When the spring is thus tied up under tension, its replacement is easy. This is not necessary, however, if a valve-spring lifter of the proper kind is at hand.

After grinding valves, always check the valve-stem clearance between the end of the valve-stem and tappet, because the relations between the two were changed during the grinding operation.

It is also advisable to check the valve timing after checking the valve clearance, particularly on an engine that has been in service for some time with worn parts.

The compression of the cylinders can now be tested. If valve-seats are properly seating and there are no other leaks, such as piston rings, scored cylinders, loose pistons, or out-of-round cylinders, they should test approximately equal in all cylinders (see page 767).

Grinding Overhead Engine Valves

The foregoing instructions are for grinding valves in an "L" or "T"-head type of cylinder.

Valves placed overhead, are either in **cages,** as shown on pages 53, 71, or **in cylinder heads which are detachable,** as in Figs. 112 to 115, page 57, and the process of grinding is similar to the method of grinding valves explained on pages 772 and 57.

Where valves are in cages, the cages are usually removed, as shown in Fig. 52 below, and the valves are ground in the cage.

The valve-cage itself is sometimes ground to its seat in cylinder block (see Fig. 53) on some makes of engines, and on others a copper gasket is used.

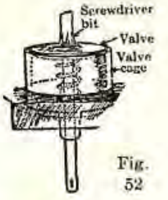


Fig. 52

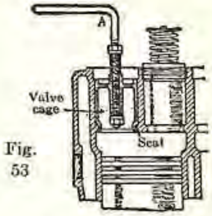


Fig. 53

Fig. 52. The cage is placed in a counter-sunk hole in the bench, with a spring under the valve to raise it. In fact, it is a good idea to place springs under all types of valves when grinding. The valve-head is then ground to a seat in the valve-cage.

Fig. 53. A simple way of grinding a Buick valve-cage[1] to a gas tight joint in seat in the cylinder block is shown here. Through the center of the cage insert a round iron rod which has been threaded for a nut at the two places shown. Then tighten the nuts. With the rod as a handle, the cage can be rotated easily. See also page 71.

When replacing cage, be sure to line up the gas port holes in cage with holes in cylinder block.

To tell when a valve is ground to a perfect seat, see blue test (page 769, and Figs. 47, 48, page 772). (See also page 776D.)

TYPES OF POPPET VALVES[2,3]

Valves may be classified as **one-piece** type or two-piece type. By one-piece is meant that the valve-head and the valve-stem are made of the same material and are integral. In the two-piece type the valve-head may be made of the same or a different metal from that of the valve-stem, and the two are welded, riveted, or otherwise fastened together.

The two-piece valve consists of a cast-iron head or of a steel head which is fused, welded, riveted, or otherwise fastened to a steel or alloy steel stem.

One of the advantages claimed is that inasmuch as both valve-head and motor-block seat are of the same material, they will wear to the same extent.

The one-piece valve consists of an integral head and stem made of special alloys of steel. The alloys used contain such elements as chromium, silicon, tungsten, nickel, cobalt, etc.

Stainless steel resists rust, which is an important factor in the valves of marine engines, owing to the presence of salt-water vapor. Stainless steel is an alloy of certain definite percentages of chromium and nickel.

Tungsten steel is very hard and tough, and consequently valves made of this material will offer great resistance to abrasion (wear) and to breakage, particularly when red hot. For this reason, they are often used in racing cars in which resistance to abrasion (caused by road dust, etc., in the intake gases), and breakage are more important features than resistance to burning.

A steel alloy of low percentages of **chromium and nickel** is often used for **inlet valves.**

One of the most popular steel alloys used for valves on aviation engines, heavy-duty trucks, tractors, busses and passenger cars contains both chromium and silicon. The advantages of valves of this alloy is that even though they may become red hot, they will retain their hardness and will not warp. "Red-hardness" is the term used to describe such a characteristic. For these reasons a steel alloy of **chromium and silicon** is particularly suitable for **exhaust** valves, and is also used in inlet valves where expense is not an important factor. There are a number of such valves, one being the Thompson silcrome valve; another, the Rich silcrome steel valve; another is the Toledo one-piece all-steel, special alloy valves for heavy duty work.[2]

The "James self-cooling" valve is the name of a valve formed of a special alloy metal known as Ni-chro-loy. The metal consists of nickel, chromium, and carbon, melted in an electric furnace and poured at a temperature of 3,800° F. This valve has a **hollow chamber under the head** with three vent-holes, a patented feature known as the Grant hollow-head construction. When engine is running and exhaust valves are open, the rush of the gases by the valve tend to create a suction below the head, and this action draws the excessive heat in the hollow chamber away from the head, thereby cooling the valve-head.

Another make of valve is the Boyle **flat-seat** type of valve. It is claimed that with the same lift as the ordinary taper valve, this valve will have a greater valve opening and that this gives an increase in effective valve area which produces more power, quicker acceleration, etc.

If difficulty is met with in grinding some of the valves, owing to the fact that the abrasive cuts the surface very slowly, it is because that particular engine has a very hard alloy steel valve.

The valves should then be refaced on a refacing machine (page 775) grinding type preferred; this will eliminate a good deal of work.

[1] Buick valves are now ground in a detachable cylinder head.

[2] **Some of the manufacturers of valves are:** Boyle Valve Co., Chicago, Ill.; James Motor Valve Co., Detroit, Mich.; Michigan Engine Valve Co., Detroit, **Mich.**; Rich Tool Co., Detroit, Mich.; Thompson Products Inc., Cleveland, Ohio; Toledo Steel Products Co., Toledo, Ohio.

[3] See page 775 for **valve refacing and reseating tools formerly on this page.**

Where hard alloy steel or Tungsten valves are used, they can be ground if a good valve grinding compound is used for the purpose; but if they are badly pitted, they should be refaced. The usual practice is to **grind** them on a valve-grinding machine or to place them in a lathe and emery them down with special devices for the purpose, or to use fine emery cloth on a block, while a valve is rotated at a high speed.

Valves for replacement, in standard sizes and oversize (see page **776A**) of various makes can be obtained of automotive supply or equipment jobbers.

Valve-Stem Ends or Tips

There are five types of valve-stem ends (Fig. 54), namely, slot (**S**), drilled (**D**), grooved (**G**), threaded (**T**), and taper grooved (**TG**). The ends or tips of valve-stems are usually hardened and beveled to a 30° or 45° angle to a distance of $\frac{1}{32}$" for valves less than $2\frac{3}{8}$" dia., and $\frac{1}{16}$" for larger valves. On some of the steel valves the heads also are hardened.

Fig. 54. Valve-stem ends or tips; Fig. 55. Valve-head slots or holes.

Valve-head slots or holes. To facilitate the regrinding of valves and valve-seats, either a slot is milled or holes drilled in the valve-head (Fig. 55). The holes range from $\frac{3}{4}$" to $1\frac{1}{4}$" apart, depending on the size of the valve.

Valve-head faces are beveled at either 45°, 30°, or 60°—usually 45°.

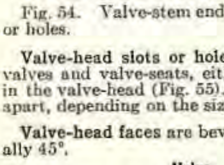


Fig. 55A. The S.A.E. recommended practice specifies a 45° bevel on valve-face and seat.

The illustration shows how the **depth** and **diameter** of valve-face compares with valve-seat.

The small diameter of valve-face (**B**) is always a little less than the small diameter of valve-seat (**A**); also depth of valve-seat (**D**) is always less than depth of valve-face (**E**).

Valve Dimensions

When ordering a valve which cannot be identified by stock number, model of car or engine, the most important dimensions, which are given below, should be specified. A sketch avoids mistakes. Also mention the angle of valve. Most valves have faces of 45° angle.

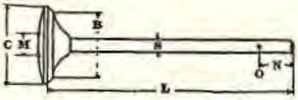


Fig. 56. **B,** small diameter of valve-face; **C,** overall diameter of valve-head; **L,** distance from top of valve-face to tip of valve-stem; **M,** distance between holes for valve grinder tool; **N,** distance from center of hole for spring retainer pin to tip of valve-stem; **O,** drill size of hole for spring retainer pin. (**Note:** If a slot or groove is used, give complete dimensions on a sketch.) **S,** valve-stem diameter. Also mention port dia. of valve-seat (see **A,** Fig. 55A).

The valve dimensions of a finished standard Ford model T-valve for the intake and exhaust are as follows: B, $1\frac{11}{32}$" to $1\frac{9}{32}$"; **C,** $1\frac{15}{32}$" to $1\frac{31}{64}$"; **L,** 5" (approximately); **M,** $\frac{3}{4}$"; **N,** $\frac{13}{32}$ to $\frac{15}{32}$"; **O,** No. 31 drill (.120"); **S,** .3100" to .3115" (about $\frac{5}{16}$"). Width of valve-face is $\frac{3}{32}$".

When installing a finished valve, it should be lapped or ground to a tight seat.

Reconditioning or Replacing a Valve

Some of the valve manufacturers advocate the replacement of a new valve instead of reconditioning the old one. The reason given by one manufacturer is that after a valve has been used for several thousand miles service, if subjected to an acid etch,[2] quite often fatigue cracks are revealed around the diameter of the head, penetrating toward the center of the head and through the face of the valve.

In a great many instances this can be removed by refacing, but if the refacing operation does not penetrate to the bottom of the cracks and the valve is put back into the engine, the cracks will start to lengthen further.

The manufacturers of valve refacing machines claim that a valve can be reconditioned and will be as good as new.

It is better practice to replace valves with warped or bent stems, as it is difficult to straighten a bent stem so that it will not bind if a really good fit in the guide is desired.

Any valve-stem that is worn so that it has a clearance in the valve-guide of .008" or over should be replaced. A new valve-guide bushing does not correct the worn stem (see page 776A). A properly fitted valve has but .0025" to .003" clearance.

The repairman should carefully examine the valve. In most instances the probabilities are the valve can be refaced and made as good as new if it is not too far gone.

Methods for refacing valves and reseating valve-seats will be taken up in the next subject.

RECONDITIONING VALVES AND SEATS BY REFACING VALVE-HEAD FACES AND RESEATING VALVE-SEATS (POPPET TYPE)

Refacing Valve-Head Faces

If valve-faces are warped, burned, pitted, or worn until shoulders or grooves appear (as greatly exaggerated, in Fig. 57) seating on the surface (**A**), with ridges (**B**) and (**C**) on either side of the seat (**A**), it is manifest that we must remove these ridges before we can commence to grind the valve in place.

It might be well to say right here that the valve seat (**D**), (Fig. 57), is usually narrower than the seat of the valve-head, so that if there is any grooving to be found, it is almost certain to be exclusively confined to the valve-head as shown.

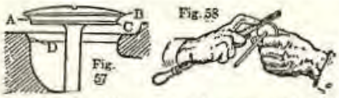


Fig. 57. An exaggerated illustration showing how ridges may form on valve from wear.

Fig. 58. Ridges can be removed with a file. The modern method is by means of a valve-head refacing machine.

Ridges can be removed with a file by holding the valve-head in the fingers, as shown in Fig. 58, and with very short strokes work round and round the valve, but the quicker and more accurate method would be to reface the valve on a refacing machine which will also remove any other defects and also true the valve-head seat with stem.

Very likely too, if valve-head is in bad shape, the valve-seat is also and it should also be reseated, as will be explained farther on.

The illustrations (Figs. 57, 58) are taken from the Clover booklet and are intended for those not equipped with machines suitable for valve refacing; but in either case the valve should be ground or lapped to a seat afterwards.

Many shops have adopted the practice of refacing valves on a refacing machine and then grind or lap them to a fit afterwards.

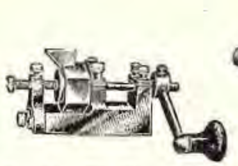
Valve-heads can be refaced on a lathe, or hand refacing tool, or by an electric-motor-driven grinding machine.

[1] **See page 776A for valve-stem guides, oversize valves,** etc., formerly on this page.

[2] **By boiling in a compound consisting largely of sulphuric and hydrochloric acid, the acid eats away segregations and other impurities in the steel which fill forging or fatigue cracks that are not visible otherwise. It is usually not possible for the repairman to detect cracks in a valve until they open up.**

The hand-type refacing tools are shown in Figs. 59 and 60, which **cuts** the face of the valve as on a lathe. The hand type grinder shown in Fig. 61, and the electric-motor-driven valve refacing machines, Figs. 62, 63 **grind** the valve face.

Always clean valve thoroughly before refacing and never grind off so much of the metal that a sharp edge is formed. After refacing valve lap or grind to a perfect fit.



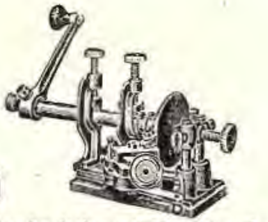


Fig. 59. The Sioux **valve-head refacing tool** No. 304, to be held in a vise. It is made with cutters for valve-faces with 45°, 60°, and 30° angles. Removes carbon pits, etc.

Fig. 60. The Sioux **valve-lathe** No. 600. Refaces valves of either 45°, 60° or 30° angles. Will cut Tungsten valves also.

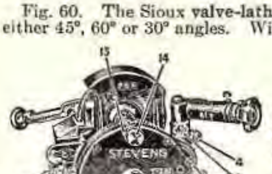


Fig. 61. **A hand-driven type valve-face grinding machine.** Grinds valves to any bevel desired. Grinds hard Tungsten valves also. When not being used as a valve grinder, this machine can be quickly converted into a tool and drill grinder.

Fig. 62. An **electric-motor-driven valve-face grinding machine.**[2] **M,** electric motor; 3, switch; **E,** emery wheel; **V,** valve to be ground; 1, 2 and 4 are for positioning the valve (**V**) with wheel (**E**).

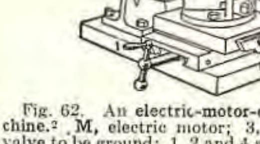


Fig. 63. **An electric-motor-driven valve-face grinding machine.**[3] This machine is operated with two **electric motors.** One of them drives the grinding wheel at 3,450 r.p.m., and the other operates the work spindle through a gear reduction, making a final speed of 430 r.p.m.

Valve-face grinding machines will reface valves at any angle and true up the face of the valve with the stem which insures a perfect joint between valve and seat. A tungsten valve can also be refaced in 20 seconds.

The ends of valve-stems and valve-tappets can also be ground on machines of this kind. Many of these machines will also **grind the valve reseating cutters and are equipped with attachments to clean carbon from the valve-stems before refacing.**

Fig. 64. **The McCullough valve reseating tool** consists of a carborundum cloth cone held to the face of the valve as shown. The valve is used just the same as a reamer, the cloth cutting the seat in the valve seat of cylinder at the same bevel as that of the valve-face. Emery cloth or sandpaper will do quite as well, but will not last as long.

Many mechanics clean carbon from valve-seats before lapping in or grinding the valves, by cutting a piece of carborundum cloth (about No. 60), then cutting a hole in it, and placing the pilot stem of a valve-seat reamer through it. The edge of the reamer will turn the cloth (rough side down) and clean the valve-seat. The valve-head face can be cleaned in the same way with the rough side of cloth up, holding the edge to keep it from turning. Turn valve in one direction.

Tools for Reseating Valve-Seats[2]

To obtain a satisfactory job of valve fitting, it is essential that the valve-head be faced true with relation to the valve-stem, and it is equally important that the valve-seat in the cylinder block or head be true in relation to the valve-stem guide and that a narrow seat of even width, square and central with the guide be obtained.

If valve-seats are pitted, burned or crystallized with scale and hardened, or if they have worn excessively deep or wide, which in many cases is wider than the valve-head face, by constant hammering, then it is advisable to reseat the valve-seats with a cutter or reamer which performs a milling operation.

If valve-stem guides have previously been reamed oversize, a reseating tool with an oversize pilot should be used. The valves are then ground or lapped to a tight seat.

There are a number of different kinds of valve reseating devices. Usually they are in the form of reamers or cutters (**R**) shown in Figs. 65–65B.

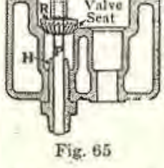


Fig. 65

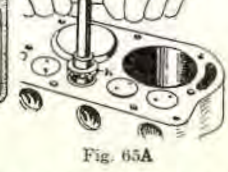


Fig. 65A

Fig. 65B

Pilot stem (P) is placed through the hole in cutter or reamer as in Fig. 65. The pilot stem is then placed into the valve-stem guide hole (**H**), and reamer (**R**) on to the valve-seat. The pilot stem should fit snugly in order to insure a valve-seat that is true in relation to valve-stem guide.

Pilot stems to fit valve-seat cutters or reamers come standard size, over-size, and under-size. Valve-stem guides vary even in new engines as much as .001" to .003"; hence the need for **under-size pilots.** Valve-guides wear and thus **over-sizes** are necessary. Pilots should fit just tight enough to "drag" lightly when inserted or turned. The reamer shown in Fig. 65**B** is a type with **two cutting faces:** the coarse one (**R**) for "roughing-in" and removing the hard glaze, and the other (**F**) for "finishing."

Before reseating, the valve-stem guide hole should be cleaned. The best method for doing this is to first run a steel brush through, or a valve-stem guide reamer of standard size which will not enlarge the hole (do not confuse this with an oversize valve-stem guide reamer). See also page 776**A.** Steel brushes can be had for use with portable, electric drills. See Fig. 76**A**, page 776**D**.

Cutters and pilots are operated by hand. To operate, place pilot in valve-stem guide hole and press cutter to valve-seat and rotate as shown in Fig. 65**A.**

Valve reseating cutters or reamers are used to reseat the valve-seat by a milling process.

Cutters or reamers have different kinds of cutting faces. Usually, a **coarse**-faced one is used first to remove the scale or hard glazed surface from the valve-seat, termed "roughing in."

[1] See page 776**B** for **valve-stem clearance,** formerly on this page.

[2] **Some of the manufacturers of valve-face grinders, valve-reseating cutters and reamers are:** Albertson & Co., Sioux City, Ia. (Sioux); Black & Decker Mfg. Co., Towson, Md.; Cedar Rapids Eng. Co., Cedar Rapids, Ia.; Foster-Johnson Reamer Co., Elkhart, Ind.; Storm Mfg. Co., Minneapolis, Minn.; Simplicity Mfg. Co., Port Washington, Wis.; Stevens-Walden-Worcester Co., 375 Broadway, N.Y.; Sawyer-Weber Tool Mfg. Co., Los Angeles, Cal.; Speaker Products Co., Indianapolis, Ind.; Van Dorn Electric Tool Co., Cleveland, Ohio; and auto supply houses (page 687). See pages 714, 790**B** where to obtain reamers for aligning bearings. [3] Made by Black & Decker.

Then a 15° and 75° reamer is used to bring the seat down to the proper width.

Then a **finer faced** one, usually a 45° reamer, is used to remove pits and irregularities and for finishing the valve-seat to a polished finish, after which the valve is lapped or ground to a hair-line seat in the valve-seat.

This last-mentioned reamer usually has a 45° angle of cutting face, because most of the valve-faces and valve-seats are originally cut to a 45° angle. There are, however, some cut for 30°, and 60°, and cutters or reamers can also be had accordingly.

How Valve-Seats Are Reseated

As an example, the Sioux method will be used. Quoting from their instructions, we read as follows.

In reaming valve-seats mechanics often find difficulty in centering the reamer over an uneven valve-stem guide hole. When this happens use oversize pilot stems, as it is necessary to recut the valve-seat to get it into alignment with the guide hole.

After using the finishing reamer, it is usually found that the seat is wider on one side than on the other.

To bring the seat back to its original condition, use the 15° or 75° reamer, or both. The 15° reamer will recess or narrow the top of the seat on the outside, and the 75° reamer will narrow the bottom of the valve-seat inside.

To get a more accurate job on the seat, follow the method as shown in Figs. 66–66D.

Fig. 66

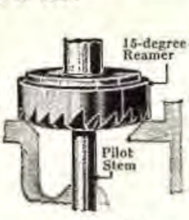


Fig. 66A

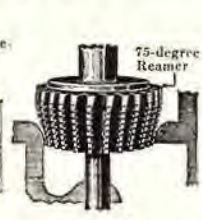


Fig. 66B

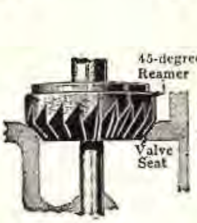


Fig. 66C.

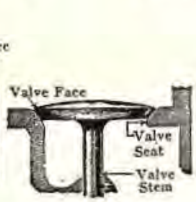


Fig. 66D

Fig. 66. **First operation:** Use the **coarse or roughing reamer** to remove the crystallized hard glazed surface. (This comes in 30°, 45°, 50° and 60° angles, usually 45°.

Figs. **66A, 66B.** **Second operation:** Use either the 15° valve-seat reamer (Fig. 66A) or the 75° valve-seat reamer (Fig. 66B) or both, to bring the valve-seat to center of valve-face.

The 15° reamer narrows the valve-seat from the top. The 75° reamer narrows the valve-seat at the bottom. (The 15° and 75° reamers are nicked-toothed. The teeth are so arranged that one cut overlaps the other, thus leaving no ridges.)

Fig. **66C.** **Third operation:** Use the **valve-seat finishing** reamer very lightly. To get a mirror finish on valve-seats use kerosene or gasoline mixed with oil, on "finishing reamer" only. (This finishing reamer comes in 30°, 45°, 50° or 60° angles usually 45°, as most valve-seats are cut at this angle.)

Fig. 66D. **Fourth operation: Lap the valve** lightly with fine valve-grinding compound to get an impression of valve-seat on valve-face and to **check** your work.

The valve-seat when finished should have a seat a little less than 1/8", or not over 3/32" width, and on engines with small valves, the seat should not be over 1/16" in width.

As stated in the fourth operation, the valve-head should be lapped or ground lightly into valve-seat after having reamed the seat and refaced the valve-head. This is necessary in order to check the work before assembling parts that were removed and to see that the valve seats properly, and also to see that valve-stem guide hole is in proper alignment.

Before reaming, it is necessary to see that the pilot stem fits snugly in the guide hole to assure a perfect job and to eliminate the possibility of the reamer wobbling or traveling.

If the guide hole is larger than the standard pilot stems, oversize or undersize stems can be obtained to .001", .002", .003", and .004" on any size at same prices.

When ordering 15° and 75° valve-seat reamers the 15° should be approximately 1/8" larger than the valve-head, and the 75° in most cases should be approximately one-eighth inch smaller.

A perfect seat is assured when a white line extends clear around both the valve and the seat, when giving the Prussian blue test. The width of the line is immaterial, but the narrower the line, the better the compression will be, because there is less area for the pressure of the valve-spring to act on. However, it is not well to have the ring too narrow, especially on large valves with heavy springs.

When reseating valve-seats, the novice must be careful not to cut too deep into the seat and thereby lower the valve-seat and stem. Always adjust the valve-clearance after either grinding or reseating valves (also check valve timing).

It will sometimes be noted that valve-stems seem to wear very much on one side. This may be caused by one or more things, viz.: (1) the hole is not concentric with the valve seat; (2) the top of the valve lifter is not at right angles with the valve-stem, wedging it off to one side; or (3) the same may be true of the valve-head on the stem of the valve; (4) sometimes the guides are not reamed square with seats. These troubles can be remedied by grinding the valve-face and reseating the valve-seats and on (4), by replacing valve-guide.

Check and adjust valve-clearance after lapping, grinding or reseating valves as this clearance is very important as explained under the subject of valve-clearance. Also check valve timing; page 773.

Valve-Seat Grinders

Valve-seat grinders[1] were introduced originally to grind hardened valve-seat inserts which could not be cut with the reamer. Inasmuch as the grinder will also recondition cast-iron valve-seats it is now used extensively for reconditioning all kinds of valve-seats and produces a fast cutting, mirror finish.

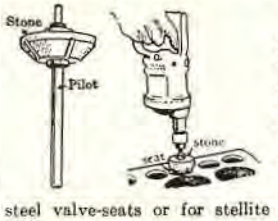


Fig. 67. **The valve-seat grinder is an abrassive grinder stone driven by a portable electric drill and universal joint (not shown). A pilot is** provided for placing in the valve-stem guide while grinding to insure the seat being true with relation to valve-stem guide. Stones are obtainable in angles, sizes, and grades to suit cast iron or soft-steel valve-seats or for stellite and hard steel valve-seat inserts.

Valve-Seat Inserts

Valve-seat inserts. Since the advent of the high compression engine, hardened valve-seat inserts have come more into use and are now standard on a number of engines, especially for the exhaust valve-seat. In some rare instances engine manufacturers are using cylinder blocks of special alloy.

[1] **Concerns manufacturing valve-seat grinders:** Albertson & Co., Inc., Sioux City, Iowa; Black & Decker Mfg. Co., Towson, Md.; Cedar Rapids Engineering Co., Cedar Rapids, Iowa; Hall Mfg. Co., Toledo, Ohio; Keystone Reamer & Tool Co., Millersburg, Pa.; Van Dorn Electric Tool Co., Towson, Md.; Van Norman Machine Tool Co., Springfield, Mass.

See page 776C for valve-springs, formerly on this page.

The advantage of inserted valve-seats, it is claimed, is longer life of the valve-seat and less frequent valve tappet clearance adjustment, especially in modern high-speed, high-compression engines where run for long periods at full throttle opening. A good seat retains compression, therefore saves gas.

Valve-seat inserts are made of hardened steel of various sorts, such as stellite, molybdenum chromium material, etc. They maintain hardness at red heat, consequently resist burning and pitting action. They are also made of steel not hardened which do not necessarily require a valve-seat grinder to reseat them; also cast iron of a special close grain, tough material. These are recommended for intake valve-seats which do not beat down and wear as rapidly as the exhaust seat and also for economical reasons.

Replacement valve-seats. When cast iron valve-seats have become worn or damaged beyond reconditioning a recess can be cut in the cylinder block by means of a tool[1] made for the purpose and inserting a replacement valve-seat into the recess; one popular method is to drive it in place and peen the metal around it. This restores the valve-seat to its former elevation and retains the standard size valve-head.

Hardened valve-seats can be refaced by means of valve-seat grinders which will also true-up the seat concentric with the valve guide. When necessary to replace a valve-seat insert an oversize insert of 1/64″ or 1/32″ is usually installed.

Valve-seats should be checked when a valve job is being done, **with a valve-seat gauge.**

[1] **Concerns manufacturing tools for installing valve-seat inserts are:** Albertson & Co., Inc., Sioux City, Ia.; Cedar Rapids Eng. Co., Cedar Rapids, Ia.; Hall Mfg. Co., Toledo, O.; K. O. Lee & Son Co., Aberdeen, S.D.; Weber Tool Mfg. Co., Los Angeles, Calif.

RECONDITIONING VALVE-STEM GUIDES, OVERSIZE-VALVES, AND VALVE-TAPPET-GUIDES[1]

When valve-stems become badly worn, it is almost a certainty that the **valve-stem guide,** or hole through which the valve-stem passes, is worn **out of round.** This permits air to be drawn through the inlet valves when they are open, which causes an **imperfect mixture,** resulting in bad starting, poor idling, and noise.

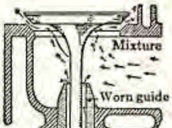


Fig. 69 (left). Exaggerated view of a worn valve-stem guide (SG) and valve-tappet guide (TG) wear in an L-head valve-engine. The same applies to an overhead valve-engine.

Fig. 69A (right) shows how air is drawn into mixture during suction stroke.

A properly fitted valve-stem in the valve-stem guide should have .0025″ to .003″ clearance. Warped or bent valve-stems will cause valve-guides to wear rapidly.

It is also better practice to replace valves having bent or warped stems with **new valves,** as it is difficult to straighten a bent stem so that it will not bind in the valve-guide.

If valves are warped or badly pitted or if the valve-stems are worn to more than .008″ clearance between valve-stem and valve-stem guide, install **new** valves.

To check valve-stem guides for wear, insert a new valve-stem in valve-stem guide and check the clearance. If there is more than .008″ clearance between stem and guide, the valve-guide should be reamed with an **oversize reamer,** and valves with 1/64″ **oversize stems** fitted. See next column for explanation.

On many engines there are valve-stem guide-bushings which can be renewed when worn or "out of round," and reamed out for a new valve, which is fitted at the same time, and then the valve is ground to a seat.

If new valve-stem-guides are installed, use standard size valve-stems. However, it is usually more economical to ream out old guides than to replace them. If new valve-guides are installed, it is necessary to use a valve reseating tool, as the new guides may not come in absolute alignment with the valve-seat, causing the valve to bind. By the use of a reseating tool with a pilot, the valve seat will be brought concentric with the new valve-guides and proper valve functioning will result.

Some valve-stem-guides are not bushed, but are simply drilled passages in the metal of the engine, and in this construction, **if valve-stem or valve-stem guide is worn, the guide is reamed larger, and a valve with an oversize stem is put in.**

For example: In the case of a valve-stem whose diameter is 3/8″ (reading decimally .375) use a 25/64″ reamer. Oversize stems are generally made approximately .003″ under the standard reamer size to allow for clearance.

Extreme care should be exercised, in fitting oversize stems, to be sure that they work freely in the guides. If they are fitted too close, they are liable to "seize" or stick.

Valve-guides on some engines are a part of the cylinder casting. Reaming and fitting oversize valve-stems is the first recourse. Afterwards, if already oversized, valve-guide bushings can be obtained which can be installed by enlarging the guide hole.

The valve-stem guides should come in absolute alignment with the valve-seat, and valve-stems should move freely.

Fig. 69C. **Oversize valve-stem guide reamer** (Sioux) for reaming 1/64″ oversize on all sizes of valve-stem guides, especially designed for reaming outworn valve-guide holes. Its pilot guides the reamer and prevents it from following the worn part of hole. Made in the following sizes:

21/64—For reaming 1/64 over 5/16 in
23/64—For reaming 1/64 over 11/32 in
25/64—For reaming 1/64 over 3/8 in
27/64—For reaming 1/64 over 13/32 in
29/64—For reaming 1/64 over 7/16 in
31/64—For reaming 1/64 over 15/32 in
33/64—For reaming 1/64 over 1/2 in

Standard size valve-stem guide reamer (Sioux) is especially designed for cleaning out valve-stem guide holes without increasing the size of the holes. Do not confuse this standard size reamer with the oversize valve-stem guide reamer. With this standard size reamer there is no chance of increasing the size of the valve-stem guide hole. This reamer of course, is for use where the holes are not so badly worn as to require refitting with oversize valve-stems.

Concentricity of Valve-Stem Guide and Valve-Seat Important

When reaming valve-stem guides, it requires very careful operation with a valve-stem guide reamer to obtain concentricity between the bore of valve-guide and the valve-seat in the block.

A simple test to tell if valve-guide bore is concentric with valve-seat in block or head is to drop valve into guide hole and let it seat; then tap sharply with finger; if there is a dull, solid sound when valve head is tapped, it indicates that valve-guide bore is concentric with valve-seat in block. If a rattling or clicking kind of sound is heard, it indicates that valve-guide bore is not concentric with valve-seat.

Oversize Valve-Stems and Heads

Oversize valve-stems are necessary when worn valve-stem-guides are reamed oversize. The standard oversize valve-stem is 1/64″ (or, in other words, the valve-stem-guide is reamed 1/64″ oversize).

[1] S.A.E. nomenclature terms this "valve-lifter guide."

Valves can be obtained with $\frac{1}{64}''$ and $\frac{1}{32}''$ oversize stems; they can also be obtained with **standard size stems** and $\frac{1}{32}''$ **oversize heads;** also **oversize stems** of $\frac{1}{64}''$ and $\frac{1}{32}''$, **with heads** $\frac{1}{32}''$ oversize. When valve-seats are worn so that valve-head is too small, an **oversize valve-head** should be used.

Where valves are of the overhead type with rocker arms, the bushings in the rocker arms must sometimes be renewed to relieve noise or to avoid too much side thrust on valve-stem causing excessive wear on stem and guide.

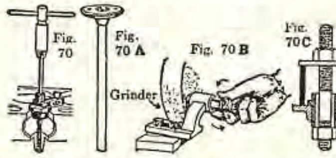


Fig. 70. **A valve-guide reamer.** When reaming the valve guides it is necessary to ream true; therefore a guide is necessary. The guide is shown clamped to the cylinder block. The reamer is then passed through the guide and turned by a hand tap-wrench.

Fig. 70A. **An oversize valve-stem** which must be fitted when a valve-guide is reamed.

Fig. 70B. **One method of truing valve-tappets,** when worn is shown in this illustration. If **valve-tappet adjusting screws** have hollows pounded into their ends, they can be ground flat by placing in a chuck of a drill press and running them against an oil stone, or grinding them in a grinding machine.

Fig. 70C. **Valve-tappet guide puller** can be made of a short section of 2″ iron pipe, or any size larger in diameter than the guide. A washer is then placed over the top of the pipe. A bolt which will go through the guide hole, and two nuts, will complete the puller.

Worn Valve-Tappets and Guides[2]

Valve-tappet guides usually wear out of round as a result of the cam striking lower end of valve-tappet in one direction (see Fig. 69). Thus in time wear will be such that at each time the cam strikes the tappet to raise it, the tappet is thrust to one side of its guide, and a clicking noise will result.

The remedy is either to put in new valve-tappet guides and tappets, or to ream out the old tappet-guides (which are usually removable) and fit **oversize tappets.**

(On the   the valve-tappet guide is not removable but guide bushings can be obtained and installed by enlarging guide hole.)

To check valve-push-rod or tappet clearance in tappet-guide on the   insert a new tappet. If there is more than .006″ clearance between tappet and guide, the guide should be reamed with a $\frac{33}{64}''$ reamer and oversize tappets installed.

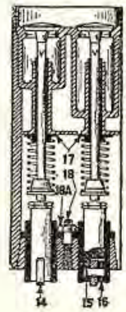


Fig. 70D. Illustration showing a detachable valve-lifter (or tappet) guide (16), valve-lifter (or tappet) (15), valve-lifter (or tappet) roller (14), valve-lifter (or tappet) guide clamp (18), valve-stem guide bushings (17), valve stem (V).

Noisy Valve-Action

There are **three points** in connection with valve operation where a clicking noise may occur, as follows:

1. Too great a clearance between valve-stem and valve-tappet.[1]
2. Worn valve-tappet-guides.[2]
3. Valve-springs too strong.
4. Flat rollers and worn pins.

The best way, perhaps, is to go about it in a systematic manner, starting with the most likely sources, as, for instance, in the valve-stem-clearance.

VALVE-STEM CLEARANCE

The adjustment of valves for the proper clearance between the end of the valve-stem and the top of the valve-tappet[1] is very important. The average clearance to give is shown on pages 58, 59 (see also pages 1052–1054). To get the best results, the engine should be warm when making the adjustments. **After adjusting valve clearance it is also advisable to check the valve timing** if engine has been in service for some time and parts are worn.

This subject is fully dealt with on pages 57–59 and 73; therefore only some of the effects produced by improper valve-clearance will be dealt with here. **An example** of what is meant by proper valve clearance is shown in Fig. 71.

Proper adjustment of the valve-tappets will help in reducing the noise which invariably occurs when there is any wear, as a result of the increased space between the valve-stem and the valve-tappet.

The proper space between the ends of the push-rod (also called valve-tappet and valve-lifter[1]) **and end of valve-stem** is as explained on pages 57–59 and 73. The smaller the space, the less the noise; but sufficient space must be allowed to provide for expansion when the engine is warm and for irregularities in the shape of the cam or roller. See page 57 which explains the ill effect of setting the valve-stem clearance too close, which results in **burned and warped valves.**

When the ends of the valve-stem and tappet wear, the clearance between them becomes greater and valve-lift gradually becomes less. If the **wear on valve head and its seat in cylinder block** is more rapid than wear on stem end, gradual closing up of valve clearance is obtained which sometimes results in the valve riding open and leakage and frequently burning of valve.

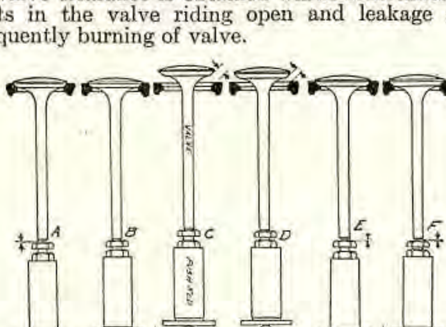


Fig. 71. **At (A) the correct clearance** is shown which permits the valve to **seat properly.**

At (B) is shown how **excessive valve-clearance reduces the valve lift** as the push rod must travel the distance indicated by the arrows before the valve starts to open.

(C) shows the **full opening** of the valve **with proper clearance.**

(D) shows the **reduced lift due to excessive clearance.**

(E) shows the **proper closing** of the valve **with proper clearance.**

(F) shows the effect of **excessive clearance on the closing** of the valve. The excessive clearance shown at (B) causes the valve to **open late** and also causes it to **close early** as shown at (F) (*Automobile Digest*).

Sometimes only one or two valves may need adjustment, while others may be in good shape; in such cases there will be a **clicking sound** at regular intervals.

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[1] The S.A.E. automobile nomenclature approves the use of the term "valve-lifter," which is correct. Inasmuch, however, as some manufacturers use the term "tappet," others "push-rod," we have used all these terms in this book.

[2] S.A.E. automobile nomenclature terms this a "valve-lifter guide."

The repairman can generally find a tappet that is badly out of adjustment in a very short time by simply working the tappets of each cylinder up against the valve-stems and down again, with his fingers, while the pistons of the respective cylinders are on their compression strokes.

Another plan is to place the blade of a thickness gauge under a suspected valve-stem, as shown in Fig. 72, and when the noisy one is found, the insertion of the tool will cause the clicking to cease abruptly and the valve will remain quiet until the tool is removed. (See also Fig. 3, page 58.)

Adjusting Valve-Clearance

Minimum clearance can be given engines which run cool and where short runs are made and where quietness is desired.

Maximum clearance should be given to engines which have a tendency to run hot and where long-continuous runs are made. See also page 57.

Adjustable valve-clearance means that a valve tappet adjusting screw (S) (Fig. 72) is provided which can be raised or lowered, and thus will adjust the clearance or gap space between the end of valve-stem and tappet. The nut (N) locks the screw after adjusting.

The valve should be fully seated and the valve tappet should be on the heel of cam when adjusting valve-clearance. (See also Figs. 1 and 2, page 58.)

To test or adjust valve-clearance, the best plan is to use a thickness gauge[1] and follow instructions above and also as given on pages 57–59.

In the absence of a thickness gauge, a piece of paper of proper thickness, as at (C) (Fig. 72A) can be used. It is slipped between the ends of the stem and tappet; the lock nut is loosened, and the screw is screwed up or outward until it just begins to pinch the paper and prevents it from sliding about as readily as at first. Paper is then removed and the nut tightened.

Such a method is little more than guesswork, however, because paper varies in thickness. **The average thickness of newspaper** is approximately .00275″ and the **approximate thickness of this sheet of paper is** .002″ to .0025″ (the **thickness of a postal card** is approximately .009″). The best method is to use a thickness gauge.

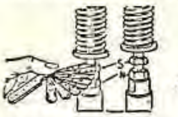


Fig. 72 (left). Adjusting valve-stem clearance between end of valve-stem and tappet with a thickness gauge.

Fig. 72A (right). A piece of paper (C) can be used if nothing else is available, but is not recommended.

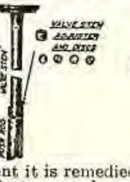
When both the inlet and exhaust valves have been adjusted, each one should be individually tested or checked (see page 73, and see also page 1052 for the adjustment or gap necessary for different engines), **to see if the valves remain tightly closed** throughout their required period.

This is done by sliding a thickness gauge or a single thickness of paper back and forth as the engine is being turned slowly from the closing to the opening points of each valve. (The marks on the flywheel may be used to advantage in this operation if accessible.)

Slide the gauge or paper under a stem and turn the engine crank until the paper is **seized**, which indicates the valve **opening**. Then turn it a little farther until it is free again, which marks the **closing** of the valve. If the engine is turned still farther, and the paper is continually slid about, and not seized before the regular time for the valve to open (according to either the position of the piston or the crank handle), the adjustment is about right, but if the paper is **prematurely seized,** the space is insufficient or timing incorrect. Check each valve in the same manner.

When adjusting valve-clearance, remember that if no space at all is left between the valve-stem and the tappet, the valve will not seat properly; and a burned and warped valve will result as explained on pages 57, 58, which causes missing, sluggish pick-up, loss of power, inability to idle and waste of gasoline, therefore, it is important to get the distance exact.

Non-adjustable valve-clearance means that no adjustment nuts are provided, as on the Ford. Therefore when the clearance is too great, new valve-stems and often tappets also must be installed, or valve-adjusters can be used as explained below. (See also pages 1103–1105.)



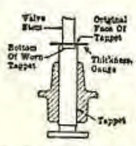


Fig. 73 (left). Valve-clearance adjusters for non-adjustable tappets: When the space between the end of the push rod and the end of the valve-stem is more than $\frac{1}{32}$″, then a clicking noise occurs. As the Ford valve has no means of adjustment it is remedied either by installing new valves or by using adjusters, as shown in this illustration, which are made of steel lined with fiber. These can be secured of supply houses. The clearance on a Ford valve should be not less than $\frac{1}{64}$″ or over $\frac{1}{32}$″. See also pages 1105, 1103.

Fig. 74. **If the end of a valve-tappet (non-adjustable type) becomes worn with a depression in the end of the tappet,** this would throw the valve out of time if clearance was measured with thickness on the top or sides of the depression. Install a new tappet, and also a new valve-stem. (See also page 1103.)

If the end of a valve tappet (adjustable type) becomes worn, which is in the form of an adjusting screw (see **S,** Fig. 72) it can be ground flat as explained in Fig. 70B.

VALVE SPRINGS

Valve-springs are usually made of chrome-vanadium steel, also of good carbon steel of the proper analysis and physical properties.

Weak or broken valve-springs will cause trouble, such as missing, overheating, and burned valves.

Valve-springs may become "permanent set," that is, the shortening of the spring after long service which results in a reduction in a pressure on valves. Test length with a new valve-spring.

Note. On some engines the intake spring may be lighter and have less tension than exhaust valve-springs.

If the springs of the exhaust valves become weak from use or heat, the pistons will draw burned gases into the cylinders, past the valves with the incoming gasoline charge, **giving an improper mixture.**

The reason why an explosion from a weak exhaust spring misses is, that when the throttle is closed, the piston cannot get much of a charge, and consequently it sucks the exhaust valve open and draws back some of the burned gases, which spoils the small charge in the cylinder, causing misfire.

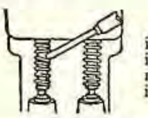


Fig. 75. **To test for a weak exhaust spring,** insert a screwdriver between the coils, thereby increasing the tension. If missing stops, then remove the spring and stretch it about an inch, or put in a new one.

A stronger spring will sometimes close valves that have a tendency to leak.

Valve springs that are too stiff, however, are to be avoided, because they may close the valves with so much force as to break the stems at the key, or the heads from the stems, and it is a certainty that the seats will be pounded out of shape, even if the valves do manage to stand the constant hammering action. **An excessively stiff** spring consumes power which might be used to a better advantage, and there is also considerable **noise.**

[1] **If valve tappet or rocker arm has a depression worn in it,** as in Fig. 74, first grind or face off, otherwise clearance will not be correct; that is, it will be more than the gauge thickness.

A weak inlet valve-spring usually makes itself evident by the mixture back-firing into the carburetor. Springs too weak to hold the valves on the cams will also produce **clattering noises,** owing to belated seating of the valves.

To increase the tension of a weak valve-spring, stretch the spring slightly, by opening up the coils with a screwdriver (Fig. 75), or by securing one end coil of the spring in a vise and tying a cord to the other end, so as to get a grip. Then stretch it a little in the ordinary way.

The best plan is to install new valve-springs.

One of the most important features necessary to obtain increased power is good valve action. Valve-springs are cheap, and it pays to install a **new set** of valve-springs occasionally, even if the old ones do not seem to be worn. Lively springs close the valves promptly, and this is especially necessary if the engine is to be run at high speeds. If it is to be used for racing and the last ounce of power is desired, it may be advisable to use special valve-springs that are stronger than the regular type, but such springs are more prone to break valves and more noisy.

Double or auxiliary valve springs consist of a light spring within a heavy one, which increases spring pressure at the high peak valve opening, causing the valve closely to follow the valve actuating mechanism when closing, reducing the lag. It is used on several makes of cars.

On some engines the spring on intake valve may be lighter and have less tension than exhaust valve spring.

Replacement springs should be obtained only from the manufacturer of the car or engine, to assure their conforming to the quality and tension strength originally intended. Springs of improper design often cause serious troubles.

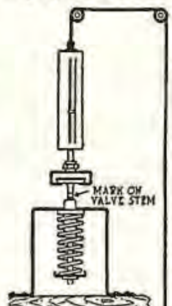


Fig. 76. When the engine is overhauled, **the old valve-springs can be** tested to see that they have not weakened, and whenever a new spring is put in, it can also be tested. The illustration shows a simple means of determining whether a spring is in good condition or not.

The apparatus consists of a bracket in which is mounted a valve-guide, valve, spring seat, and retaining key. Two marks are placed on the valve-stem, one indicating when the compression of the spring is zero, and the other when it has been compressed a certain amount, say ½". The number of pounds required to compress the spring ½" may **be ascertained by testing a new spring known to be of the proper tension: then compare the test of the good spring with the old one.** The pedal is depressed and the valve is raised until the lower mark on the valve-stem is on a level with the top of the valve-guide, at which time the pull as registered by the spring scales should be that of a good spring tested previously in the same manner.

VALVE RECONDITIONING AND CARBON REMOVING EQUIPMENT AND OPERATION

Carbon removing and valve-grinding are service jobs that are probably done more than any other service operation. In order to do the work efficiently, proper equipment and a system to follow is necessary.

Fig. 76B. **A valve-tester.**[1] To test, drop valve in seat without valve spring; place cup (C) over valve; pump air pressure with bulb (B). If valve leaks, hand on gauge (G) will fall back; if valve is tight hand will hold steady.

Seven Steps of Reconditioning Valves

The seven major steps in reconditioning valves, assuming that the compression test indicates leaky valves, are as follows:

1. Test compression.
2. Remove carbon.
3. Clean valve-guides.
4. Reface valve-seats.
5. Reface valve-faces.
6. Test valve in seat.
7. Test compression again.

Equipment For Reconditioning Valves

1. **Compression gauge** (Fig. 27A, p. 767) is necessary to first test for leaks. See also **air pump,** p. 779; **valve-tester,** Fig. 76B.
2. **Carbon-removing outfit** which will do the work in minimum time is a good investment, such as an electric drill with wire brushes as shown in Fig. 76A. See also page 763.
3. **Portable work bench,** such as Fig. 5, page 693 with vise, which can be moved to the job and on which tools are assorted and parts to be worked on separated.
4. **Hand tools and miscellaneous material:** Pliers; tappet wrenches (two long thin ones generally used); valve-lifter tool; valve grinder tool (see Fig. 44, page 771); thickness gauge; valve grinding compound (see page 772).
5. **Other tools and appliances** would include valve refacing machine, either a hand or electric motor type (see page 775); valve reseating set (see pages 775, 776); valve stem guide and valve tappet guide reamers (page 776A).

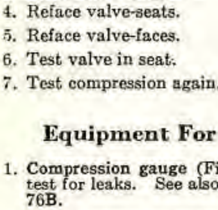


Fig. 76A. **A typical carbon-removing set.** The parts, from top down, are as follows: portable electric drill, wire brush for general carbon removal, wire brush for removing carbon and burnishing cylinder head, wire brush for removing from sides and bottom of port hole, wire brush for cleaning valve stem guides. (The outfit shown is made by Temco Electric Motor Co., Leipsic, Ohio.) See page 700 for list of other drill manufacturers.

Procedure For Reconditioning Valves

It is assumed that tests have determined that valves leak compression and that they need reconditioning.

1. **Place portable bench** with tools at the car.
2. **Put car overalls on car** (page 662); protect upholstering.
3. **Drain cooling system and take off hood.**
4. **Remove parts** that interfere with the work.
5. **Remove cylinder head and valves.**
6. **Remove carbon** (see Fig. 76A, also page 763).
7. **Inspect valve-head** to see if it should be ground or refaced.
8. **Inspect valve-stem in guide** to see if it should be reamed oversize and a new oversize valve fitted, otherwise clean.
9. **Inspect valve stem** to determine if it is bent.
10. **Inspect valve-seat.**
11. **Reface valve-head** (assuming this is decided upon).
12. **Reseat valve-seat** in cylinder block.
13. **Place valve in seat and grind or lap.**
14. **After grinding, clean valve and seats thoroughly and replace valves and test per Fig 76B.**
15. **Replace spring on valves.**
16. **Carefully adjust valve-clearance** (after engine is assembled run engine and readjust valve clearance when warm, then **check valve timing.** See page 1052 for clearances).
17. **Examine cylinder-head gasket:** best to put on a new one.
18. **Replace cylinder head,** drawing down the nuts in the order explained on page 733 (after engine has been assembled and run until warmed up tighten a second and a third time).
19. **Put water in cooling system** (new water hose if necessary).
20. **Remove spark plugs;** clean and adjust points from .025" to .031"; Replace spark plugs.
21. **Inspect ignition interrupter points;** clean and adjust; (see page 1052 for clearances).
22. **Put fresh high-grade oil in engine.**
23. **Start engine,** and adjust carburetor if necessary.
24. **Test compression** as outlined on page 766 to see if all cylinders are equal in pressure or nearly so.
25. **Remove** car overalls and remove all grease or stain.

[1] Black & Decker Mfg. Co., Towson, Md., are manufacturers; they also manufacture attachments for their make of electric drill for cleaning carbon from valve-stem and for cleaning valve-guide, etc.

LOCATING ENGINE KNOCKS[1]

Parts of an engine that are not functioning properly generally give warning by a peculiar sound or knock which usually comes at regular periods according to the speed of engine.

There are two causes of knocks: the mechanical condition of the engine and the **operating conditions.**

Knocks due to mechanical condition may originate from any of the following engine parts:

1. Pistons (piston rings, piston-pins)
2. Valve mechanism (valves, stems, valve-stem guides, valve springs, valve-lifters [push rods or tappets], valve-lifter guides, cams, camshaft bearings, timing gears or chains)
3. Connecting-rod
4. Crankshaft (main bearings, lower connecting-rod bearings, flywheel)

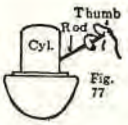
Knocks due to operating conditions are:

1. Overload knock
2. Carbon knock
3. Spark knock
4. Fuel knock
5. Detonation or pinging

Devices for Testing for Knocks

To test for knocks due to mechanical condition, testing devices can be used, such as:

1. Sounding rods, sonoscope or stethoscope
2. Spark plug short-circuiting device
3. Pressure-vacuum air pump
4. Manual feel test



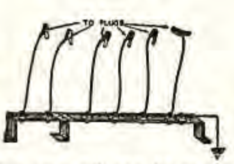


Fig. 77. **A sounding rod** (of iron or steel) can be made useful to locate the source of knocks. Place the thumb over the end of the bar and then place the ear close to the thumb. **The closer you get to the noise, the louder it will be.**

Fig. 78. Detecting noises in the engine by sound, with **a sonoscope**, on the same principle as that of the sounding rod. Made by American Elect. Co., Chicago, Ill.)

Fig. 78A (right). **A spark plug short-circuiting device.** On the modern six and eight-cylinder engine it is necessary to short-out more than one cylinder sometimes when testing. This home-made shorting device may be attached while engine is running. **Testing equipment** should also include a compressometer (page 767). An air pump (page 779) is also a good investment.

Remarks on Locating Engine Knocks

First determine that knock is in engine and not elsewhere by disengaging clutch when testing.

It is particularly important to learn at just what point in the engine the trouble exists, and what the cause is likely to be. With this information to start with, no unnecessary parts need be removed, and much time will be saved. An engine is always more or less marred by tearing down and this unnecessary expense should be avoided.

We have often seen good automobile mechanics stand around a knocking engine, and have heard each one name a different cause for the trouble. Taking an engine apart is a costly piece of work, and often much labor and expense could be saved **if the cause could be accurately located before the parts are disturbed;** in fact, the knock is not always in the engine itself, although it may sound as if this is the case. It may be found in the rear axle or elsewhere, and could perhaps be easily remedied **if the repairman would do a little reasoning and some testing** beforehand.

For example, a new car had a front-end knock that fooled many. Some recommended tightening bearings, others said it was a piston-pin knock, etc. A repairman who used his brain tried different tests, one being that of tightening the timing chain. This removed the knock, but the chain was too tight and made noise. If it was loosened the slightest amount, the knock would return. He used his brain a little more and figured out that if tightening the chain removed the noise and yet the chain did not need tightening, something in connection with it was causing the trouble. He found **a loose camshaft sprocket,** and on practically a new car. There are many such examples occurring daily, and the owner is paying the bill.

Another case that fooled several mechanics was found to be loose cylinder-head nuts. This will cause a knock and vibration, and in some cases a knock has been caused by the **engine being loose on the frame** or chassis.

Test for Minor Causes First

One should always try to reason out the cause of a trouble first and avoid the sad experience of doing the wrong repair job.

The first step in determining the cause of abnormal noises is to **tune the engine** so that it fires properly on all cylinders. The engine should be **warm** when testing.

Minor causes: Before making tests, first determine if the cause of the knock is not one of several **minor causes,** which are easy to locate:

1. See if the cylinder is free from carbon.
2. Find out if the knock is due to running with the spark lever too far advanced; check ignition timing, also valve-stem clearance and valve timing.
3. See if fuel knock, due to a lean mixture is caused by carburetor not being properly adjusted, or fitted with correct size jets.
4. Ascertain whether the valve tappets are badly worn.

After determining that the minor causes enumerated above are not producing the knocks, then it will be necessary **to test from the outside of the engine with a sounding bar, also by short-circuiting the spark plugs** so that the **location** of the knock will be determined or its **approximate position** learned.

How Short-Circuiting Spark Plugs Determine Location of Knocks

Testing for knocks by short-circuiting the spark plugs: With the exception of a carbon knock, the particular cylinder in which engine knocks occur, such as loose pistons, connecting-rod bearings, main bearings and piston pins, can be located by short-circuiting each spark plug with a screwdriver as described on page 238 (see also Fig. 78A above).

For example, on the Ford three-bearing engine: If, when No. 1 spark plug is shorted, the knock is no longer heard, the knock is either in the front main bearing or in the piston and connecting-rod assembly of No. 1 cylinder, the sound of the knock determining whether it is in the bearing or in the assembly. This also applies to No. 4 cylinder, the knock being either in the piston and connecting-rod assembly of No. 4 cylinder or in No. 3 main bearing.

If shorting No. 2 spark plug eliminates the knock, the trouble lies in the piston and connecting-rod assembly of No. 2 cylinder. If, however, the knock can still be heard but not as plainly, the trouble is probably due to a worn center main bearing. The same applies to No. 3 cylinder.

[1] See also Index for locating discussion of knocks elsewhere in this book.

Miscellaneous Pointers on Testing for Engine Knocks

First examine the valves: Noises from worn valve stems, push rods, or guides are usually caused by

too much space between the end of the valves and the push rods or tappets (as at S, ill. at left), or worn guides (ill. at right). These conditions, too, are usually the **cause of most clicking noises.** They can easily be detected as explained on pages 776B and 776C.

In some instances, slight knocks, or clicking noises have been due to strong spring tension in the oil pump check valve and in some carburetor auxiliary air-valve springs, there is a clicking noise.

Piston-pin knocks can be tested as follows: While the engine is running slow or idling and with advanced spark, short-circuit the spark plugs, one cylinder at a time, to cause it to miss. While this is being done, if the piston pin is loose there will be a sharp, metallic double knock each time piston reverses its movement. May be very sharp when engine is laboring. If all are loose the noise would be a kind of rattling metallic sound. The surest method is to remove the piston and connecting rod, and to test on the bench by "feeling" for the looseness.

To test for loose pistons: Remove the spark plugs and put ⅛ pint of heavy oil in each cylinder; crank by hand slowly until the oil works to the piston rings. Replace the spark plugs and start the engine; see if the same noise occurs. If it does not, the heavy oil has cushioned the piston from the cylinder and has stopped the knock temporarily. The oil will soon get hot and run from the rings and piston, and the knock will occur again. See also page 779.

To test for loose fly wheel: Allow the engine to run idle at about 500 r.p.m.; then throw off the switch and wait till it slows down to about 75 or 100 r.p.m., after which throw the switch on with spark slightly advanced. Repeat this a few times, and if the fly wheel is loose there will be one distinct knock each time the switch is thrown on.

Another method of testing for a fly-wheel knock is to rock it (remember that the flywheel may be entirely all right, but some other part attached to it may be loose). The nuts on cap-screws holding flywheel to flange may be loose. When replacing a flywheel always replace it in same position it was before removing; see that flywheel flange is not burred or nicked and bolt securely.

Noises from the camshaft and timing gears or timing chains can easily be detected with the sounding rod.

A connecting-rod lower bearing knock can be determined by removing the bottom of the crank case, placing the finger on one edge of the bearing while someone rocks the flywheel or starting crank gradually back and forth (switch off). Looseness can be felt.

Main bearings can be tested in the same manner. A main-bearing knock can also be determined when running the car, by suddenly opening the throttle or when pulling a stiff grade. If the main bearings are loose, a distinct knock can be heard, usually a dull heavy knock or thud, having the sound of a block of wood striking the ground, which will occur once to every explosion, but may be heavier at the explosion of any one cylinder. The knocks may occur very close together, so close that when first heard it will sound like one pound. Excessive **end-play of bearings** will cause a sharp noise or rap occurring at irregular intervals. In very bad cases this pound can be felt by the driver when touching clutch pedal. (See page 777 for an example of testing engine-bearing knocks by short-circuiting.)

How to Locate a Knock by the Sound

To locate the cause, first see that engine is firing properly on all cylinders, then drive the car until the engine becomes warm or reaches its average temperature; second, select a run of about half a mile, running into a grade of about 8 to 12 per cent, of whatever length may be had.

Drive the car at from 10 to 15 miles per hour on the level road, and maintain this speed up the grade if possible. At this speed engine should run quietly.

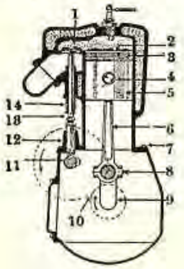


Fig. 79: **Sound indications of some of the common engine knocks are as follows:**

1. **Carbon** (also 2): Metallic sound when laboring, accelerating or overheated; will not diminish noticeably when spark is retarded.
3. **Piston rings:** May be due to interference with cylinder head gasket, variations in cylinder bore diameter, ridge or shoulder in cylinder bore, pounding in worn grooves; broken rings producing a light tapping sound, a click or a sharp rattle at idling and acceleration; cannot be entirely eliminated by short-circuiting. Rings fitted too tight in grooves make a snapping noise, sometimes noticeable when new pistons and rings are fitted.
4. **Loose piston pin:** Sharp metallic double knock at idling and with advanced spark; when shorted out may change tone and become more intense; less audible with retarded spark; loudest, usually, when idling. **Connecting-rod upper end** striking piston-pin boss may be mistaken for loud tappet noise; determine by removing oil pan and checking clearance on each side; distances between rod and bosses should be equal on each side.
5. **Loose piston:** Usually causes a piston slap, as explained on page 779, and is a hollow tinkling bell-like sound. If driven 10 to 15 m.p.h., then accelerated, may give a clicking sound; more pronounced on acceleration and increasing in intensity as load is applied and the throttle opened. Piston slap may also occur at idling speed when engine is not under load, but will always show up under load. When closing throttle for slowing down or coasting noise will cease (see also page 779).
   If an aluminum-alloy piston with split skirt is installed with split facing the explosion thrust side (Fig. 11C, page 814), it would probably slap (see page 811 on how to install).
6. **Connecting-rod bent or twisted:** Light knock at idling increasing when accelerating; cannot be entirely eliminated, but will be diminished by short-circuiting spark plugs.
7. **Loose cylinder nut:** Intermittent knock and vibration.
8. **Loose connecting-rod lower bearing:** Light pound, sometimes a clatter or series of short raps becoming louder with increasing speed; best located by shorting out, which will reduce the intensity of noise; may also occur when coasting.
9. **Loose crankshaft main bearing:** Dull pound or thud; usually noticeable when quickly accelerated at intervals; may be slightly diminished by retarding spark; loudest under a load or pull (see short-circuiting spark plug example for bearing test, page 777).
10. **Loose timing gears:** Sharp clatter or knock; varies with different engines; loudest at idling particularly when engine does not idle smoothly; may disappear at low speeds, then appear at about 25 to 30 m.p.h. as a growl similar to noise of gears that are too tight; test by causing engine to lope by partly closing carburetor choker. **Loose timing chain** is usually a rumble at idling and accelerating (when striking case may be a dull scraping noise); noises from either gears or chain can be located by sounding rod; cannot be shorted out.
11. **Worn cam, valve-lifter roller or pin:** Light tapping at idling; flat spot on cam of camshaft or tappet rollers causes an intermittent noise at low speeds.
12. **Worn valve-lifter guide:** Light tapping at idling.
13. **Worn valve-stem end and valve-lifter (also called tappet or push-rod):** Causes too great a clearance; clicking noise; test with feeler gauge and readjust.
14. **Valve-spring cocked:** Light knock at idling if face of tappet is cupped

Knocks Due to Operating Conditions

An overload knock: When placing engine under extreme loads a pounding will be heard. Shift transmission to lower gears and noise should cease.

A carbon knock: When an excessive carbon deposit accumulates in the combustion chamber and on the piston heads, valve, etc. this usually causes a knock. Carbon is a **non-conductor of heat;** therefore the piston head (hottest part of engine) is unable effectively to conduct the heat to the cylinder walls and into the water, with the result that **the increased temperature** causes the carbon to become very hot and the gas is ignited, at times causing **pre-ignition.** Considerable carbon also increases the compression.

A carbon knock develops **after** engine becomes very warm and usually occurs when laboring or accelerating. It becomes louder as the throttle is opened or more gas is admitted into cylinder. The noise is a metallic ringing sound, and if due entirely to carbon will not diminish noticeably when spark is retarded.

A **visual inspection** of the combustion chambers is the surest method of determining the presence of carbon.

Carbon **deposit** is a residue left by incomplete burning of the fuel and lubricating oil. The deposit tends to accumulate whenever more oil passes the piston rings than can be burned up by the fuel charge. If **piston rings** are worn, or loose in grooves (see bottom of page 832), oil will pass to combustion chamber. If an excess of oil is supplied to the cylinder walls the rings cannot prevent oil passing even though they fit properly.

A spark knock is caused by the time of spark being too far **advanced** owing to incorrect position of spark lever, incorrect ignition timing or trouble in ignition governor. It is a sharp metallic sound usually evident when engine is laboring.

A gas or fuel knock may be due to too **lean a mixture** or to unsuitable fuel. It may be confused with a spark knock. Before deciding be sure that spark is not advanced too far. The knock is increased by rapid acceleration and usually can be diminished by using a richer mixture.

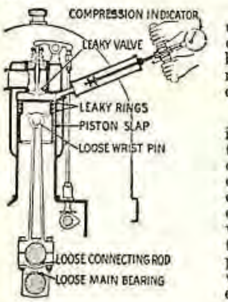
Detonation, also termed **pinging,** is usually encountered on high compression engines and is a metallic sound which becomes loudest when the engine is under load, overheated, or accelerated rapidly. See definition on page 1075. See also pages 806, 1079A, 779, Addenda 44–45.

A brand of gasoline known as **ethyl gas,** it is claimed, will eliminate pinging and sometimes, resetting spark-plug gap will assist in eliminating it.

A compression knock may result from any cause which decreases the space between the head of the piston and combustion chamber. This knock, also a spark, detonation, carbon and fuel knock are similar in sound, and it is best to check ignition, spark-plug gap and carbon deposit before deciding.

Detecting Location of Engine Knocks with a Pressure-Vacuum Air Pump

A device known as "The Hammett Motor Tester," illustrated below will **locate** mechanical knocks and leaks when **intelligently** used.



Principle and operation: A vacuum and compression pump with compression gauge attached is used by hand to alternately lower and raise the air pressure in engine cylinder.

Tests are made when engine is idle but warm. The tester is attached at spark plug opening and one cylinder tested at a time. The crank is turned so the piston of cylinder tested is at top dead center of compression stroke with all valves closed. A normal engine in this position will show strong compression and vacuum and no noise when tester is operated. If defects exist they are evident as follows.

Procedure of Tests

Compression: To determine compression of cylinders push handle down and turn to right thus locking plunger. Turn crank two complete revolutions. The gauge will indicate the pounds compression.

Piston rings: With piston at top of compression stroke, remove breather cap; push handle down slowly. If piston rings leak, compression can be heard blowing by when listening through the breather (tube or hose inserted in breather will magnify sound).

If rings **do not fit cylinder walls,** compression will be poor, regardless of position of the piston.

If **rings leak in grooves** (assuming rings do not leak at cylinder walls), compression will be good because rings are seated on bottom of ring groove. Crank slowly until piston starts down, which moves rings to top of groove. If, on pushing tester handle down, compression forces ring away from top of groove and air escapes behind ring and past piston into crankcase, then compression is poor and very little resistance will be offered plunger.

Valves: With piston at top of compression stroke, push plunger handle down. **If inlet valve leaks,** compression will be heard escaping through intake manifold into carburetor (or through intake manifold to cylinder that is on suction stroke, then out through spark plug opening). **If exhaust valve leaks,** compression will escape through exhaust manifold and muffler (or through spark plug hole in cylinder that is on exhaust stroke).

Pistons: Crank engine 30° past top dead center of compression stroke so that connecting rod will be at an angle; work tester handle up and down with a short stroke. If piston is loose, a clattering noise will be heard as piston slaps from one side of cylinder wall to the other.

Piston pins: With piston at top of compression stroke, work tester handle up and down with a short quick stroke. If you hear a knock and cannot feel a pound on crankshaft, by placing hand on starting crank when engaged; piston pin is loose (as piston slap never occurs when piston is at top d. c.)

Connecting-rods: Use same test as for piston pin; if connecting-rod is loose, pounding can be felt on shaft as if tapped with a hammer.

Main bearings: With piston in same position as in testing piston pin and connecting-rods, push tester handle to bottom of stroke, then lift with a quick jerk; crankshaft loose in bearings will be felt to rise and drop (assistant under car with oil pan removed can feel the rise and fall and see oil film working in and out of bearing).

Piston Slap

This knock is caused by loose-fitting pistons or by connecting-rods being bent or out of alignment, resulting in a tendency for the piston to strike the cylinder walls at an angle, as explained in the illustrations (Fig. 81, page 780).

The looser the piston, the greater will be the slap. If the piston fits properly, the slap is negligible. The slap may be due to **worn cylinders,** to the connecting-rod being out of alignment, or to worn pistons. **Aluminum alloy pistons** (or slightly loose cast iron pistons) may knock only when the engine is **cold,** as the pistons are contracted and are looser than when hot.

Piston slap is a very common trouble with aluminum pistons with solid skirts, which, **when cold,** contract and leave a space between the cylinder wall and the piston. After the engine is warmed up, the pistons expand and the noise ceases. Aluminum expands approximately twice as much as cast iron. The **constant-clearance type of aluminum piston with split skirts** (see pages 807–809) are not so susceptible to piston slap.

Pistons with correct clearance and proper alignment of the piston and connecting-rod is the remedy for piston slap. Alignment of the piston and the connecting-rod is an **important factor** (see page 803). It will thus be apparent that this kind of knock can occur even though the piston rings fit tightly.

Bear in mind that a piston may slap when the engine is first started, but after it has warmed up and expanded, the knock may cease, if due to a clearance only slightly excessive.

Knocks that sound like piston slaps are frequently caused by **connecting-rods being slightly bent or out of alignment,** which sometimes happens when fitting the pistons to cylinders.

To determine which piston is causing the slap, there are several methods. One is to open the compression cock to release the compression and then short out the spark plug of the cylinder being tested. If the knock is due to a loose piston it will diminish and in some instances will be entirely eliminated. Another method is to test with heavy oil (see page 778; see also "5 loose piston" under sound indications on page 778).

Always test for piston slap when engine is thoroughly warm, as a cold engine may show noises that disappear when warm.

Compression and Explosion Thrust of Piston

There may be two or more distinctive piston slaps during the cycle, due to what is termed **compression thrust** and **explosion thrust** of piston (see below; also page 814).

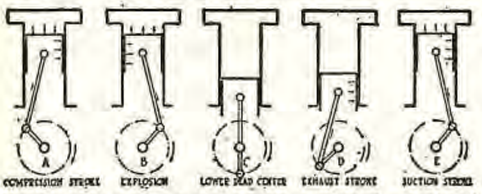


Fig. 81. When the piston is on the compression stroke (A), assuming we are in front of engine, the **piston thrust** and the contact of it is with the right side of the cylinder (see arrow points), due to the angle of connecting-rod and the compression pressure on the piston.

As the crank pin swings by dead center, the inclination of the connecting-rod is changed to the opposite side, thus forcing the **piston thrust** to the other side. Under the full **explosion pressure** (B) the piston will strike a very heavy blow when it makes the change.

The piston remains in contact with this cylinder wall throughout the stroke, and when lower dead center (C) is reached, the pressure on it is entirely relieved, so that it is quite likely that the piston is then more or less able to **float** between both walls.

On the **exhaust stroke** (D) the piston is thrown gently to the right side of the cylinder, owing to the downward pressure of the inertia, as well as to the slight exhaust pressure. It is very doubtful that this ever causes an audible slap.

The piston remains in contact with this wall throughout the **suction stroke** (E); then the downward pulling force of the connecting-rod is resisted by the suction on the piston as well as the inertia.

At very high speeds inertia may change some of the details of this explanation, but these can hardly be of interest or importance. (See also page 814 on this subject.)

One manufacturer states that piston slap is not always due to loose fitting pistons, providing the cylinder walls are straight and true and piston pins are parallel with the crankshaft. They further state that by careful examination the trouble can usually be located in any one, or a combination of the following: bent connecting-rod, wrist-pin hole not true, cylinders out of line or not true with crankshaft. **The theory** is that piston slaps are sometimes caused by the connecting-rod upper ends striking the piston **boss.**

To observe if such a condition exists, as mentioned above, remove lower part of engine crankcase and while someone cranks engine slowly with a light at the other end of cylinder, **observe if the connecting-rod shifts sidewise or twists as it travels from top to bottom of its stroke.** If so, remove piston and rod and inspect for bushing clearance, straight piston pin bore, bent or twisted connecting-rod.

Pre-Ignition: Cause of Knocks

Sometimes it happens that the mixture is ignited before the ignition spark occurs. This is termed **pre-ignition** and may result from some of the **causes following:**

A deposit of carbon on the piston head and combustion chamber will, owing to intense heat after long runs, become red hot and will ignite the mixture before the proper time. This causes a "carbon knock," as discussed on page 779.

If the points of the spark plug are too thin and of poor material, they will get hot enough to glow in the same manner, and in such a case spark plugs with heavier points should be used.

Small points of metal, the result of rough castings or other causes, should be filed down, as they assist in collecting carbon.

If the water circulation stops, or if the air cooling is not effective, carbon, or even the overheated piston head will get hot enough to ignite the charge, in which case the engine will continue to run after the ignition has been cut off. **The remedy** for this, of course, is to make sure that the engine is properly cooled, otherwise a "seized piston" will result. See Index.

Eliminating Compression Knock by Adding a Gasket

Compression may be reduced by placing a gasket (Fig. 82) between the cylinders and the crank case.

This is sometimes desirable when the car is equipped with a heavy closed body. In such cases a better job may be done by making the thick gasket of cast iron. It is made in a similar manner, but must be planed or milled to a uniform thickness and with a smooth finish. Otherwise the cylinders will be thrown out of alignment or the joints will not be tight. **Another method would be to use special pistons to decrease compression.**

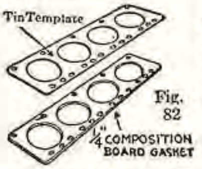


Fig. 82: **Procedure of fitting a gasket:** (1) Remove cylinders. (2) Place cylinders on a bench, and clean both cylinder flange and engine base thoroughly. (3) From a sheet of tin, make a **template** which is an exact reproduction of the base of cylinders, except that all openings, such as piston and bolt holes, are about 1/8" larger than those in cylinders. The template is used as a pattern for marking out and forming the cylinder-raising gasket. (4) Procure a sheet of red composition board desired thickness. (5) Using template as a pattern, scribe out cylinder and the bolt holes and the outside form to the red composition board. (6) Using a gasket-cutting tool and a drill press, carefully cut out piston holes. Make these 1/8" larger than cylinder bore. (7) Drill bolt holes slightly larger than the diameter of bolts. (8) With a band saw, or key-hole saw, cut composition board to outside shape of pattern. (9) Remove all burred edges with a file. (10) Place composition board on engine base, and bolt cylinders in place. Shellac should be used sparingly to prevent leaks.

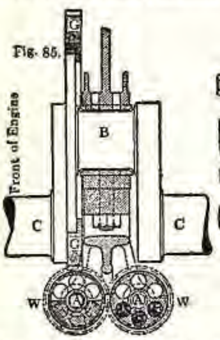
As a result of this the cylinders have been raised, giving a larger compression space and less compression. This may result in that the compression knock will disappear and the engine pull better on low speeds and it may not; in other words it is an experiment. **To increase compression pressure:** See page 766.

Note: It will be necessary to readjust valve clearance and retime after the cylinders have been bolted down securely.

Unless the compression is the same in all cylinders, the engine will not be in good balance and loss of power will result. The power lost when one cylinder does not fire is greater than the mere elimination of one power stroke, and this is largely the result of a loss of balance.

LANCHESTER VIBRATION BALANCER AND DAMPER. HARMONIC BALANCER

The Lanchester vibration balancer (Fig. 85), is designed to overcome **vertical vibration** in a four-cylinder engine. (See also page 805.) It consists of two small balancing flywheels (W) turning in opposite directions, with their axes (A) crosswise of engine and below the center crankshaft bearing (B). They are driven by a helical gear (G) from crankshaft (C). The two flywheels (W) are out of balance, and by properly unbalancing and timing them, they produce a vertical vibration opposed to and neutralizing the vertical vibration in a four-cylinder engine.



The Lanchester vibration damper (Fig. 86) is a device developed to overcome **torsional vibration** (see page 805). This consists of a small flywheel (W) at the front of the engine, which runs loosely on the crankshaft (C). A friction clutch (D), having a slipping torque in the neighborhood of 150 inch-pounds, tends to make this flywheel rotate with the crankshaft.

When high pressure is exerted on the piston, a rapid acceleration is applied to the crankshaft which would cause torsional vibration; to prevent this the flywheel (W) slips, thus preventing a winding-up or torsional vibration of the crankshaft.

When the speed of rotation of the crankshaft and main flywheel is steady, the clutch (D) grips the flywheel (W), and both flywheel and crankshaft revolve together.

When the speed of rotation of the crankshaft is reduced, such as by the suction stroke, there will be a tendency for the crankshaft to lag behind the main flywheel and thus cause torsional vibration. In this instance the flywheel (W) again slips, and the friction disks in clutch (D) will exert a force on the crankshaft and assist in bringing it up to speed. (See also pages 805, 806, for torsional vibration.) (*Automobile Digest.*)

The harmonic balancer neutralizes **torsional vibration** of crankshaft. Located between number one and two crank pins; a light steel bar, pivoted to shaft at its center and tensioned by stiff springs at both ends. Has a frequency of vibration same as shaft itself. When there is movement of shaft, the balancer picks it up and vibrates in an opposite direction, applying the force through its springs, thus holding the shaft steady.

ENGINE BEARINGS: Main Bearing Adjustments; Fitting Bearings; Scraping, Burning-In, Boring, Reaming, Lapping, Etc.; Crankshaft Alignment; Cam shaft Adjustments; Connecting Rod and Piston-Pin Bearings and Alignment; Relation of Vibration to Balance; Oil Test for Engine Bearings: Ricardo Cylinder Head.

ENGINE BEARINGS[1]

There are three different kinds of bearings: ball bearings, roller bearings and plain bearings. The last-mentioned is the type in general use. The ball bearings have been used to a limited extent on the racing type of engines, and some truck engines. The roller bearing is seldom used except on V-type motorcycle engines.

Ball bearings are sometimes used for main crankshaft bearings, but very seldom. To insure success, they should be large. It must be remembered that the surface contact of a ball with its race is practically a mathematical point. For this reason they are not found to be successful for connecting-rod lower-end bearings, as the impact is too great for such a small surface.

Where there is a whip, even of small degree, ordinary ball bearings should never be used unless they are of very great size. In a short, stiff shaft with a center bearing, ordinary sizes and types are satisfactory, but otherwise double-row bearings of the self-aligning order are used.

Where a crankshaft is fitted with ball bearings, the crankshaft must either be a two-bearing crankshaft, as, for instance, the White ¾-ton truck engine, which is fitted with a crankshaft of very large diameter, so that the bearings can be fitted at each end of the shaft, or, if more than two bearings are used, then the crankshaft must be of the built-up-type, or the center bearing-pin or journal must be large enough to carry a bearing that can be passed over the cranks when assembling bearings to shaft.

Roller bearings are seldom used. These have, of course, a very much greater contact area than ball bearings, and have been used in the connecting-rod lower end, but not as a general practice.

Plain Bearings and Bushings Defined

A plain bearing refers to the split type of bearing in two parts, such as is used on the crankshaft main bearings and the connecting-rod bearing lower end. See Figs. 2 and 2A.

A bushing is usually a tube made of high-grade bronze that is not split, such as is used in the upper end of connecting rods around the piston pins, camshafts, water pumps, etc. See Fig. 3. They may be plain bronze or babbitt lined. Bushings are also of die cast babbitt.

Classification and Location of Engine Bearings

The most important bearings in an engine may be classed in four divisions:

1. Crankshaft main bearings.
2. Lower connecting-rod bearings.
3. Upper connecting-rod bearings (piston-pin bearings).
4. Camshaft bearings (generally bushings).

The bearings that require the most attention on an engine are the crankshaft main bearings. (Figs. 1 and 1A), the lower connecting-rod bearings, and the piston-pin bushings (Fig. 1B).

The bearing which usually first shows sign of wear is the crankpin bearing in connecting-rod (G, Fig. 1B), the rod-half showing considerably more wear than the cap-half.

The bushing in the upper end of connecting-rod (B, Fig. 1B) is next in showing sign of wear.

The crankshaft main bearing (Fig. 1) **is next, with the cap-half** (see lower illustrations 1 to 7 in Fig 1A) **showing more wear** than the upper-half (see upper illustrations 1 to 7 in Fig. 1A) in the engine block or crankcase.

The main thrust bearing (F, Fig. 1A), **usually requires replacement before the other main bearings** owing to additional wear on the end faces.

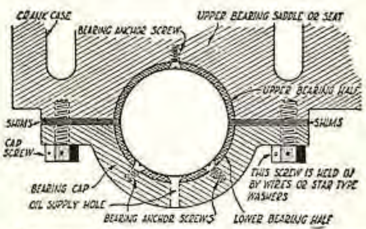


Fig. 1. **Crankshaft main bearing.** The cap screws, usually termed crankshaft bearing cap screw, stud or bolt, are always locked with cotter pins, locking wires or star washers. The illustration shows cap screws, but studs with nuts are often used.

The upper part of the bearing seat or saddle, is a semi-circular depression cast in the crank case, into which is fitted an **upper bearing** half.

The lower part of the bearing, which bears the weight of the crankshaft and the thrust of the impact of explosions, is in the form of a cap, termed a lower **main bearing cap,** which is fitted with a lower half main bearing. This cap is held securely around the crankshaft bearing by being bolted to the upper half of the bearing by cap screws, studs or bolts. It is made of steel, brass, or bronze and where aluminum case is used, the cap is usually aluminum, and is often supported with a steel plate.

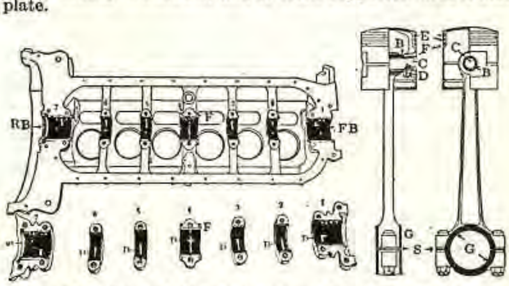


Fig. 1A. **Crankshaft main bearings** showing upper halves in crankcase which is turned upside down (crankshaft removed). Lower bearing halves are shown in the **bearing caps** below.

RB is rear main bearing; **FB** is front main bearing. Some bearings are **flanged** and some are not. If a bearing is to withstand thrust, it must be flanged and the faces of flanges are sometimes babbitted; for example, the **end thrust of crankshaft** in this particular engine is carried against flanges (**F**) on center main bearing. This **thrust is from flywheel end of engine** and is due principally to pressure from **clutch spring.** The bearing at flywheel end is usually longer and in some instances greater in diameter.

Fig. 1B. The **connecting-rod upper bearing** (piston pin bushing) is shown at (**B**). The **connecting-rod lower bearing** which is made in halves is shown at (**G**).

Names of other parts are: B, bushings; **C,** piston pin; **D,** piston pin lock screw; **E,** piston rings; **F,** oil regulating ring; **S,** shims.

Kinds of Plain Bearings

The upper bearing seat and lower bearing cap are lined with soft metal, such as babbitt or white metal.

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[1] See footnote page 783 for list of bearing manufacturers. See also pages 802, 944, for additional bearing information pertaining to trucks and tractors.

There are two kinds of bearings: the solid or integral bearing which is not removable, and the removable bearing. Both are generally in two halves, termed split bearings.

The solid integral or cast-in babbitt bearings are those where babbitt metal in a molten state, is poured, or run, into the upper bearing and the lower bearing cap, and thus they are lined with a stationary babbitt lining which cannot be readily removed.

When bearings which are lined with babbitt metal become worn, the bearing cap can be drawn up by dressing down, or if shims are used, they can be removed and the cap can be drawn up as the wear continues. If bearings are too badly worn, new babbitt linings are installed or poured into the upper bearing and lower cap.

The babbitt metal bearings used on the Ford engine, for example, are of the **integral or cast-in** solid type. In this case, the old babbitt is removed and the surface on which the babbitt is to be poured is tinned. The molten babbitt metal is run in around a mandrel smaller than the shaft. A true bore slightly less than the shaft is then made with a boring tool and the bearing is then reamed with a clearance for an oil film, after which the necessary oil channels are cut in the surface of the bearing.

Removable bearings are either **die-cast** bearings made of babbitt, or **bronze-backed babbitt-lined bearings.**

The babbitt may be inserted by one of the following methods: (1) poured in by gravity, (2) poured in under pressure, (3) the bearing may be rapidly revolved while the babbitt is poured in, and the centrifugal force causes adhesion to the bearings termed a "spun bearing." The last method is a manufacturer's process.

All bearings and bushings are made from either bronze or babbitt, or a combination of the two metals.

Formerly, phosphor-bronze was regarded as the best, but in modern practice, where large bearing surfaces can be used, babbitt is usually preferred.

In the case of small bearings which must sustain a heavy shock, such as a small bearing at the big, or lower ends of the connecting rods, babbitt is scarcely hard enough to resist the spreading action of the impact. Phosphor-bronze, or a composition metal, is therefore necessary if small bearings are used here; but where sufficient surface can be obtained to insure against this tendency, babbitt—owing to its antifrictional properties—is generally considered preferable. Since it is composed largely of tin, the result of a failure in lubrication from any cause is merely to **melt it out** without harming the shaft, which would probably occur if a tough metal like phosphor-bronze were used.

The secret of a successful babbitt bearing, or indeed of a bearing of any kind, is a true and highly polished surface on the journal. The babbitt bearing can then be fitted comparatively tightly, and will rapidly accommodate its surface to that of the steel, and long life will be insured if the lubrication is correct.

The essential requirements to be considered in a bearing are that it should have anti-friction properties, and should withstand the heavy impact or pressure against it during the hard pulls and high-compression impulses and at high speeds, without heating; it should be hard enough not to give, crack, or break under severe shocks and blows, and must be of such a construction as to be easily renewed when worn.

There are two kinds of bearing metals, (1) those which contain a greater percentage of copper and a small amount of softer metals, which are known as hard metals, such as brass or **bronze:** (2) those which contain a large proportion of tin and a small percentage of copper, known as soft metals, as **babbitt** metal, anti-friction metal, and white metal.

Popular metal specifications are 83 per cent copper, 3 per cent tin, 7 per cent lead, and 7 per cent zinc for the **bronze;** and 85 per cent tin, 7½ per cent copper, 7½ per cent antimony, with a maximum of 1 per cent lead for the **babbitt.**

The soft metal (babbitt) is generally used in the replaceable bearing, so that the soft-metal lining will wear rather than the crankshaft. The soft-metal bearing does not have sufficient strength, alone, to sustain the weight and impact of the rotating parts; consequently it is used as a liner in a bronze-back bearing. This forms a support to the babbitt, or it is cast in the bearing seats that have been tinned.

Fig. 2 (left). **A die-cast bearing** consisting entirely of babbitt metal cast in a die under pressure. Not machined.

This illustration shows a lower main bearing half. Note that the oil groove does not extend to sides of bearing: therefore it would likely be installed on an engine having pressure lubrication.

Fig. 2A (right). **A bronze-back babbitt-lined bearing** consisting of a bronze backing lined with babbitt. It is machined. The bearing shown here is a full-half bearing used without shims for pressure feed lubrication and the chamfered slots shown serve as oil pockets, distributing the oil over the entire length of bearing, and in many cases oil grooves or leads extend to these pockets at the split edge.

The fact that these slots or oil reservoirs retain the oil within the bearing would indicate that it was designed for pressure lubrication. If these serrations were connected with oil grooves which extended to side of bearing, then it would likely be for splash-feed lubrication.

Oil grooves for pressure-feed lubricated bearings are usually confined to the bearing and should not run out to the side of bearing. Purpose being to retain oil in bearing. The oil is fed by pressure through one oil tube or duct from oil pump and thus a film of oil is maintained in bearing around shaft when operating so that the shaft actually rides on a film of oil. There are a number of different designs of oil grooves, and in pressure-feed bearings the oil grooving has been cut down to a minimum—the less the better—simply a slight lead from the oil hole being all that is necessary to start the distribution of oil. Some pressure-feed connecting-rods have no oil grooves.

The oil groove shown in Fig. 2 is not of as good form as that shown in Fig. 2A, as too much bearing surface is cut away at parting line where it is needed most.

Oil grooves for splash-feed lubricated bearings usually run out to and are open at sides of bearing, and the leads should be such that oil will be spread over the entire surface of bearing, the purpose being to allow oil to circulate and cover the entire bearing surface. **The oil is fed** by splash to holes in bearings.

Die-cast bearings are split removable bearings and are often referred to as slip-in bearings. They were used before the bronze-back babbitt-lined bearings were introduced. They consist entirely of babbitt metal which is cast in a die under pressure. Some are slipped into place and others anchored with screws or dowel pins. Bearings may have flanges, usually to take thrust, but they may also have flanges for assisting in anchoring.

Bronze-back babbit-lined bearings* consist of a cast and machined bronze backing lined with babbitt metal. This is a **machine** product and naturally is more expensive than a die-cast bearing. The bronze backing is made in the usual way in the form of a bronze cylinder. This is machined on the outside and also in the bore. Then the babbitt metal is inserted as a lining into the bronze after the inside surface is thoroughly cleaned and tinned, by some process.

A patented process of spinning or centrifugal action, is explained as follows: The bronze shell is clamped to a revolving plate and babbitt is poured into the center of the bronze shell and is thrown out against the inner walls by centrifugal force. This gives a dense grain and the babbitt is stuck at all points. The babbitt is then machined on the inside surface, the oil groove, chamfers, etc., put in and the bearing split into the two halves.

The bronze-back babbitt-lined bearing it is said, gives longer life than a die-cast bearing, on account

* Steel-back babbit-lined bearings are quite popular, particularly those of the interchangeable type. See also p. 786.

of the rigidity obtained by the bronze backing and also the fact that the bronze back is a **heat conductor,** carrying heat away from the babbitt metal bearing surface which is an important factor, because excessive heat causes the crankshaft to expand and when excessive expansion occurs this produces wear.

Methods of fastening or anchoring bearings are either with dowel pins, lips or tongues, or screws. In some cases where shims are used, the shims themselves hold the bearing halves in place.

Fig. 3 (left). **A bronze bushing** machined and ready for installation. Bushings are used in such places as the upper-end of the connecting-rod, piston-pins, camshafts, the water pump, etc.

Fig. 3A (right). **A bronze cored bar**[1] which is carried in all sizes from which the repairman can machine any size bushing for which he may have a demand, not only for engine work, but also for chassis work, for such places as steering assembly, springs, etc.

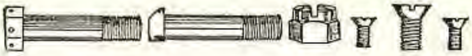


Fig. 3B. **Bearing accessories** are illustrated as follows: **Main bearing capscrew** with holes for locking wires. Studs and bolts are also used for supporting the main bearing cap. Fig. **3C. Connecting-rod bolt.** Fig. **3D. Nut** for connecting-rod bolt or main bearing stud. Fig. **3E. Bearing-anchor** screws.

REMARKS ON BEARING CLEARANCES

The clearance space between the bearing and crankshaft journal when the bearing cap is drawn tight is known as **diametrical clearance** (see p. 827 explaining). This space is divided on both sides of the journal, making a **radial clearance** all around the circumference of the journal, which space is **occupied by a film of oil.** While this condition exists, and if the metal of the bearing remains hard without giving under the constant pounding of the power impulse and vibration, this oil film remains unbroken and the bearing remains in perfect condition. But the softer metal will, in time, give way to the pounding and vibration, with the result that the **bearing will wear oval-shaped,** because the weight of the crankshaft and the thrust of the power impulses will all concentrate on the supporting half of the bearing, the lower half in main bearing and the upper half in connecting-rod bearing. Most of the wear and weight is on the lower part of the main bearing, called the lower bearing cap.

Whenever the crankshaft main bearing or connecting-rod bearing has become worn until the inner surface is **no longer** absolutely **round,** or when the clearance between bearing and shaft exceeds the natural thickness of the oil film, it makes itself known by a **knock** noticeable when engine is suddenly accelerated, or when engine is pulling hard.[7]

If the worn bearing continues to pound against the shaft, the **shaft itself will wear flat** on the pressure side, and in the case of the main bearings, the looseness will permit the shaft "to whip" or spring out of **alignment.**

Bearings should not be allowed to run loose for any length of time; when the knocking or pounding is first noticed, time should be taken to make a proper job of bearing fitting and replacement or adjustment, as the case may be. If the bearing is allowed to pound, it will wear the **crankshaft oval,** making it impossible to fit a new bearing perfectly without having crankshaft ground undersize.

Crankshaft Main Bearing and Lower Connecting-Rod Bearing Clearances[2,4]

Bearing clearances cannot be stated accurately[4] since they vary with the type of bearing construction, material used, design of engine, and its lubrication system, also climatic conditions. About .001″ for each inch of crankpin or journal[3] diameter is considered approximately correct.[6] Applies to **pressure-feed lubricated bearings.**[5] This space is occupied by an oil film.

Main bearings on engines with pressure-feed lubrication, on the average engine, are usually given a clearance just sufficient to permit enough oil to pass around it to form an oil film. There should not, however, be enough clearance to allow oil to pass quickly out of the bearing and thereby lower the oil pressure to such an extent that the other bearings are deprived of the proper oil film and circulation. Therefore it is important that all bearings be adjusted alike. Bearings too tight will block off the oil holes and prevent free circulation, resulting in a burned bearing.

A practical way to gauge the clearance on a pressure-lubricated engine is to adjust the bearing until the shaft is turned with considerable resistance. This determines that the bearing is fitted to the shaft and ready to be set for clearance. Now remove the bearing cap and install enough .0015″ or .002″ shims on each opposite side of bearing cap to secure the desired clearance. The shaft should then revolve with a degree of freeness so that there will be no

[1] **Special assortment of bearing bronze** consisting of sizes chosen to replace and service most all straight bushings in any make of automobile or truck can be obtained of Federal-Mogul Corp., Detroit, Mich.; Bunting Brass and Bronze Co., Toledo, Ohio.; Phosphor Bronze Smelting Co., Philadelphia, Pa., and others, and also from auto supply houses listed on page 686. Die-cast and bronze-back bearings for various makes of engines, also **babbitt metal** and **bearing accessories,** such as bearing bolts, anchor screws, etc., can be obtained of Federal-Mogul Corp., and some of the other bearing concerns listed below, as well as automotive supply jobbers.

It is false economy for a repairman to use inferior brands of bearings, bushings or bearing metal just because they might be a few cents less in cost. If he guarantees his work, which he should, he must use quality guaranteed parts which conform to the manufacturer's specifications.

[2] **Some of the engine bearing manufacturers are:** Bohn Aluminum & Brass Corp., Detroit, Mich. (engine bearings); Bunting Brass & Bronze Co., Toledo, Ohio (bushings); Federal-Mogul Corp., Detroit, Mich. (engine bearings and bushings, bronze-cored and solid bars, babbitt metal, bearing bolts, nuts, shims, screws, connecting-rod bolts and nuts); Johnson Bronze Co., New Castle, Pa. (bushings); Milwaukee Die-Cast Co., Milwaukee, Wis. (engine bearings); McQuay Norris Mfg. Co., St. Louis, Mo. (engine bearings, piston pins, pistons, piston rings). Bearings, accessories, etc., can also be obtained of automotive supply jobbers.

[3] Mention of the **journal or pin** relative to crankshaft work is intended to apply to that part of the crankshaft where the bearing halves fit, generally known as a **crankpin,** where the connecting-rods fit (acting as a crank), and **main bearing journal** where main bearings fit.

[4] **Obtain manufacturer's instructions for exact clearance.** This discussion of the subject is only approximate and to give the general idea.

[5] See page 782 under Figs. 2 and 2A for explanation of difference between "pressure" and "splash" lubrication.

[6] **See next page for recommendations. See footnote 6, page 786.**

[7] **Applies to main bearings.** Connecting rod bearings knock mostly when running downhill and engine is neither pulling car nor holding it back (clutch and transmission engaged).

binding. Be sure to bolt caps in place by drawing up all nuts or capscrew evenly, avoiding pinching or binding bearing on one side.

In case bearings are of the shimless type, it will be necessary to allow for clearance in scraping and fitting. This is simplified by align-reaming or align-boring, by setting up the cutters for the required amount of clearance. Some mechanics install shims for clearance.

Main-bearing diametrical clearances for the average-size crankshaft (2 3/4″ diam. or less) using *splash or gravity* lubrication systems should be approximately: .0005″ minimum, .0025″ maximum and .001″–.0015″ desirable. For *pressure* lubrication systems they should be: .001″ minimum, .0035″ maximum, .002″ desirable.

Connecting-rod diametrical clearances for the average-size crankpin (2 3/4″ diam. or less) using *splash or gravity* lubrication systems should be approximately: .0005″ minimum, .002″ maximum, .001″ desirable. For *pressure* lubrication systems they should be: .00075″ minimum, .0025″ maximum, .0015″ desirable.

For larger crankshafts (2 3/4″ or more in diam.) the maximum clearances mentioned should be favored, and in many cases should be exceeded by as much as 50 per cent. See footnote 6, page 786.

Whenever engine manufacturers' instructions can be obtained they should be followed rather than using any average clearances.

Bearings that are scraped or spotted in should be fitted to permit the shaft to be turned with a slight drag by means of a bar (about 24″ long; see Fig. 12, page 787) when bearings are set up tight. If bearings are aligned reamed or bored, there should be less drag.

Connecting-rod upper-end and piston-pin clearances are discussed on pages 795–797.

Crankshaft and Connecting Rod Bearing Side-Clearances

When installing new bearings, see that proper **end-clearance** or play is allowed on thrust bearing, also **side-clearance** on other bearings.

End-play of crankshaft is necessary to allow for expansion of thrust bearing. The one bearing designed to take the crankshaft end-thrust is termed **an end-thrust bearing.** It is **flanged,** and sometimes the flange face is babbitted. The size of the flange surface is determined by the clutch-spring pressure and other factors. **The thrust bearing on some engines** is the rear main bearing; on some it is the front main bearing; on some it is the center main bearing; and on some, bronze thrust plates are used.

The clearance between the end of thrust bearing and crankshaft, also the end-play or **side clearance** for **connecting rod bearings** for the average crankshaft using *splash or gravity* lubrication systems, should be approximately: .004″ minimum, .011″ maximum, and .006″–.008″ desirable. For *pressure* lubrication systems it should be approximately: .003″ minimum, .011″ maximum, and .005″–.006″ desirable.

Fig. 3F. A flanged type bearing, designed to take thrust.

Too much end-clearance causes a slight knock at idling speeds; **too little** will cause bearing to heat and burn out.

To determine end-clearance, move cranksha-t backward and forward with a screwdriver or bar and use a thickness gauge.

A preliminary test can be made by applying light pressure on clutch pedal when knock occurs; if knock ceases, test as above.

The only practical means for the removal of excessive end-play in a crankshaft (where thrust washers or shims, or screw type adjustments are not provided—see page 794) **is to replace the bearings.**

Most bearings are provided with a slight extra amount of stock on the bearing flanges to allow for fitting. When **removing stock** from the flange face for fitting, care should be taken to keep the faces square with the bearing surfaces.

A temporary repair can be made on old bearings by building up babbitt at ends with soldering iron and special solder made in proportions of pure block tin, 1 lb., to half-and-half solder, $\frac{3}{4}$lb. These are melted together and poured into sticks. Muriatic acid with zinc is used to clean the surface, and soldering is done with a well-tinned iron. After end of bearing has been built up, it is then scraped to fit.

Other main bearings (not thrust) should have at least 1/32″ and preferably 1/16″ or more clearance at each end. The clearance is governed by elongation of bearing when heated.

Undersize main and connecting-rod bearings should be used with reground crankshafts.

REMARKS ON BEARING WORK PROCEDURE, INSPECTION, ETC.

To test the condition of bearings: Usually where bearings are loose they make a knock. One method of testing for knocks is an **air test,** by testing with a vacuum pump (page 779) to ascertain where the knock is. Another test for the condition of pressure-lubricated bearings is the **oil test,** as explained on page 806. A simple test is with a jack which can be placed as shown in Fig. 24**B**, page 790**B**, to ascertain the condition, or if engine is on the bench looseness can be detected by the feel and examination. A visual inspection can be made by removing and examining the bearing caps.

Where main bearing work is done, it is best to remove engine to the bench; however, bearings can be taken up or adjusted by removing the oil pan and without removing engine from chassis. For instance one bearing cap at a time can be removed and examined and adjusted, but there is no means of knowing if the crankshaft is in proper alignment. **The connecting-rod bearings can be adjusted** and fitted while engine is on chassis; however, it is necessary to remove piston and rods in order to check their alignment on an aligning jig, as explained on page 803.

If the bearing caps are examined to find out the condition of bearing, the bearing should be examined for looseness in seats, cracks, burns, scores, if worn thin, and also if it is making correct circular contact with shaft. Also the **crankpin should be examined** to see if scored; if so, the score will damage bearing again after adjusting or fitting, and should be removed as explained on page 791.

When upper bearing half is not worn enough to spring shaft out of alignment when adjusting the lower bearing cap, it can be used; when the upper bearing half is worn enough to require considerable scraping, it is best to replace with a new bearing. Also, when the babbitt surface becomes glassy hard or crystallized, it is well to replace them, as they develop flaws and do not cushion the shock.

If the bearing is only slightly worn and there is sufficient babbitt metal, then the next procedure would be to see if the bearing is making good contact with shaft—at least an 80 or 90 per cent contact—and if so, to adjust by removing shims, or dressing cap. If not making good contact, which can **usually be determined** by observing that the contact is mostly at the bottom and not so much on the sides, then test by blueing and spotting, and then **scrape to proper fit.** There should be sufficient babbitt present when scraping old bearings, otherwise the thin layer left will cause heating and probably cracking.

A scored bearing is one whose surface has been slightly roughened but where the babbitt metal has not been burned and run. A bearing of this kind can be refitted. It is best to instal a new bearing, however.

If a bearing is badly worn, cracked, burned and run, scored, or worn thin, then the old bearing should be discarded and **a new one fitted,** if of the removable or interchangeable type, or by rebabbitting, if of the solid or cast-integral babbitted type.

On the **cast-integral type** the bearings are replaced by removing the old babbitt and casting in new.

On the **die-cast** and **bronze-back-babbitt-lined** bearings they are removed and new ones fitted.

Alignment, Circularity and Contact; Important When Fitting Bearings

Alignment: The bores of main bearings must be in perfect alignment; the connecting-rod crankpins must be parallel to the main bearing journals, and the piston pin and crankpin bearing must be parallel.

Circularity: Crankshaft crankpins and journals must be circular, smooth, and straight.

Contact: Bearing halves must be properly fitted to their caps and seats or saddles, and have correct contact area with them as well as with the crankshaft journals and crankpins.

Installing Bearing Halves in Their Seats (Contact)

The first operation, in renewing bearings, is to fit the backs snugly in the saddles or seats which retain them. Clean caps and crankcase bores; remove all burrs.

Bearings fitting tightly should be inserted in seats carefully with the aid of a hard-wood block tapped lightly with a hammer. Caution however must be taken that sides of seats or sharp corners do not dig into the backs or flanges of a bearing, causing it to be distorted (see also Fig. 69, page 802).

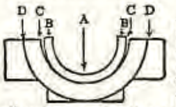


Fig. 3G. End view of bearing-seat with bearing-half (A) not making full contact at (C). Note the space at (C), and that (B) projects slightly above (D). When inserting bearing-half (A), it will usually project slightly and should be faced off, allowing approximately .001″ to .002″ projection above the edge of (D). When the other bearing-half is bolted rigidly in place, sufficient pressure will be exerted at (B) to force bearing to make full contact with seat at (C) and flush at (D). When shims are used, they will intervene between points (BB) of both bearing-halves.

When old bearings of the removable type are worn and are loose in seat and do not fit properly, the back of bearing-half can sometimes be tinned with solder and filed to the desired seat.

Fitting Seated Bearing to the Crankshaft

After installing bearing halves in their seats they are fitted to crankshaft journals. This can be done by spotting-in and scraping, by burning-in, by align-reaming or align-boring, etc., as discussed farther on.

Remarks on Alignment of Crankshaft Main Bearings

Main bearings are often align-reamed, or align-bored to bring their bore into perfect alignment with each other, as explained on page 786.

When doing this work, the important point to bear in mind is that **the crankshaft main bearings must be in perfect alignment with the crankshaft journals.** If one bearing surface is lower or higher than the others, this will cause great vibration as well as wear. The purpose of this process is to align the bearing surfaces to the crankshaft main bearing journals. **Bearings usually come undersize,** and are then line-bored or reamed to size and finish. The amount of clearance to give is predetermined, then the bearings are align-reamed accordingly, and then tried for fit, then run-in to limber up.

Usually, only new bearings, or bearings with sufficient metal stock, **are line-reamed or bored.** If bearings are **old and worn,** it is best to **replace them** with new ones and line-ream or bore, or they can be scraped and spotted.

The align-reamer[1] **or align-boring machine for align-reaming or boring crankshaft main bearings is much quicker than scraping,** and with the proper equipment allows the shop to turn out a job in the least possible time.

Always inspect the crankshaft bearing crankpins and journals before fitting the main bearings or connecting-rod bearings to a crankshaft. **Test the crankshaft** to find out if it is out of alignment itself, by being bent or sprung, or if the bearing pins or journals are worn flat or oval, or if they are scored, cut, or rough, as explained on pages 791–793.

Always inspect and test the connecting-rod, piston-pin, and piston assembly for alignment before installing. See page 803.

MAIN BEARING ADJUSTMENT METHODS

Where crankshaft main bearings are only slightly out of round, or worn, the bearing can be drawn tighter by **adjusting the lower bearing cap.**

There are two methods for adjusting or taking up on a lower bearing cap so that it will be tighter on the shaft: (1) by removing shims; (2) by dressing down the sides of the bearing cap.

Usually, the rear main bearing, owing to the increased weight of the flywheel and thrust is the one which wears first, and usually the bearing in the lower bearing cap wears most.

The bearing cap is either fitted without shims or with shims.

If bearings are without shims, adjustment for wear is made by dressing down the bearing cap by placing it on a sheet of emery paper on a surface plate, or by filing it down.

If bearings are provided with shims, adjustment for wear is made by removing an equal amount of shim stock from each side of the cap.

Adjusting a Bearing by Removing Shims

Taking up main bearings: First, take down the oil pan. To do this remove all the bolts underneath, and all bolts at each end of pan. Then remove the lower oil pan.

The bearings on many engines are fitted with **brass or other forms of separators** of a standard thickness, made up of a number of thin **shims** in various gauges, .001″ to .005″ thick and one or more shims of $\frac{1}{64}$″ to $\frac{1}{16}$″ in thickness.

Shims.[2] There are three types of brass or steel shims used in automotive engine bearings.

[1] See page 790B for addresses of some of the concerns who manufacture or supply main bearing align-reamers or align-boring machines.

[2] **Shims of all types can be obtained of automotive supply houses.**

(1) The **solid shim** consists of one piece of brass or steel (Figs. 4 and 4A).

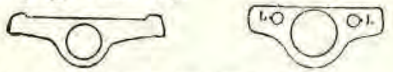


Fig. 4. A solid main bearing shim (single).

Fig. 4A (right). A solid connecting-rod shim (single).

(2) The **loose-leaf** shim consists of several brass sheets. A typical combination of a loose-leaf shim having a total thickness of 1/8 inch would consist of one shim 1/16" thick, one 1/32" thick, one 1/64" thick, three .004" thick and two .002" thick.

(3) The **laminated shim** (Fig. 4B) consists of a number of thin brass sheets sweated together by means of a special binder metal. **Standard thicknesses** for automotive engines are as follows:

1/64" consisting of five .003" laminations

1/32" consisting of ten .003" laminations

1/16" consisting of one 1/32" solid piece sweated to ten .003" laminations

1/8" consisting of one 1/16" solid piece sweated to twenty-one .003" laminations

The standard thickness is as stated, .003" but .002" can be obtained. Where shims are made up of more than one thickness, the thicker ones are usually placed in the center and the thin ones outside.

The laminated type of shim is often used. It is made of thin layers of laminum, which can be peeled off as desired (Fig. 4B). This type of shim can be used in the main crankshaft bearings and also in the connecting-rod lower bearings.

To make proper adjustment, simply remove one or more thin shims from each side of the bearings.

The bearing cap must be drawn up tight, not against the shaft, but **against the shim** or spacing sleeve. If drawn tight against the shaft, it will burn out, and if left loose, it will pound and perhaps strip nuts off the cap screws.

If more than one bearing is loose, each bearing should be tightened separately, and when the proper adjustment has been secured, loosen the nuts sufficient to take the pressure of the bearing from the crankshaft. Then proceed to the next bearing in the same manner. After each bearing has been adjusted separately, tighten all nuts.

After adjusting, the engine should be run idle under its own power for some time to work-in the bearings, using plenty of oil. Bearings which are set up too snug will heat readily at first, therefore observe carefully until they are worked in.

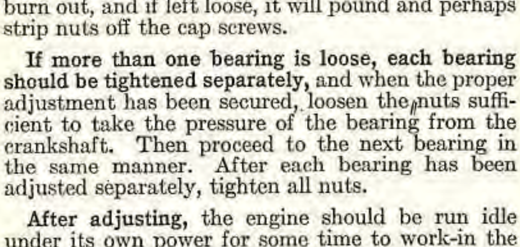


Fig. 4B. **The laminum shim:** Note the laminated layers of thin brass .003" or .002" thick. In the illustration, the top layer is being started with a knife blade, enough to get a hold, then it can be **peeled off.** (Laminated Shim Co., Inc., Long Island, N.Y.)

Fig. 4C. **Plain or regular laminated shim.**

Fig. 4D. **Babbitt-faced laminated shim used on engines** having pressure oil feed to bearings when the shim thickness is 1/16" or greater, the 1/8" being standard thickness for connecting-rods, and 1/16" and 1/8" for main bearings. The babbitt face or tip is shown at (B).

Shims used in engine bearings lubricated by pressure feed should be babbitt faced when the shim thickness is 1/16" or greater. The babbitt face is necessary to effectually seal in the oil. Otherwise, the oil would be forced out through the recess between the shim and the shaft, and oil pressure could not be maintained in the bearing. The clearance between the babbitt face of the shim, and the shaft should be exactly equal to the bearing clearance. It is, therefore, important that babbitt-faced shims should be **machined** with the bearing.

Adjustment with the laminated babbitted shim is accomplished in the same way as with the regular laminated shim. The necessary number of laminations are peeled from the shim as usual, and then the **babbitt is easily filed or scraped down** to the approximate thickness of the shim. Under pressure the babbitt is flattened slightly to fit closely and accurately. The babbitt faced shim is covered by patents.

Laminum is also made in standard sheets 6" wide and 36" long in various thicknesses from .010" up to 1/8", with laminations either .002" or .003" thick.

When installing shims in bearings, place an equal amount of shims on each side of bearing; adjust cap, and if bearing is too tight, add shims; if too loose, remove shims, adding or removing equal amounts on each side.

Don'ts for Shims in Service

1. **Don't** use shims unless they are flat and free from burrs.
2. **Don't** use shims which are not free from dirt and grit.
3. **Don't** use shims over connecting-rod or main bearing studs and bolts, unless holes fit like dowel holes.
4. **Don't** use tubes or other tools to hammer shims over studs. Shims must be placed by hand so as not to injure them.
5. **Don't** have stud holes in shims so large as to permit the shims to shift over edge and touch shafts.
6. **Don't** neglect to replace shims on same side of bearing as taken off.
7. **Don't** lose sight of the fact in adjusting bearings that when bearings are scraped in, there are high spots that will wear down in running-in; this means, adjust scraped-in bearings a little tighter. When bearings are align-reamed or bored, little or no high spots are to be reckoned with; therefore adjust bearing to a working clearance.
8. **Don't** leave sharp corners on oil holes in shafts which might score bearings.
9. **Don't** remove a .003" thick shim from one side and a .002" one from the other. Nor should you remove a shim of any thickness from one side and none from the other.
10. **Be sure** babbitt in bearing is properly grooved to distribute oil in bearing before placing shims, because a badly grooved bearing can do as much damage as a badly placed shim.
11. **All main bearing shims** should be recessed at all times, so as to maintain plenty of oil in bearing.
12. **If no reamers of proper size can be obtained,** babbitt faces of shims should be scraped or filed to fit.

Adjusting Main Bearings by Removing Shims; Reo "T6" as an Example

The main bearings are adjusted as follows: Remove plug and drain oil from crankcase; take out cap screws; disconnect oil line at rear of case, and drop oil pan (applies to model "T6" where oil is forced to the four main bearings and connecting-rods lower end, splash lubricated).

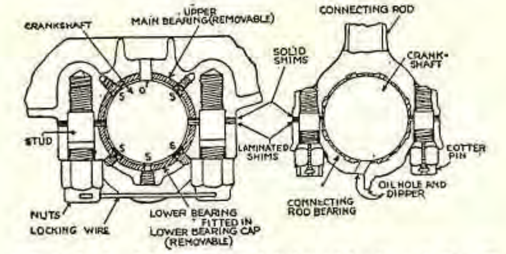


Fig. 5 (left). Main bearings lubricated by force feed. Fig. 5A (right). Connecting-rod lower bearing lubricated by splash. Both fitted with shims. See page 799 for adjustment of Reo "T6" connecting-rod.

Now remove the locking wires which anchor the nuts and back off locking nuts one full turn on all main bearings. Remove nuts and cap from No. 1 bearing.

Remove one lamination from each of the metal spacing shims provided; replace the cap and nuts; tighten the nuts, and if the crankshaft still turns easily, repeat the operation **until a slight drag can be detected.**

Again remove cap and nuts; **replace one .002" shim** on each side to give proper **running clearance.**

Replace cap and nuts, but do not tighten nuts because the other bearings must be adjusted.

For example, let us suppose that with the spark plugs removed (thereby eliminating compression) the crankshaft can be turned over very easily. Commence with the first main bearing and adjust it properly, following the directions as given above. Were we to allow this bearing to remain properly adjusted, some difficulty would undoubtedly be experienced in detecting the exact tightness of the second bearing. Therefore, in order to ascertain this point, slack off on the first bearing just a trifle.

Instructions given for No. 1 bearing, apply to the balance of the main bearings.

When the second bearing has been correctly adjusted, slack off on the nuts a trifle, and adjust the third bearing, and so on.

After all of the bearings have been adjusted, tighten the lock nuts and replace the locking wires.

Testing after adjusting: If the main bearings have been properly adjusted, no difficulty should be experienced in turning the engine over with the hand starting crank.

When testing the bearing, keep in mind that while it should have no appreciable amount of looseness, this does not mean that the drag on the shaft should prevent its free rotation.

When all main bearings are properly adjusted and the caps are bolted in place, **the crankshaft should be just loose enough in the bearing to permit revolving it by hand** or turning it readily with the fly wheel, and without the assistance of a bar or pry.

Remember, there is a possibility of getting the bearings too tight, and under such conditions the babbitt alloy in the bearing is likely to cut out quickly unless precaution is taken to run the engine **slowly** for the first few days, with plenty of oil.

When bearings have been taken up, replace the oil pan, being careful not to damage the gasket (if this happens replace with new one), and do not forget to see that **all nuts** are securely tightened and that the cotter pins are inserted.

Note the Reo method of replacing the oil pan: Care must be taken in replacing the oil pan, as there is danger of damaging the gasket for the cam-gear housing cover and causing oil to leak from the front end of the engine. A thin strip of tin placed over the gasket will serve as a guide for the oil pan, and prevent damage to the gasket. Before fastening the pan in place, withdraw the tin strip. Best results can be obtained by fastening up the pan on the left side of the engine first. In this manner it is possible for one person to guide the pump plunger into its barrel while raising the right side of the pan in place. Before replacing the underpan, be sure that all cap screws are tightened securely.

Adjusting a Bearing by Dressing Bearing Cap

Where there are no shims between a bearing cap and the upper bearing by which adjustment can be made, as previously explained, the bearing cap (containing bearing-half) can be dressed down so that it can be drawn tighter around the shaft-bearing-journal.[1]

Main bearings and also connecting-rod caps can be reduced either **by dressing off on the sides by filing** (termed "draw filing") or by **lapping** the sides down on a sheet of emery cloth stretched over a smooth board or preferably over the face of a surface plate. This work requires careful and painstaking effort, and frequent inspection or checking while dressing down.

[1] Bearings on V-type engines, not fitted with shims, on fork and blade type rods, are best replaced. See also page 804.

Lapping is recommended for all pressure lubricated rod or main bearing caps simply because it is the most accurate method in the hands of the average mechanic. Few men engaged in engine repairing can file a cap to the degree of smoothness and **trueness** required on a pressure lubricated bearing.

Factors other than looseness that produce oil leakage out of pressure-lubricated bearings are largely poor filing of the cap and rod forgings in the case of rod bearings and of the cap in case of main bearings.

When removing a main bearing cap, always inspect the bearing to see if the babbitt is damaged to such an extent as to need scraping, or if the bearing is burned out or worn so thin that the bearings should be replaced. Usually the lower main bearing wears most. If it is an integral babbitted bearing, a new cap with bearing in it can be used to replace the damaged one, or if it is a removable bearing, the bearing can be replaced. Usually, however, when this is the case, it will be found that all bearings must be replaced and properly lined up by scraping, or burning-in, or reaming, as will be explained farther on.

It is also advisable to inspect the crankshaft pins and see if they are smooth and are not scored or cut, or worn oval or flat, or out of round, for if they are, then the attempt at adjustment will be time lost.

In this case, the crankshaft should be removed and tested (see pages 791–793), and bearings properly fitted.

If the crankshaft pins are in good condition, and the babbitt bearings have not been damaged, the cap can be dressed down by draw-filing with a large mill file, as shown in Fig. 6 (or lapping, as explained farther on). The repairman must exercise great care to hold the file squarely on the cap (see page 718 for "Draw filing").

When the cap has been dressed down sufficiently, try the surface of the cap for high spots, by holding a scale across it at several points and angles, as shown in Fig. 7, or try it on a surface plate (a smooth

Fig. 6

Fig. 7

steel slab) by tapping the cap lightly with the fingers at several points to note any slight variation in the surface. If the cap is rubbed lightly over the surface plate and dark spots appear on the surface, these are the high spots and they should be dressed off with the file until they are distributed evenly over the surface of the cap.

The best method for dressing a bearing cap down on the sides, especially where one is not an expert with a file, is to **lap** the edges or sides of the cap down on a sheet of emery cloth glued to a perfectly flat hardwood block, a sheet of glass, or a steel surface plate.

Unless filing is carefully done, the edges of the work are practically certain to be filed out of line, resulting in twisting when the cap is pulled down.

To test after adjusting: The bearings should not be fitted too tight or too loose. Follow the plan for testing the resistance of the crankshaft in the bearings after adjusting, and run-in engine, as explained on page 787.

Interchangeable Type Main Bearings

Some manufacturers state that their bearings are interchangeable, and should a crankshaft bearing burn out from lack of oil, the bearing can be removed quickly and a new one installed without the necessity of removing engine from frame, or crankshaft from engine. **New bearings are installed** by simply loosening caps, dropping shaft just enough to slide out upper half bearings and inserting new ones.

This bearing is a removable type bronze-backed babbitt-lined or die-cast bearing of the close-limit interchangeable type. Being pressure lubricated, a definite set clearance is allowed; and so long as the crankshaft is not damaged and the bearing half is accurate in the fitting, this is possible.*

If crankshaft is reground or touched up in any way, undersize bearings must be used, as these bearings are right to size for original crankshaft, having the proper oil clearance all figured out.

VARIOUS METHODS OF FITTING AND ALIGNING BEARINGS TO THE CRANKSHAFT[6]

There are several methods of fitting and aligning bearings to the crankshaft main bearing pins as follows:

1. By "spotting-in" and scraping and running-in in oil.[1]
2. By boring, then reaming, then "spotting-in" and scraping, then "running-in" in oil.[2]
3. By boring, reaming, and burning-in,[3] which might be termed "melting-in"; then "running-in" in oil.
4. By boring, then reaming.[4]
5. By align-reaming or boring with adjustable cutters; then running-in to burnish.[5]

Either of these processes can be used, and **all are intended to accomplish the same purpose,** that is, to give a good bearing surface and to align the bearings with each other and to the crankshaft main bearing pins. **Each process will be discussed in** pages following:

Spotting-in and Scraping a Main Bearing (1)

Usually, for all ordinary wear, the adjustment of bearings is all that is necessary (for removing shims or dressing the sides of the bearing caps as the wear increases; more often by removing shims), and the removal of the oil pan is usually all that will be required.

Where bearings are spotted-in and scraped, it is best to remove engine from frame of car (see also page 784 dealing with this subject).

To scrape and spot-in bearings: Remove the engine from the frame by means of a hoist or otherwise; remove the pistons; remove the oil pan and cylinders, or the cylinder head, if of a detachable type.

Mark each part when removed: Before disassembling the bearing caps to remove the crankshaft, the timing gears should first be carefully marked, as also the pistons, etc., that were removed, so that they can be assembled later on in their proper place.

Usually, the connecting rods and caps are marked as shown on page 799.

Turn the crank case on its side, preparatory to removing the crankshaft. The crank case will then look something like that shown in the illustration (Fig. 8).

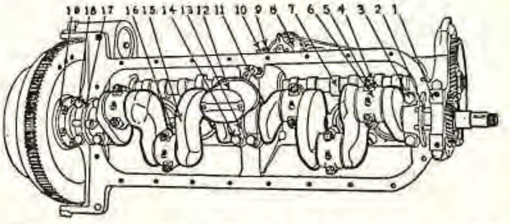


Fig. 8. Crankcase with crankshaft in place (a six-cylinder engine as an example). (1) front support; (2) oil ducts to carry oil back in crank case; (3) crankshaft front bearing cap; (4) connecting-rod lock nut; (5) connecting-rod bolt; (6) connecting-rod cap; (7) cam; (8) ignition distributor (Delco); (9) and (10) set screws for distributor; (11) oil pipe from pump to distributing tube; (12) oil-pump screen; (13) center bearing cap; (14) center-bearing lock screw; (15) crankshaft; (16) connecting-rod shims; (17) rear-bearing cap; (18) rear-bearing lock screw; (19) crankshaft fly-wheel flange.

The oil-pump screen (12) is removed, as well as the fly wheel, by disconnecting it at the crankshaft fly-wheel flange (19). Mark the fly-wheel bolt holes.

The connecting-rod caps are then marked and removed, as are also the connecting-rods themselves.

The crank case is then turned up-side-down, and the main bearing caps (3, 13, and 17) are removed. Be sure to mark each one carefully.

The crankshaft is then removed and the work of spotting-in and scraping will be done on all of the upper halves of the crankshaft bearings first, in order to have the crankshaft align with them.

Before proceeding further, **the crankshaft should be inspected for alignment,** etc., as outlined on page 792, and as will be explained farther on.

After determining that the crankshaft is in perfect condition, the next procedure is to "spot-in" and scrape the upper bearings.

Do not remove the bearing-halves from their seats or caps (if of the removable type), unless it is necessary to replace them. Be sure the bearings are firmly seated and rest snugly against bottom in seats and caps.

Spotting-In and Scraping the Crankshaft Upper Main Bearing Halves

Clean the crankshaft main bearing pins and upper bearings with a soft cloth and wipe perfectly dry.

Then give the crankshaft main bearing pins a very light coating of blue, or marking compound.

The marking compound is Prussian blue which can be secured at any supply house, and comes ready mixed (lamp black is also sometimes used). A little dab on the fingers is sufficient to wipe on the shaft, as a very light coat is required. If too much is given, it will run all over the bearing, and spots will show which should not be scraped.

[1] **Spotting-in and scraping** are done when fitting new bearings where align-reaming or align-boring tools are not available, or for reconditioning a used bearing where there is not sufficient metal to allow for align-reaming or boring. This process does not of course align bearings as accurately as align-reaming or boring, and alignment of bearings depends largely on the operator's skill in finishing the bearings to the same level or position of main bearing journals of the crankshaft (now seldom used).

[2] This is a **duplication of work** not now deemed necessary.

[3] Some of the bearing manufacturers claim that burning depreciates the babbitt texture. It is used most on cast-in or solid types of babbitt bearings.

[4] This is the **Ford Model "T"** service method, as explained on pages 790 and 790A.

[5] **With modern type align-reamers or align-boring fixtures** with adjustable cutters, bearings can be finished by either align-reaming or align-boring and then run-in to limber up

[6] Federal-Mogul "*Engine Bearing Service Manual*" is a very instructive booklet. Explains different types of crankshaft main bearings, connecting rod, and camshaft bearings in common use today; how to diagnose and service engine troubles caused by worn or cracked bearings; how to check clearances; how to check bearings with an oil pressure tank, etc. Federal-Mogul *Bearing Oil Leak Detector* is also explained. Write: Federal-Mogul Service, Div. Federal-Mogul Corp., 4809 John R. St., Detroit, Mich.

***Interchangeable bearings** of the steel-back type are quite popular. On many engines the bearings can be removed without dropping the crankshaft, a pin inserted into the crankshaft oil hole, being used to rotate the bearing out of place. They are also often used in connecting rods. **See footnote,** p. 36, "*Bearings.*" See p. 690, "*Engine Bearings.*"

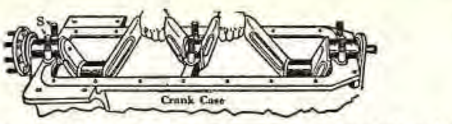


Fig. 8A. **Spotting-in the upper halves of the crankshaft main bearings** by giving the crankshaft bearing surface a thin coat of blue and rocking it back and forth.

Put the crankshaft in place, and rock it back and forth with the hands (Fig. 8A). Do not use pressure.

Remove the crankshaft and note in what manner the blue has spotted the upper main bearings. The "high spots" inside the **bearing** will be found marked in blue, showing that at these points the crank touched; but the part which is white was not touched by the crank. Therefore the problem is to get the high spots down until the bearing will mark, or have a blue surface, all over.

This is accomplished by scraping the high spots down, as in Fig. 9, with the scraping tools shown in Fig. 10, which can be secured at any supply house or can be made of old files. This is a slow job, for if too much metal is removed it cannot be replaced.

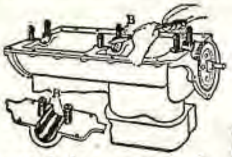


Fig. 9. **Scraping upper halves of the crankshaft main bearings in their seat.** Bearings should be firmly seated when scraping. Lower illustration[1] shows how bushings (B) made of sawed-off pieces of steel tubing can be used to hold bearing down.

Fig. 10 (right) **Bearing scrapers.**

This marking, or "spotting-in" and scraping process is repeated from time to time till the whole surface is marked, as shown in (D) (Fig. 11). In practice, it is not possible to get every white mark off the bearing; therefore continue the scraping and spotting-in until at least three-fourths of the total surface is blue, and the rest will wear in.

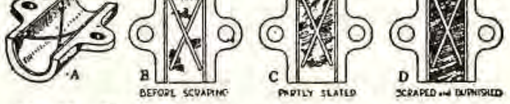


Fig. 11. **Showing appearance of markings as the scraping proceeds.**

After the scraping is done, the **burnisher** shown in Fig. 10 may be run over the entire surface of the bearing to shine it up and smooth the surface.

If, when first placing the crankshaft in the upper bearings, it is noticed that the end bearings are colored and the center one is not, it is an indication that the center bearing has received more wear than the end ones, and that the end bearings must be reduced in height to bring them down to a perfect line with the center one.

If the center bearing and only one of the end bearings is colored, it indicates that one of the end bearings has worn more than the other two, or that the center bearing has not received as much wear as both end bearings.

Whichever may be the case, the remedy is to scrape the babbitt bearing metal at the required points until the three (or whatever number of bearings there may be) **are in perfect alignment with the crankshaft.**

While marking or "spotting-in" these bearings, the weight of the crankshaft is sufficient. Do not put on the caps at all, as they would force or spring the shaft down and mark the low part of bearings.

Spotting-In and Scraping the Crankshaft Lower Main Bearing Halves

After the upper main bearings are completed, the lower main bearing caps are treated in a similar manner, being scraped down to a perfect marking.

A very important point is to "spot-in" and fit the rear cap first and to test it for stiffness; then loosen it, then "spot-in" and test the next, and loosen it, and the other likewise. After doing this, tighten down on all. Otherwise, if each bearing is tightened as you proceed, the bearing being fitted could not be properly tested for clearance.

Fig. 11A

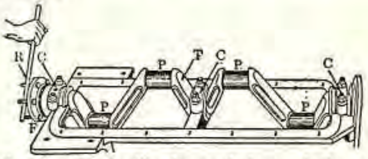


Fig. 12. **Spotting-in the lower halves of the crankshaft main bearings** (Chevrolet as an example) by giving crankshaft bearing surface a thin coat of blue and placing it in the upper bearing halves; then place thin metal shims in place between upper and lower bearing caps and tighten all bearing caps. Then place a bar (R) between the flywheel bolts as shown and turn crankshaft several times, then remove bearing caps and examine for blue spots. If the bearings do not touch or fit snugly on the shaft it may be necessary to remove equal number of shims from each side. Scrape out the blue spots.

Clearance: After spotting-in and scraping the main bearing caps, the caps are tightened down and engine is "run-in" on a **running-in machine,** using plenty of oil. The caps are then removed and bearing surfaces examined. If bearing **heats-up considerably,** add a shim, if **too loose,** remove a shim. If shims are not used dress off bearing cap if too loose, or scrape bearing if bearing is too tight. See also page 783 on bearing clearances.

Adjusting and testing: When the lower caps are fitted and the nuts are drawn up tight, the shaft should turn with some resistance. Some repairmen judge the amount of resistance by being able to move the crankshaft with the hands as shown in Fig. 8A. The bearings must not be so tight that they will overheat and seize. See also page 783.

When testing with all bearing caps drawn down, do not misjudge tight bearings for bearings out of alignment, as bearings out of alignment also cause drag or locked shaft.

After fitting the bearings, run the engine idle under its own power with plenty of oil to limber up bearings. Use plenty of lubrication during this process, as bearings which are set up too snug will heat rapidly at first. Therefore the danger of scoring or burning is very great until the bearings have time to work in.

Care must be exercised in driving car for approximately one hundred miles after bearings have been tightened. See page 833A about adding oil to the gasoline when running-in after fitting pistons and rings.

Bearing Fitting Pointers

When removing bearing caps, be sure to mark them so that they can be replaced in the same position on bearing from which they were removed, and always **put oil on the bearings when replacing a cap.**

[1] Illustration and suggestion from *Repairman's Guide* as in footnote 6, page 786.

Before marking and after scraping, dust all the metal chips out with a small paint brush. **Wash all** parts off with gasoline or kerosene.

Have the scrapers sharp, and never try to scrape with nicked scrapers.

Do not forget, when taking-up on bearings, to examine the oil grooves. They may be worn shallow or filled with metal, and should be opened up. Examine oil line and pump.

Oil holes in main bearings on pressure-lubricated type should line up with oil holes in crankshaft main bearing journals. This is **important,** as the oil hole in the main bearing of the drilled crankshaft supplies oil to the connecting-rod bearings. See that passages in a drilled crankshaft and also holes in bearings are clear. **Reversing a bearing cap** will limit the oil supply; if removed for adjustment, replace in original position.

Care should be taken in setting up a used bearing not to have it as tight as a new bearing, as the metal in the old bearing has been compressed and will not seat itself and wear down, as in the case of a new one. **The bearings should not be set up so tight that the crankshaft cannot be readily turned by the hand.** On pressure-feed bearings it should turn more freely than on splash feed.

If the shaft turns too hard, do not think that loosening up the nuts is the remedy. In such a case an extra thickness of shim brass will have to be put in, so that the nut can set down tight and still allow the shaft to turn.

If the bearing or metal babbitt lining in one-half of a bearing is worn badly or is very thin, then replace the full bearing, as it is better than replacing only one-half. The fitting process will be necessary just the same, however.

Locking nuts or bolts on bearings securely after assembling is very important. When studs are used, castellated nuts which are locked with cotter pins are usually provided; when bolts are used, there is usually a hole in bolt head for locking wires.

In renewing bearings, care must be taken to see that they are of about the same thickness of metal as the original ones. If too thick, the pistons will be pushed higher into the cylinder and will alter the compression and cause vibration. On two-cycle engines it would change the port timing.

When scraping in the upper halves of new main bearings where timing gears are used, the camshaft with the gear attached should be placed in the cylinder block and the crankshaft gear fitted to the crankshaft to determine whether the gears are meshing properly. **If the crankshaft and timing gears mesh too deep or do not mesh deep enough, after scraping the bearings,** they will be noisy.

If the timing gears are too tight, owing to the top of the teeth coming in contact with the bottom of the spaces in which they mesh, it may be possible to effect a remedy by turning off metal from the outside diameter of the gear. If the teeth bind on the pitch line (near center of tooth; see Fig. 11, page 869), the gears may be lapped in, but **caution** must be used to keep abrasive from bearings. One method is to cut cardboard or thin metal to fit behind gears.

If too loose, instal two new **standard-size gears,** and if this does not take up play then install **over-size replacement gears.** (Where align reaming jigs are used extreme care in setting up will remedy the trouble.) There should be only a slight amount of backlash in timing gears after the bearing caps are drawn down tight.

Timing gears should fit fairly snug when new, with little backlash, so that after they are run-in they will mesh properly.

Sometimes when main bearings as well as crankshaft journals are so badly worn that refitting bearings would throw **shaft out of its original center,** then it becomes necessary to regrind shaft and apply new **undersize bearings,** and then to align-bore bearings back to the original centers.

After fitting bearings, never turn the car over to the owner with the bearings so tight that it is difficult to start the engine with the starting motor, otherwise he will run the battery down in cranking the engine. It is best to have them moderately tight, and then, after the car is driven for about 1,000 miles with plenty of oil, to examine the bearings and see if the cap should be adjusted.

Boring, Reaming, Spotting-in, and Scraping Main Bearings (2)

This is another process for aligning the bearings with each other and with the crankshaft main bearing pins, which is similar to the scraping process, except that two other operations are added. (This is a **duplication of work** not now deemed necessary.)

The main bearing caps are fitted in place (the crankshaft removed), and then the bearings are **rough bored,** then **align-reamed** to about .001" larger than the crankshaft.

The crankshaft is then put into place, and Prussian blue is used for **spotting-in** the high spots, which are scraped down as previously explained.

After these processes are completed, the crankshaft is **run-in** by belt power, using plenty of oil, until the crankshaft can easily be turned by hand.

Boring or Reaming, Burning-in, and Running-in Main Bearings (3)

The burning-in process is supposed to take the place of scraping. By this process, the bearings are aligned with each other and to the crankshaft pins.

The theory underlying the process of burning-in bearings is that if a very thin skin of the bearing metal next to the shaft is heated almost to the melting point while the shaft is revolving, it will form itself to a 90 or 100 per cent running fit. Such perfection is, of course, impossible of attainment. However, the process approaches it closely enough for all practical purposes.

There is some difference in the procedure, depending upon whether the bearing is a removable **bronze-backed** or **die cast** bearing which can be replaced, or plain **babbitt cast** into the cylinder block main bearing seat and cap, which of course is solid.

Care must be taken in the preparation of bearings for burning-in, when boring or reaming, to see that crankshaft is properly located to insure correct gear mesh.

Considerable care is necessary when burning-in die-cast babbitt bearings which are removable, as they are not anchored as tight as cast-in babbitt bearings and may crack; likewise, considerable care is necessary in burning-in the babbitt lining on bronze-backed bearings, as the lining is only about $\frac{1}{64}$" to $\frac{1}{32}$" thick on an average bearing.

If the bearings are badly worn or thin or loose, then new bearings must first be fitted, either by installing removable bearings or casting in the plain babbitt bearings.

Main bearings are usually burned-in when new ones are installed, or cast-in; however in some cases slightly used bearings can be burned-in where the texture and thickness of metal permits. The process is used most with cast-in babbitt bearings.

If only the lower bearing is worn and it is a babbitt bearing, as on the Ford, a new cap with a babbitt lining can be secured.

As an example, the process of fitting bearings to a Ford engine will be explained.

Babbitting: The first process is to rebabbitt the bearings if necessary.

Boring or reaming: The main bearings in cylinder block are then align-bored or align-reamed (or rough bored and then align-reamed) with special fixtures to approximately .001″ less than crankshaft journal diameter.

Testing and installing crankshaft: After the main bearings have been properly reamed or bored, or roughly hand scraped, as the case may be, the crankshaft is installed and a slight amount of oil is applied to the journals to prevent scorching; if too much oil is applied, it will prevent burning-in. Before installing the crankshaft, **test it**, as explained on pages 791, 792, 793.

Fitting bearing caps: There are two methods, with or without shims. The shim process will be explained.

Fit No. 1 bearing very tightly by shimming, leaving a "rock" of from .004″ to .006″, that is, in such a manner that, with the shims in place, it will be impossible to push the bearing cap down to them by hand.

The proper distance can be measured with a feeler gauge. For instance, a distance of .005″ on one side with the cap pulled down to the shims on the opposite side is equal to .0025″ on each side when the bearing is exactly centered on the shaft.

Should it be impossible to fit closely enough by shimming, the bearings may be dressed off on the sides.

After fitting No. 1 bearing, loosen it, and proceed with the remaining ones, loosening each as it is finished. Particular attention must be given to chamfering or removing a small extra amount of babbitt at the split edge of bearing caps and clear across from side to side. This will take care of slight offsets at cap and main bearing along split edge of bearings.

Errors had best be made on the side of looseness until experience is gained, as with all **bearings pulled down too tight,** the **shaft is subjected to a tremendous strain,** which may spring it.

The bearing caps are then drawn down tight on the crankshaft, one at a time, and are then **tested out** with the turning-bar or lever which has two pins in it and fits into the flange of the crankshaft; each bearing should show considerable resistance to turning.

Burning-in the main bearings: Each bearing should be shimmed up to the same amount of tightness, and should then be put in the burning-in machine (Fig. 13), connected with coupling (**D**), then clamped tight with clamp rods (**CC**).

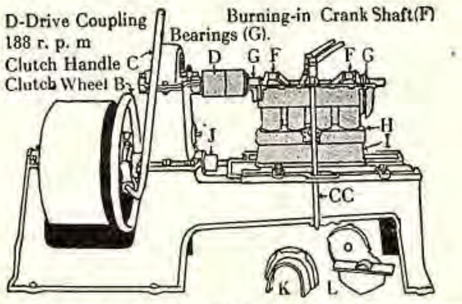


Fig. 13. **A burning-in machine.** Burning-in the main crankshaft bearings on a Ford engine. A belt drives the fly wheel. The power is then transmitted through a clutch to the gearing, thence to coupling (D), which drives the crankshaft (F) at 188 r.p.m. The same operation is used for burning-in the lower connecting rod bearings. The base (I) permits the pistons to pass the cylinder block slightly when burning-in the connecting-rod bearings. (See footnote, page 803, as to where shop equipment of this kind can be obtained.)

The machine is then **started** by means of the hand lever (**C**) which operates the clutch, and the crankshaft is revolved at 188 r.p.m., by belt power, for about 30 to 40 seconds, until the bearings begin to burn and showing a dark straw color and smoke, then oil is poured on the bearings, and after about 30 seconds more, oil is again poured on the bearings. After about 2 to 5 minutes the clutch lever (**C**) is thrown out, and the bearings are then **tested** by means of the hand wheel (**B**). If the crankshaft cannot be turned by one hand, then the operation of burning-in is repeated for a few seconds.

If one bearing should not get as hot as the others, the operation should be stopped and either shims should be removed or the cap should be draw-filed to tighten on the bearing, thus insuring its being burned-in the same as the others. This attention must be given at the start of the burning-in process.

When the burning-in operation is completed, the final clearance between the bearings and crankshaft pins will be about .002″ to .003″, or approximately the amount which was melted down in the burning-in process. Thus a clearance is gained for the film of oil which is necessary to lubricate the bearings.

After the burning-in of the main bearings, the engine is removed from the machine, all surplus metal is scraped out of the oil grooves of the bearings, and the caps are replaced and **lubricated.**

Burning-in[1] Connecting-Rod Lower Bearings

The main and connecting-rod bearings had best be burned-in separately, the former first.

After the main-bearings have been burned-in and lubricated, the pistons and connecting-rods are assembled to the engine, after the pistons and connecting rods have been tested on the alignment device, as will be explained farther on. The engine is then returned to the machine; mounted on the same base (I) (Fig. 13), which permits the pistons to pass cylinder head block slightly. The operation is then the same as the burning-in operation on the main bearings just explained.

It is well to relieve the tension on the main bearing caps slightly while burning-in the connecting-rod bearings. When burning-in the connecting rods, it is important that, though the pistons and cylinders and main bearings are flooded with oil, the connecting-rod bearings should be **kept dry** until the running-in oil process is reached. Should they get even a few drops of oil, they will remain tight and will not burn.

The connecting-rods should be assembled to the shaft tight enough to require a hammer blow sidewise to move it along the shaft.

After burning-in, test with the hand wheel (B) to see if the work is completed, and when the hand wheel (B) can be turned over freely by hand, the connecting-rod cap is removed, the oil groove is scraped out, and the job is reassembled.

The engine is now ready for running-in in oil, or burnishing. The main bearing caps are tightened and cotter-keyed.

Running-in in Oil or Burnishing,[2] Main and Connecting-Rod Bearings

The engine is returned to the machine in an upright position, and instead of base (I) being used, the upper half of the crankcase is bolted to the oil sump on the machine at (M). The oil sump is filled with oil to the oil level (Fig. 14). The engine is run at 550 r.p.m. until it is limbered up to the extent that it is possible to turn over the crankshaft by the hand wheel.

[1] **Burning-in** involves tightening the bearings around their journals and then rotating the crankshaft by means of a device called a burning-in machine, until sufficient heat is created to flow the babbitt slightly into conformity with the surface of the crankshaft main and connecting rod journals. The burning-in process is carried on **without lubrication** between bearing and journal.

[2] **The burnishing-in process** is accomplished with a burning-in machine or other outside source of power to rotate the crankshaft. The caps are drawn down until there is a drag at each bearing and oil is introduced and the crankshaft rotated to produce the final smooth finish and to limber up the bearing.

After all, the final fit of a bearing is controlled by the "breaking-in" and as soon as the bearing stops overheating, it is then a bearing. In other words, it may be put up as tight as possible, and after running 300 to 400 miles it will sufficiently loosen up the bearing as it should be, so that it can be hand-cranked.

After this operation is completed, the engine is ready to complete assembly and for adjusting, testing, and inspection, before installing it in the car.

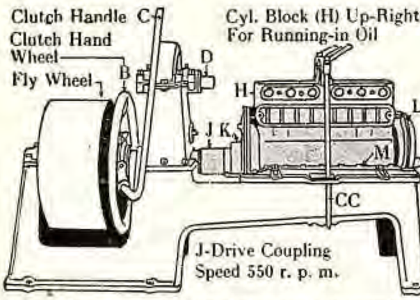


Fig. 14. A burning-in machine being used for **running-in the engine bearings in oil, or burnishing-in.** The main and connecting rod bearings, and the piston and piston rings are also run-in. Note that the lower coupling (J), which turns the crankshaft at 550 r.p.m. is used in this instance.[1]

Testing, Adjusting, and Inspecting Engine

The next operation is to test the engine under its own power on the machine, as illustrated in Fig. 15.

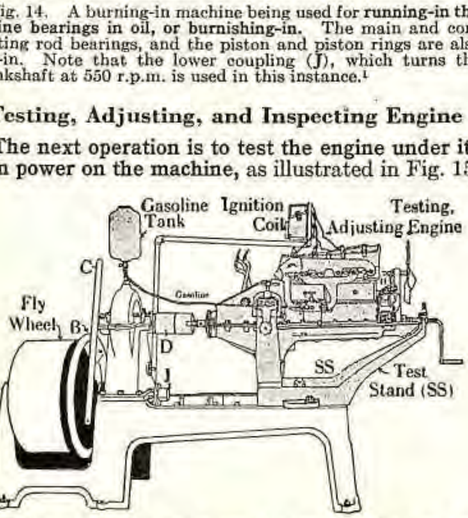


Fig. 15. A machine being used for **testing, adjusting and inspecting engine under its own power,** before installing in car. Note that the stand (SS) has been attached to the machine for this purpose. (See footnote, page 803, as to where material of this kind can be obtained.)

After the engine has been completely assembled, it is then connected to the machine with the fixture (SS), as shown in Fig. 15; it is then connected with the gasoline tank, which is furnished with the stand. The ignition system is then connected with the battery, and hose connections may be made for running water through the cylinder blocks for cooling. Pipe exhaust out-of-doors to eliminate fumes.

After the engine is ready for this operation on the machine, the clutch (C) is thrown in and the engine is run until it starts under its own power. The machine is then shut off and the transmission of the engine is set at neutral point and the engine is run until freed up to the point of being able to crank easily by hand.

After all adjustments for oil leaks, ignition, valves, etc., are made, the engine is ready to be placed in the car. It is far better to exercise the several tests described, rather than to have to tear it out again for some trivial reason which could not be detected until the engine had been replaced.

[1] See page 790B for home-made running-in machines, formerly on this page. [2] From *Ford Service Bulletin;* see footnote, page 790A. Applies to Model "T" Ford.

Boring and Align Reaming Main Bearings; Ford Service Method[2] (4)

This process consists of rebabbitting main bearings in cylinder block, then rough-boring the rebabbitted bearings, to which are fitted rough-babbitted main bearing caps, then align-reaming them .002" larger than diameter of the crankshaft journals.

To insure a satisfactory job when overhauling an engine, it is always advisable to rebabbitt the main bearings in the cylinder blocks. Attempting to recondition old bearings by hand scraping is an extremely slow process and is not as satisfactory as when new bearings are installed and properly fitted. **The procedure (condensed) is as follows:**

Rebabbitting Main Bearings[2]

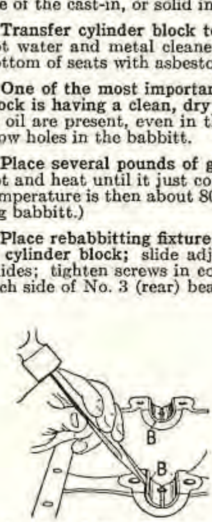
Remove old babbitt (B) from seats (Fig. 16). The bearings are of the cast-in, or solid integral type.

Transfer cylinder block to wash tank and wash block with hot water and metal cleaner; **clean seats** and fill oil holes in bottom of seats with asbestos wicking (flush with seat surface).

One of the most important items in rebabbitting a cylinder block is having a clean, dry surface for the babbitt. If water or oil are present, even in the smallest quantity, there will be blow holes in the babbitt.

Place several pounds of genuine Ford babbitt into melting-pot and heat until it just commences to show a dull red. The temperature is then about 800° F. (See also page 801 on melting babbitt.)

Place rebabbitting fixture (F, Fig. 17) **in the bearing guides in cylinder block;** slide adjustable collars up against ends of guides; tighten screws in collars; place pouring blocks against each side of No. 3 (rear) bearing.



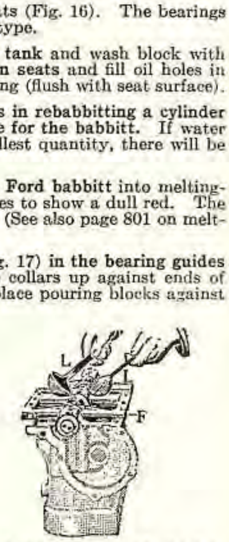


Fig. 16 (left). **Removing old babbitt.** Fig. 17 (right). Pouring the babbitt into upper main bearing seats.

When babbitt reaches a dull red, turn flame down slightly so that the babbitt does not get too hot and stir thoroughly before pouring, also skim off the dross; this should not be skimmed off, however, until just before the babbitt is poured, as the dross is composed of tin oxide and will form nearly as fast as skimmed. Remember each time you skim, the percentage of tin is reduced and babbitt becomes harder.

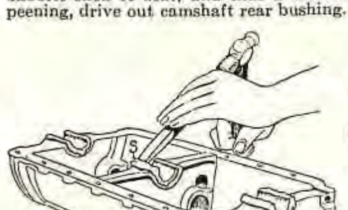
With pouring blocks placed against each side of No. 3 **bearing,** take one ladle (L) in each hand and fill with sufficient babbitt and **pour rapidly.**

After pouring No. 3 **bearing,** transfer pouring blocks to center bearing and pour it, then repeat the operation on No. 1 bearing.

After pouring, examine bearings. If one is loose, or is not properly poured, remove and pour again without disturbing the others.

Cut off lugs or sprues (S) from each side of bearing (Fig. 18). Level off top of bearings with file. Drill oil holes and remove the asbestos wicking which was put in them before pouring to prevent clogging the oil holes.

Peen the babbitt with tool **(P,** Fig. 19) to make a tight fit of babbitt shell to seat, and thus avoid a loose bearing. After peening, drive out camshaft rear bushing.



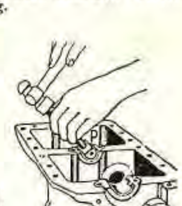


Fig. 18 (left). **Cutting lugs or sprues (S) from sides of bearings.** Fig. 19 (right). **Peening the babbitted bearings.**

Installing Boring Fixture

Transfer cylinder block to combination machine and secure in position. A false camshaft is inserted into camshaft bearing guides for the purpose of correctly locating the babbitt boring fixture on cylinder block so as to insure correct gear centers of crank and camshaft gears.

Checking Crankshaft

Examine crankshaft journals for scores, cracks, wear, and alignment. If badly scored or cracked, instal a new shaft. Light scores can be removed as described on page 791. If **out-of-round** more than .0015″, install a new shaft; if **sprung** .015″ or less, straighten; if **flange checks** out more than .0015″, instal new shaft.

Installing Shims

After inspecting shaft, measure the three main bearing journals with a micrometer to determine the exact amount of wear on each journal. If journals all measure up to standard size, that is, 1.248″, place three standard Ford shims on each side of the three main bearing journals preparatory to installing the bearing caps.

If, however, crankshaft main bearing journals are worn undersize, the wear must be taken up by building up the bearing caps with additional shims to an amount equivalent to that which shaft bearing journals have worn undersize in addition to the usual three shims which are carried between each side of the bearing halves during the rough boring and line reaming operations.

For example: Suppose the front main bearing journal on shaft is worn .001″ undersize, the center journal .002″, and rear journal .0015″.

Then with the bearing fixture bolted to the block, and the usual three shims placed on each side of the bearings, we should, in the case of **No. 1 bearing**, place an additional Ford shim on one side of the bearing. (A standard Ford shim is .0025″ thick.) By placing the shim on only one side, it would raise the bearing cap half of the thickness of the shim, which would be .00125″ at the center of the bearing, which amount practically corresponds to the amount of undersize of that bearing.

The center bearing would require two extra shims, one on each side; this would raise the cap .0025″ or .0005″ too high. This difference, while not important, can, however, be taken care of by only tightening the bearing bolts sufficiently during the boring and reaming operations to prevent the cap from shifting.

The same process is then used on the **No. 3 bearing.** In using this method, it is an easy matter to arrange any combination of shims to obtain the correct adjustment on a bearing which has worn slightly undersize.

These additional shims which are installed for adjustment purposes are used only during the line-boring and line-reaming operations; they are then removed when fitting the crankshaft, thus insuring each bearing cap being drawn down to exactly the same amount that the individual crankshaft bearings are worn undersize, which insures a uniform clearance in all three bearings, with only a slight amount of hand scraping.

Rough Boring the Main Bearings

With the boring fixture positioned on the cylinder block and the correct amount of shims placed on each side of the bearings, install the bearing caps, using rough babbitted main bearing caps, instead of finished caps to insure bearings being bored round. Be sure, when removing caps to replace them in the same position.

Next, install and tighten bearing bolts. After proper **alignment of table and block and tipping to a horizontal position,** the boring bar is connected to the head of the combination machine by means of a universal joint (B). The boring operation requires about 3½ minutes (Fig. 20). (Bearings are rough bored to 1.245.″)

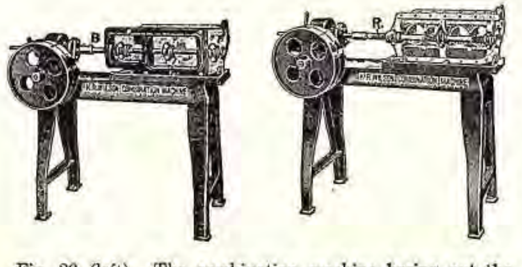


Fig. 20 (left). The combination machine **boring out the babbitted main bearings,** with caps in position and boring fixture attached to cylinder block. Fig. 21 (right). **Align-reaming the main bearings** with caps in position after having bored them.

When the boring operation is completed, the cylinder block and table are tipped to a vertical position. Bearing caps and shims are removed, and with a dry cloth remove any metal chips, oil, etc. from each bearing.

Align-Reaming the Main Bearings

Place line reamer in bearings with the pilots of reamer resting in the bearings. Place the shims on each side of the bearings, replacing the exact number of shims which were removed when the boring operation was completed.

Install bearing caps on each bearing, placing in original position and bolt caps in place. Tip cylinder block and table forward in a horizontal position (Fig. 21); **connect reamer (R) to head of machine** by means of the universal joint. **Start** machine and flow a little oil on to reamer. About 3½ minutes is required to ream the bearings. (Bearings are align-reamed to 1.250.″)

After bearings have been reamed, stop machine; then remove pins and turn cylinder block and table in a vertical position.

Bearing caps and reamer are then removed and a shim is withdrawn from each side of the three main bearings. Also remove any shims used for adjustment purposes. This will leave two shims in place on each side of the three main bearings for making future adjustments between the bearing halves. (Ford standard shims are .0025″ thick.)

Facing and Filleting the Main Bearings

With two shims on each side of the three bearings, replace bearing caps bolting them down. The rear bearing cap is then faced off, and a $\frac{1}{16}$″ radius or fillet is formed on both ends of rear and center bearings and on the rear end of the front bearing.

The rear main bearing which is the thrust bearing is faced off to .003″ to .004″ clearance or end-play between end of bearing cap and flange of crankshaft.

To determine amount to face off, measure crankshaft rear main bearing journal as shown in Fig. 22, then deduct .003″ for clearance. An equal amount of metal is then faced off each end of the bearing cap (see Fig. 23) until its length is .003″ less than the reading on the micrometer. **For example,** suppose the inside micrometer showed the length of the crankshaft rear bearing to be 3.125″, by deducting .003″ from this measurement we get 3.122″, which represents the length to which the bearing should be faced off. (The center and front main bearings are fitted with a clearance of $\frac{1}{32}$″ to $\frac{1}{16}$″.)

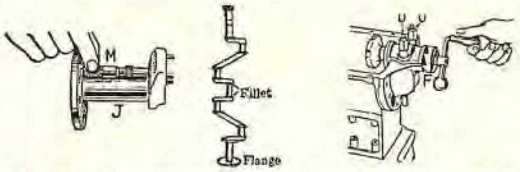


Fig. 22. **Measuring rear crankshaft main bearing journal (J)** with an inside micrometer (M) to determine amount to face off each side of rear main bearing. Fig. 22A (center). **Crankshaft.** The fillet is the rounded corner on crankshaft journals next to shoulders. The ends of bearings must be rounded off or filleted otherwise the ends of bearings would bind. Fig. 23. **Facing of main bearings** with facing tool (F). Time is saved in removing and installing the bearing caps throughout the different operations, if **quick detachable bolts (U)** are used (provided with equipment).

Fitting Crankshaft

After the filleting operation remove bearing caps and shims and wipe out any oil, chips, etc., from each bearing and clean crankshaft, and then spot up crankshaft as follows:

Place a light coat of Prussian blue on each of the crankshaft main bearings and position crankshaft in cylinder block; the shaft is turned back and forth several times (as in Fig. 8A, page 787), after which it is removed and the bearings are carefully examined. The points which show blue on the babbitt surface are the high spots; these will usually be found at the fillets, and **can be removed by lightly scraping them with a bearing scraper.**

After fitting the bearings in the cylinder block, the shaft is again positioned in the block and the bearing caps are fitted. The caps are fitted one at a time. This is done by placing two shims on each side of the bearing and bolting the cap down with the quick detachable bolts; the shaft is then turned back and

[1] These instructions (condensed) are from *Ford Service Bulletin* describing how the Ford main bearings are babbitted, bored, and align-reamed with a combination machine. Applies to Model "T" Ford.

forth several times, after which, the cap is removed and the **high spots are scraped down** with a bearing scraper. The remaining two bearing caps are then fitted in the same manner. Next place a little oil on the caps and bolt them all down in place on the cylinder block. **If the caps are properly fitted, it should be possible to turn the shaft back and forth with the hands.**

If the shaft is tight, loosen the bearings one at a time until the tight one is found, then remove the cap and lightly scrape down the high points as previously described.

Align-Reaming or Align-Boring Main Bearings and Running-in to Burnish (5)

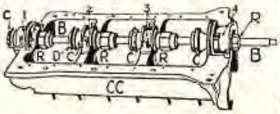
Align-reaming or align-boring are bearing reconditioning methods using either adjustable pilots fitted to the bearings, or special fixtures fitted to the crankcase to guide the work. Adjustable cutting tools are used. These methods insure perfect parallel alignment from the original crankcase bore, assuring proper timing gear mesh and clutch shaft alignment. They are quick and accurate methods of fitting the main bearings.

During either process, the main bearing caps are bolted down tightly as they would be in service, and the work is completed, usually in one operation, unless considerable metal is to be removed. The crankshaft is then installed and then run-in to burnish and limber up the bearings. **Spotting, scraping, and burning-in is eliminated.**

In addition to being able to machine the bearings to align their centers, the adjustable aligning reamers or boring machines also have the advantage of finishing the bearings to various diameters for each individual bearing. **For example:** suppose the front crankshaft main bearing journal is ground .005″ undersize, the center .010″, and the rear .005″. The cutters can be adjusted independently of one another to accommodate the undersizes above mentioned with proper oil clearances.

Either process is sufficient in finishing bearings to size and is suitable for universal use on a majority of automotive engines. Some mechanics prefer the **align-reaming method,** and others, **the align-boring method,** and each has its adherents. **The two methods are similar in finishing bearing surfaces** and differ principally in design of cutters used, method of applying them to the work, and the method of adjusting.

Fig. 24. **Example of a main bearing reamer** (Martell system) prepared to ream the main bearings. **Names of parts: (B)** reamer bar; **(R)** reamers; **(C)** adjustable threaded cones to be screwed into bearings—contain **(D)**; **(D)** conical adjusting bushings for piloting and centering reamer bar in desired position.



Example of a main bearing boring fixture and tool[1] is not illustrated. They employ adjustable fixtures which are bolted to bearing side of crankcase. Fly-cutters are used to bore the bearings.

MISCELLANEOUS

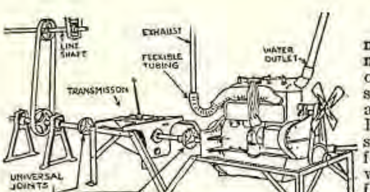
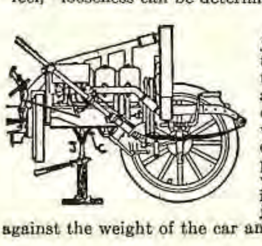


Fig. 24A. **Home-made running-in machine.** An old transmission serves as a clutch and speed ratios. Line shaft hangers serve as bearings for driven pulley, which is driven from shop line shaft at about 400 r.p.m. Engine can be tested on same stand. See also page 1036.

Fig. 24B. The subject of **testing for the condition of bearings** is discussed on page 784. This method is not exactly according to engineering practice, but with a sensitive jack and a sense of "feel," looseness can be determined to a certain extent.



Raise the car by means of a jack to suit the conditions for testing. If the rod bearings are to be tried, run a jack head against the lower half of the connecting-rod bearing and work the jack handle up and down. The smallest amount of play can be detected in this way, especially on the main bearings, where the pressure of the jack is applied on the crankshaft against the weight of the car and "play."

LAPPING COMPOUND FOR BEARINGS

Lapping the main and connecting-rod bearings instead of scraping or burning-in has not been the general practice, owing to the tendency of the hard abrasive to stick to the bearing material and thus to continue to cut the bearing or shaft after the lapping process has been completed.

A compound, known as "Timesaver," can, it is claimed by its manufacturer, be used with perfect safety as it breaks down after it has been in use for a short time. It is composed of large and small crystals, the cutting surface being the large crystal and the small crystal being a neutralizing substance. When the large crystal has been worn down so that the short crystals are in contact with the rubbing surfaces, these are broken up and, owing to their neutralizing action, destroy the cutting qualities of the entire compound. This action generally requires about 10 minutes. It eliminates scraping and works with bronze, babbitt, or brass. It is claimed to be soluble in oil, or it can be removed with gasoline or distillate after the lapping operation is completed. It cannot be used for grinding valves, or lapping in pistons and rings, as it does not work on iron or steel.

The method of using this compound is to bore or cast the solid bearings or bushings to a light driving fit on the shaft and grind in. A number of other methods can be utilized. Fig. 24C shows the car with the engine in place and the bottom half of the crank case removed. The connecting rods being fitted to the crankshaft are in the reverse position, that is, hanging down.

One shim is removed and the connecting rod is bolted up, just snug, with bearing compound and oil in the bearing, and is rocked back and forth a few minutes, tightening the nuts as the babbitt grinds out.

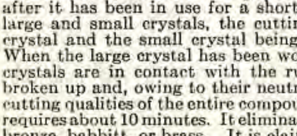


Fig. 24C. Showing how the connecting-rod bearings of an engine can be lapped with compound. Main bearings, it is claimed, can be treated in a similar manner; crankcase can be placed on a stand or block.

It is claimed that bearings treated in this manner do not have to be assembled as tightly as a scraped bearing, as there are no high spots to wear off and the bearing, if properly done, is a finished job

Some of the compounds for lapping bearings are: Zip friction paste; it is claimed that it works only with water and dissolves in oil therefore cannot imbed in soft babbitt and thereafter cut the shaft. Manufactured by the Zip Abrasive Co., Cleveland, Ohio. Pep "Safety First" babbitt bearing grinding compound, manufactured by Pep Mfg. Co., 33 W. 42nd St., New York, N.Y. The Clover Mfg. Co., Norwalk, Conn., supplies lapping compound for this purpose.

Caution: It is advisable to thoroughly wipe out any compound used for lapping, since, if for any reason it should fail to dissolve, it would probably ruin the bearing surface.

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[1] **Some of the concerns who manufacture or supply main and connecting-rod bearing reamers, boring machines, bearing babbitting fixtures, connecting-rod bearing aligning and boring fixtures, etc., are:** Automotive Maintenance Mchy. Co., Chicago, Ill. (Ammco products, reamers equip. in general); Eagle Machine Co., Inc., Indianapolis, Ind. (Norbom main bearing boring machine, connecting-rod boring fixture); Shoemaker Automotive Equip. Co., Freeport, Ill. (bearing line boring machines, connecting-rod rebabbitting fixtures, etc.); Shepherd-Thomason Co., Los Angeles, Cal. Taft-Pierce Mfg. Co., Woonsocket, R.I. (Martell main bearing reamers and connecting-rod fixtures); and others also automotive supply houses listed on page 686.

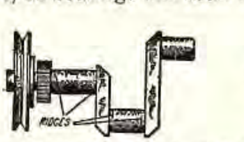
CRANKSHAFT INSPECTION AND REPAIR

Before the main bearings, or the connecting-rod bearings are fitted, or a crankshaft is installed, the crankshaft should be **inspected.** Some of the **dis-alignments of crankshafts** can be enumerated as follows:

1. Crankpin or journal scored, cut or cracked.
2. Crankpin or journal worn flat, or out-of-round.
3. Crankshaft bent.
4. Crankshaft throws out-of-line with each other; that is, those throws which are supposed to be in line but twisted out of line.
5. Flywheel flange out of true.

Scored Crankshaft Bearing-Pin

If the crankshaft bearing surfaces are **scored or cut** having ridges or rings (Fig. 25), it will cut the bearing, causing it to run hot and be damaged. Fitting of bearings under such conditions will be a waste of time, as bearings will soon wear loose.



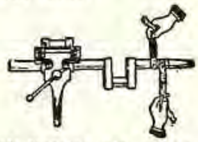


Fig. 25 (left). Scored crankshaft bearing pin. Note the ridges. This is only a slight score.

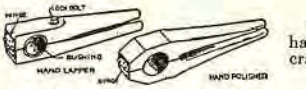
Fig. 26 (right). Cleaning roughened surfaces of crankshaft bearing pins with emery strips.

Where the crankshaft is only slightly scored, the ridges or high spots can be removed with a fine Swiss file, and the rough surfaces can be polished off by encircling the shaft with fine emery cloth saturated in oil and making a steady, even motion up and down, as shown in Fig. 26, before lapping.

The strips of emery cloth should be about 1½" wide and well oiled. Emery tape is better, if obtainable. Unless the method shown in Fig. 26 is used, there would be a tendency to make the shaft oval.

Lapping a Crankshaft Pin

Another method is to lap the crankshaft bearing pin, using a lapping compound and specially made clamps.



Figs. 27, 28. Form of hand-lapping device for crankshaft pins.

Lapping: Figs. 27, 28 show a form of hand lapper. This consists of a pair of hinged members with a central hole large enough to admit various-sized bushings to conform to the various sizes of shafts. A bolt is provided to hold the two halves together, and the flanges on the bushing prevent the bushing from slipping out the side of the frame.

The lapping is done by applying a fine emery grinding compound[1] and oil to the pin, and clamping the lapping tool to the work. The long handles serve as a lever for the work.

The pins are polished in practically the same way by a pair of long wooden clamps (Fig. 28) constructed on somewhat the same principle as the lapping tool, using a piece of emery cloth well oiled.

The connecting-rod throws on a crankshaft can be lapped and polished, the same as the main bearing journals.

One method employs offset or throw-out blocks attached to lathe face plate and tail stock. This method is suitable if done by an experienced machinist. **Another method** is to mount the crankshaft in a lathe the same as for the main bearing journals, and to use slow speed and follow the crankpins with a lapping tool, as illustrated in Figs. 27, 28, but with extra long handles.

If a crankshaft is badly scored, it will be necessary to put it in a lathe and true it up, or send it to a concern that has special crankshaft grinding machines.

When crankshafts are ground, they are first **straightened,** then the **flywheel flange is turned true,** and then the **crankshaft pins are ground** into perfect alignment (see also pages 819, 820).

Some of the manufacturers of crankshafts hone the crankshaft pins, and claim this is equivalent to 3,000 miles of actual wearing in. Both connecting-rods and main bearings get a tight fit, and thus they remain tight.

Crankpin Worn Oval or Flat

If a crankpin is found out-of-round, that is, is not circular, by testing with micrometer calipers, and is more than .002" or .003" out-of-round, it should either be ground true on a grinding machine by a concern that specializes on this work, or a crankpin returning tool should be used, before **attempting to readjust, or fit** new **bearings.**

If a crankshaft (of light and medium type construction) is **worn more** than .012" to .020" (depending upon its size and construction), it is usually discarded. On **large** truck and tractor crankshafts, as high as .020" to .025" can be removed, but bear in mind that the more metal removed the weaker the shaft. **Undersize bearings** can be obtained for crankshaft journals that are reduced in size by grinding.

Where a crankpin is roughened slightly and not worn out-of-round more than .001" and a returning tool is not available, file up the untrue part with a fine Swiss file to as accurately a circular shape as possible, testing frequently with the micrometer calipers. The crankpin is then **lapped**, as previously explained.

A crankpin returning-tool is especially adapted for truing up worn, scored, tapered or out-of-round crankpins without removing crankshaft. Such tools are made by several manufacturers, one being shown in Fig. 28A.

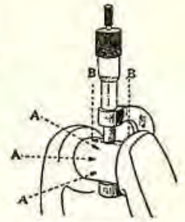


Fig. 28A (left). **Crankpin returning-tool**[1]: It is claimed that it will true up worn, scored, or egg-shaped crankpins without removing crankshaft. An **undersize reamer** is then used and scraping is not necessary.

The process is explained as follows: Determine the undersize at which crankpin will clean up. Then select a connecting-rod bearing reamer of the closest undersize; turn crankpin down to diameter of body of reamer which serves as a gauge. Bearing is then reamed to the size of the returned crankpin with the same bearing reamer (see Fig. 65C, page 800). The blade of the reamer projects just enough to provide the necessary oil clearance between bearing and crankpin. The operation is completed without any hand scraping whatever. (Care must be taken to avoid removing too much metal, thus weakening shaft.)

Fig. 28B (right). Ames **crankshaft gauge.**[2] Will show if crankshaft or crankpin is out of round, and will measure exact diameters. This precision tool shows at a glance the wear of crankshaft, crankpins and wrist pins. So aligned that its two contact points are exactly opposite and in line with the diameter of the shaft being measured, giving its exact diameter. An accurately ground, 1-inch standard is furnished and used to adjust gauge properly before measurements are taken.

Fig. 28C (center). **Checking crankpin with a micrometer:** The micrometer and an outside dial gauge (Fig. 28B) are the

[1] Tool shown in Fig. 28A is marketed by Automotive Maintenance Machinery Co., Chicago, Ill. Some of the other concerns making crankpin returning tools are Simplicity Mfg. Co., Port Washington, Wis.; Krieger Tool & Mf'g Co., Wisconsin Rapids, Wis.; General Equipment Corp., Kalamazoo, Mich.; Sawyer-Weber Tool & Mfg. Co., Los Angeles, Cal.

[2] Made by B. C. Ames Co., Waltham, Mass. Dial gauges can also be obtained of L. S. Starrett Co., Athol, Mass.

only instruments that will accurately test connecting-rod crankpin for circularity or concentricity. To test for **roundness**, place at points (A) and compare the readings; to test for **taper**, place at points (B) and compare the readings.

The cause of a crankpin being out-of-round (where the lower part of the connecting-rod fits) is often attributable to a **flat spot**, due to explosion pressure occurring constantly at one point. The result of this is that the connecting-rod bearing will not fit true and will bind. (Main bearing journals do not wear in proportion to crankpin journals). The only remedy is to have the crankshaft ground on a grinding machine or use a returning tool.

If a crankshaft (or a camshaft) is out of round, it will cause the bearings to loosen and wear out of round in a very short time and create a knock; therefore, before assembling the crankshaft (or camshaft) in an engine, they should be **tested for concentricity.** **A crankshaft gauge** especially adapted for this purpose is shown in Fig. 28**B**, also the micrometer, Fig. 28C.

A dial gauge[1] or indicator (Fig. 29) **can also be used for testing a crankshaft (or any other shaft) for concentricity,** its operation being explained as follows: The shaft is placed in the adjustable center posts (CP). The needle of the dial indicator is permitted to touch the crankshaft lightly (as at **B**) at various points, while the crankshaft is slowly turned by hand.

The concentricity of the crankshaft main bearing pins could be tested as shown in (B) on the machine shown in Fig. 29, but the test of the **connecting-rod bearing pins** on the crankshaft, which are offset to the main bearing pins, would necessitate special dogs or jigs for holding it. (The **crankshaft gauge,** Fig. 28**B**, is best suited for this.)

One method of determining whether main or connecting-rod bearings are out-of-round: Tighten each bearing cap separately and give the crankshaft a complete turn. If the bearing is out-of-round, the shaft will invariably turn free at one point and bind at another, or measurements can be taken of the shaft bearings with a pair of outside micrometers.

Crankshaft Bent; Alignment

Where a crankshaft is bent or sprung less than .015″, it can be straightened on a straightening press; if sprung more, either take it to a modern equipped shop where proper equipment is provided and where it can be ground afterwards, or install a new shaft. **Don't attempt to fit bearings on a bent crankshaft.**

To straighten, it may be placed in the blocks (V) (Fig. 29) and the press used on it. Another shaft-straightening press is shown in Fig. 30.

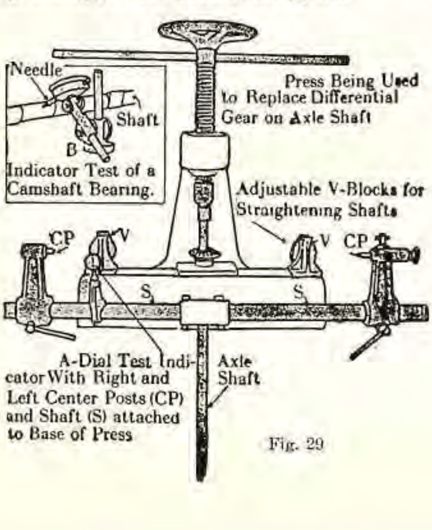


Fig. 29

Fig. 29. **Universal shaft-testing and straightening device[1]** and arbor press in one unit. (A) shows the dial indicator on shaft (S); (B) gives an idea how the needle point of the dial indicator is used to test the concentricity of a shaft when placed between the center posts (CP).

The **dial indicator** will measure from zero to one quarter of an inch, and will indicate variations in half-thousandths.

The centers (CP), may also be used for testing the concentricity of armature shafts on starting motors, generators, etc.

The arbor press is also used for pressing bushings and shafts out of gears, for straightening axles and propeller shafts, etc. The arbor press is shown removing a gear from an axle shaft.

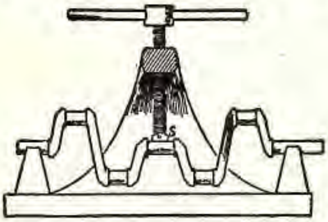


Fig. 30. **A shaft-straightening press[2]: In straightening a bent shaft** it is advisable to warm it slightly first. Then bend it far enough in opposite direction to which it is bent, so that it will be distorted the other way. The shaft is then brought to normal from this side. This prevents any tendency for shaft to spring out of line. Care must be exercised not to apply too much pressure in the first attempt and gradually to bend, and test after each attempt of straightening. Shafts are sometimes broken when straightening. Badly bent shafts, especially large ones (that are not hardened) are sometimes heated in order to bend them and then ground afterwards.

After straightening shafts, they are usually ground on a crankshaft grinding machine and should be tested for straightness, concentricity, and alignment of throws, all of which should be perfect before installing crankshaft.

To test for a bent crankshaft[3] with a dial gauge or indicator, place shaft in center blocks (Figs. 30A, or 29). Gauge or indicator is used to locate the direction of the bend, if there is any, that is in relation to the main bearing journals (**MP**) (Fig. 30A). This test would be made on the center main bearing journal of a 3, 5, 7, or 9-bearing shaft, or on the two center journals in the case of a 4-bearing shaft. The pointer of gauge is placed on shaft journal as shown in (B) (Figs. 29, or 30A). The bearings should be tested to determine out-of-roundness before the shaft is tested for bends. To avoid confusion, an out-of-round journal should be marked at its greatest and least diameters and the difference in measurements noted.

If the shaft is bent, as it is revolved, the gauge would show a variation in its reading. The amount of deflection of the dial gauge, divided by two, indicates the amount the shaft is bent, providing the bearings are circular.

For example, if gauge shows .010″ variation, this would mean that the shaft was bent off its center .005″. If bent .005″ or more, **straighten** on a straightening press.

To test crankshaft journals for worn or out-of-round condition, use micrometer as in Fig. 28C. If in "miking" the journals they are found to be, say, .005″ out-of-round, and the indicator also shows .0025″ when test was made for bent shaft, this would indicate a **worn** journal instead of a bent shaft. Bent or sprung shafts will cause bearing journals to wear more on one side and will loosen bearings quickly.

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[1] Dial gauges can be obtained of L. S. Starrett Co., Athol, Mass. (see also page 704).

[2] See also footnote, page 803 as to where equipment of this kind can be obtained. See also page 686 for list of automobile supply jobbers.

[3] A bent shaft is a shaft not straight with its centers; a twisted shaft is a shaft with crankpin throws twisted out of line, usually caused by extreme shock due to grabbing clutch under severe pulling strain and by suddenly engaging clutch while rapidly coasting with engine running at idling speed.

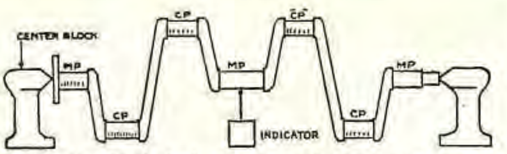

Fig. 30A. Method of testing a crankshaft for a bent place. **(MP)** are crankshaft main bearing pins; **(CP)** are crankshaft connecting-rod pins.

In testing for a bent crankshaft, one should not be misled by a bearing surface of the shaft, that is probably worn out-of-round; the test should be made first for out-of-round or worn condition with micrometers, as shown in Fig. 28C.

Crankshaft Throws Out of Line or Twisted

The crankshaft "throws" are the parts **(CP)** to **(MP)** (Fig. **30A**). On a four-cylinder engine, the four throws **(CP)** should be in exactly the same plane or line. When out of line the **crankshaft is twisted.**

A twisted crankshaft will cause the bearings to loosen quickly and will **cause vibration,** and may also throw the timing and the firing impulses out of line. In such a case, the valve events and spark would not occur in the correct relation to the piston positions.

One method of checking a twisted shaft would be to learn the position in inches in which the piston is supposed to be from the top of the cylinder at the time of the opening and closing points of the valves and to see if it checks properly. On the Ford, these positions are shown on an illustration referring to valve timing.

To test for a flywheel flange being out-of-true, check by placing shaft in V-blocks, and positioning any heavy object against the end of shaft to prevent its sliding forward while the flange is being checked. An indicator is then placed against the flange and shaft slowly revolved. If out-of-true, this will cause flywheel to run out-of-true and result in vibration and wear on bearings and shaft.

Miscellaneous Crankshaft Pointers

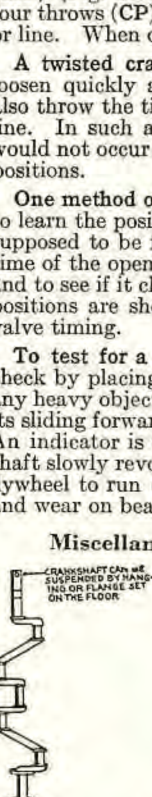

Fig. 31. **When storing crankshafts it** is advisable either to suspend them as shown, or to set the flange on the floor so that the crank will be straight. It is not generally known that a crankshaft will sag out of line when allowed to lean against the wall, but such is the case. Crankshafts have sagged as much as .002" or more in this way.

Fig. 32 (next column). **When testing devices are not available** the crank case may be used as a fixture for testing the alignment of the main bearings of the crankshaft. The case is placed on the bench in the position shown; a strip of pasteboard about 1 in. wide and $\frac{1}{32}$ in. thick is placed beneath the front and rear bearing journals of crankshaft. By these the shaft is raised from the center bearing and side play is prevented.

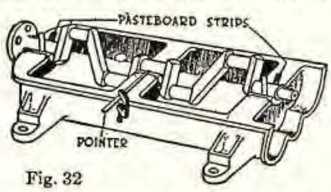

Fig. 32

A pointer is then clamped on to the side of the case at the center bearing, and by turning the shaft the amount it is out of true is determined. This method is not only better but quicker than testing in a lathe.

Figs. 33, 34. **Straightening slightly bent crankshafts where an arbor or straightening press is not available:** There are few repair men who will undertake to straighten a bent crankshaft, and by many it is claimed to be impossible to make a lasting repair to a shaft which is out of true. However, as the repair man is occasionally called upon to "fix it up," and a straightening press is not at hand, one means employed is shown.

It is best to send work like this to concerns equipped for such work, as sometimes it is necessary to heat crankshaft and grind afterwards. Only one experienced knows just how much heating should be done.

The shaft is bent as indicated by the dotted line (A) (Fig. 34), only to a very much less extent, the bend not being visible to the naked eye except when the shaft is revolving in a lathe with a tool or other object held stationary, close to the center bearing surface or crank pin.

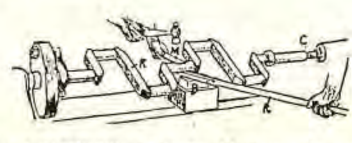

Fig. 33

The shaft **(K)** (Fig. 33) is fixed between the centers **(C)** of the lathe; blocks **(B)** are placed upon the lathe-bed for a fulcrum, and a bar of iron **(R)** or preferably of wood, is used as a lever. If an iron bar is employed, a piece of brass, wood, or lead should be placed between it and the bearing surface of the shaft for protection.

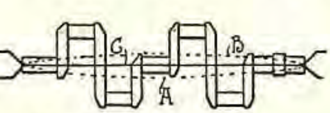

Fig. 34. Bent crankshaft.

Assuming that the shaft is bent as indicated by the dotted line (A) (Fig. 34), it is pried up with the bar till it assumes the position indicated by the dotted line (B), and while held in this position, an assistant holding a piece of brass **(M)** on the bearing surface with one hand, and with a hammer in the other, strikes the shaft a sharp light blow.

The bar and blocks are then removed, the lathe started, and the shaft tested again for results. This treatment is repeated again and again until the shaft is straight as indicated by the line (C). It is generally a long and tedious job, depending **greatly upon chance and the ability of the operator of the bar** to guess the proper amount of pressure to apply and the proper place at which to apply it.

CAMSHAFT ADJUSTMENTS

The camshaft on some engines is a case-hardened drop forging of low carbon steel. It is usually mounted in bronze or die-cast bearing bushings and in some engines on the plain cast iron bearing surface.

The usual troubles are worn bushings which produce knocks and end play, and it sometimes becomes necessary to replace the bushings; or if plain iron bearings, an oversize camshaft is fitted, or holes enlarged and fitted with bronze bushings and reamed to size.

If the front camshaft bearing has worked loose in its bushing, or is worn, the timing gears would be noisy.

If the wear is not too great, the bearing can be tightened by means of an adjustment screw which is provided on some engines, or by replacing the bearing bushings.

On some of the Continental engines the end thrust, or end play is taken up by regulating an adjusting screw in the timing-gear case cover (see question 2, page 795).

Miscellaneous Camshaft Pointers

Before installing a camshaft (or crankshaft), inspect it carefully for cracks and scores. If free of cracks and scores, then check its bearing journals for **roundness** with a micrometer. All journals should be round within .002", and if out-of-round more than this, then regrind or replace shaft.

After this inspection, test for a **bent or sprung condition** by placing on the V-blocks (Fig. 29, page

792); if more than .002" out on center journal it should be straightened (explained on page 792).

A sprung camshaft (or crankshaft) will cause bearings to loosen quickly.

If a camshaft (or crankshaft) has drilled passages for pressure lubrication, see that the passages are clear before replacing.

Clearance: No set clearance can be given. Approximately .001" is usually allowed. When camshaft bearings have more than .002" clearance and camshaft has more than .002" to .003" end play, then new bearings should be fitted and align-reamed or bored to proper clearance. It is difficult to give an exact clearance that applies to all camshafts. Usually, a knock, experience and judgment dictates as to renewal. Some camshafts have adjustment for end play. **Examples** will be given farther on.

To replace camshaft bushings it is usually necessary to remove the radiator, fan, gear case cover, etc. If timing gears are used be sure to note the marks on the gears, and if they are not marked, be sure to mark them. Remove the springs and valves; remove the cam gears and camshaft. Put in new bushings and ream them to a fit.

When reaming camshaft bushings, to prevent knocking, the rear camshaft bearings should be reamed in **perfect alignment** with the front and center bearings. An ordinary reamer is useless because the bushing is driven in and usually battered. Two forms of camshaft reamers are shown below. **After the camshaft is in place** and the gears in position, **check the valve timing.**

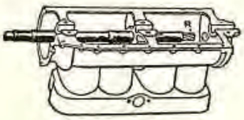

Fig. 37. Camshaft aligning reamer.

Fig. 37A. Camshaft aligning reamer.[1]

If a camshaft is sprung, it is necessary to remove and straighten it or to replace it with a new shaft, otherwise it will cause rapid wear of bearings and produce a knock.

A loose camshaft gear or sprocket will cause a knock (see page 777) explaining further.

When replacing a camshaft, inspect it first for cracks, then roundness, then if sprung or bent as explained for crankshafts on page 793.

Removing a Camshaft; Dodge as an Example

To remove the camshaft, the radiator must be taken off and then the front gear-case cover. The camshaft may then be pulled out after the valve push-rods are tied up, so as not to catch the cams as they slide by, and after the camshaft retaining pin (which will be found on the right side of the engine directly back of ignition unit on cars with 12-volt electric system, and back of generator on cars with 6-volt system) has been removed. This pin fits in a deep groove in the center journal. In the first 40,000 or 50,000 cars the pin was held in place by a setscrew, but the later cars have a spring.

[2]Ford Camshaft Bearings and Camshaft as an Example

To remove camshaft, it is necessary to remove radiator, fan, commutator, cylinder front cover, large time gear, carburetor rods, hot-air pipe, valve cover, gasket, generator, and bracket. The front and center camshaft bearings are held in place by setscrews located in the right-hand side of the cylinder-block in line with the camshaft. These set screws should be removed. Lift valves so that push rod can be raised with fingers until hole in push rod is exposed. A pin is then inserted into the hole in each push rod, in order to insure clearance for the camshaft. The camshaft is then withdrawn by means of a camshaft puller

The front and center bearings are removed with camshaft and are of the split-bearing type. They are held to the shaft by means of circular springs. These springs are removed by inserting a screwdriver under them, and forcing them off. The camshaft may then be tried on the centers as shown in Fig. 29 at (B), page 792.

Check alignment by placing in centers (CP), (Fig. 29). The camshaft should not be out more than .0015" at front bearing; .003" at center and .002" at end bearing. If camshaft is bent, straighten it on a straightening press.

Test camshaft for wear with micrometer. Diameter of bearing on camshaft is .748". If worn more than .0025" install a new shaft. The size of aligning reamer generally used for the camshaft bushings is .750" diameter.

Replacing: Position bearings on camshaft. The center bearing is assembled with notch on bearing pointing towards rear end of camshaft; front bearing with the radius on end of bearing sets toward front of shaft. The old-style front bearing which had a 30° chamfer and notch is assembled with notch towards the rear in order to allow clearance for push-rod head.

If old bearings are installed, check the fit on shaft by positioning bearings on camshaft and place in a vise (but not too tight in vise). Front bearing should fit on shaft with not more than .004" end play and .003" side play. Center bearing is checked for side play only and should fit with not more than .003" side play.

When replacing, oil bearings and place on shaft, being sure the two halves are fitted according to break in cast-iron shell. Place ring over center of bearing and tap into place. Position the two bearings on shaft so the setscrew holes in bearings line up with the setscrew holes in cylinder block. Insert shaft into engine and replace parts.

Oldsmobile 6 (Series E) Camshaft Bearings and Camshaft as an Example

Camshaft bearings: The center and rear camshaft bearing on the "E" series engines are machined in the block. The front camshaft bearing is furnished through service sufficiently machined and ready for installation.

Camshaft bearing adjustment: It will be in very rare instances that the front camshaft bearing will require attention, because the bearings are exceptionally large and well lubricated by positive force feed to eliminate bearing wear. The front bearing takes care of camshaft thrust and should be replaced when the thrust becomes excessive.

To replace the front camshaft bearing, it is necessary to remove the camshaft assembly which can be done by proceeding as follows:

Remove the radiator, the fan belt, and the fan and pulley assembly. Disengage oil pan to pump pipe from the oil pump housing.

Remove the two front engine support bolts and the timing-gear cover.

Remove the generator and gear assembly after which the timing chain can be removed.

Remove the two valve-lifter bracket assemblies, carrying the push rods that rest on the camshaft. The assembly is held in place by means of screws into the cylinder block.

Remove the front camshaft bearing locking screws, then remove the camshaft from the engine.

Remove the lock nut and washer which holds the cam gear on to the camshaft. Press the gear off and remove the bearing.

Care should be taken in assembling to see that the marks on the crankshaft and camshaft gears are in line with the crank and camshaft. This can best be determined by means of an off-set gauge.

In timing series "E" engines, the No. 1 piston should be brought up on the compression stroke and the spark set to occur at exactly upper dead center (spark lever in retard position).

Questions and Answers on Crankshafts and Camshafts

The following questions pertain to some of the Continental engines, but are applicable to many other engines:

Question 1: How can the end thrust or end play be taken up on the crankshaft?

Answer: The end thrust of the crankshaft is taken against the front bearing. To adjust this end thrust, shims are provided between the crankshaft gear and the thrust surface of the crankshaft front bearing. End play is taken up by adding one or more of these shims.

[1] See footnote, pages 714, 790B, as to where reamers can be obtained.

[2] Applies to early model cars. The Ford mentioned, is model "T." The engine bearing service manual mentioned in footnote 6 page 786, will give later information on bearings.

Question 2: How can the end thrust or end play be taken up on the camshaft and timing gears?

Answer: End thrust is taken up by regulating the adjusting screws in the timing-gear case cover. These adjustments should not be disturbed unless it is plainly evident that they demand attention. To check the end thrust, release the lock nut and turn the screw in until it touches against the end of the shaft. When this contact is felt, the screw should be backed off one turn and the lock nut re-tightened (see also page 784).

Question 3: Can the piston and connecting-rod be taken out from below without removing the crank shaft, and is that the best plan?

Answer: Piston and connecting-rod assemblies can be removed from below without disturbing the crankshaft. This is decidedly the best arrangement. Not only can the pistons be pulled, but every bearing of a Continental engine can be got at readily by removing the oil pan. Engines are assembled and inspected in this manner during the process of manufacture in the Continental factories.

CONNECTING-ROD, PISTON-PIN, BUSHINGS AND BEARINGS

Connecting-rods are usually made of I-section drop forgings of nickel steel or of forged aluminum-alloy used with aluminum-alloy pistons.[1]

Parts of a connecting-rod and piston assembly are shown in Fig. 38.

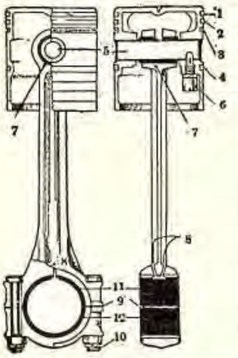

Fig. 38. Piston and connecting-rod assembly. Names of parts are as follows:

1. Piston ring
2. Piston ring
3. Piston ring
4. Oil-regulating ring (oil grooves below)
5. Piston pin[2]
6. Piston-pin lock-screw
7. Piston-pin bushing
8. Con.-rod bearing oil holes[3]
9. Con.-rod adjusting shims
10. Con.-rod bolt, nut and cotter pin.
11. Con.-rod bearing; upper half, in saddle of rod
12. Con.-rod bearing; lower half in connecting-rod cap.

Connecting-Rod Lower End

The lower ends of connecting-rod bearing halves are provided; one in the connecting-rod saddle or seat and one in the connecting-rod cap.

The bearing halves can be babbitt cast integral, or removable die-cast babbitt or bronze-backed-babbitt-lined bearings.

In the forged aluminum-alloy connecting-rods, the lower end bearings are either babbitt cast directly into the rod, or bronze-backed babbitt-lined bearings. Usually, they are babbitted cast integral, as this gives closer metallic bond and thus greater heat conductivity.

It is more difficult to cast the babbitt into an aluminum-alloy rod than a steel rod, as it is harder to get the bond between the metal. The method is to tin the inside of the crankpin end of rod, and then babbitt is cast direct in place in a casting machine. Other kinds of rods are also tinned when babbitt is cast in.)

Adjustment for wear: The bearing cap is fitted either without shims or with shims.

If **without shims** then the bearing cap can be dressed down by filing or surfacing down on emery paper on a surface block or reamed as explained on page 785.

If provided **with shims** then an equal amount of shims can be removed from each side.

Renewal of bearings: If cast integral type the old babbitt is removed and recast again.[4] If die-cast or bronze-backed babbitt lined bearings then they are removed and new ones fitted.

The first bearing on an engine to show the effect of wear, in normal service, is the crankpin bearing in the connecting-rod, the rod half showing considerably more wear than the cap half (see also page 781).

Connecting-Rod Upper End

The piston pin or wrist pin (5) (Fig. 38) is the pin on which upper part of the connecting-rod swings. It is sometimes made of solid steel, but usually of hollow case-hardened steel. It is also called a "gudgeon" pin. It is non-adjustable, and therefore, when worn, the piston pin must be renewed.

Fig. 39 (left). Piston pin showing hole (H) where the lock screw (Fig. 38) holds the pin stationary.

Fig. 40 (right). Piston pin showing groove (G) where clamping bolt (C) (Fig. 41) is clamped tight to the piston pin.

There are three general types of piston pins as follows:

(1) The **stationary,** or "setscrew" or "anchored" type piston pin.

(2) The **oscillating,** or "semi-floating" piston pin.

(3) The **full-floating** piston pin, or "plain pin."

The stationary piston pin[2] (Figs. 38 and 39) is used where there is one bronze **bushing** in the end of the connecting-rod, which **oscillates on the piston pin.** The pin is held tight by a lock screw at hole (H) (Fig. 39). They are usually fitted directly in the piston bosses.

The oscillating piston pin (Fig. 40) is used where the piston pin is clamped to the upper end of the connecting-rod, as shown in (C) (Fig. 41). The bronze bushings in this instance are pressed into bosses in the piston, and the **piston pin oscillates in the bronze bushings.** (See page 796, Fig. 46, showing where piston bosses are located in pistons.)

Piston pins are not fitted to bronze bushings in aluminum-alloy pistons as a general rule, due to the degree of difference in expansion of the two metals; therefore piston pins are usually fitted with a direct aluminum contact. Some cast-iron pistons, also, do not have bushings.

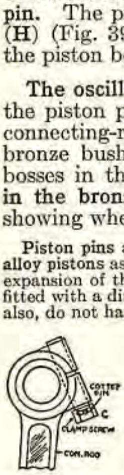

Fig. 41. **Connecting-rod with an oscillating piston pin,** showing clamping screw which clamps the connecting-rod to the piston pin. Sometimes oil holes are provided in the pins to lubricate the pin and bushing.

[1] **Aluminum-alloy connecting-rods now seldom used. Aluminum-alloy pistons** are used considerably. See page 808 giving a discussion of the three forces, namely, centrifugal, inertia, and compression and explosion which cause wear on crankpin bearing.

[2] Piston pin shown here is of the stationary type.

[3] Attention is called to this feature. The holes inside of bearing register with metering or supply hole in drilled crankshaft crankpin, at which time oil shoots up to lubricate piston and cylinder wall. This identifies the force-feed lubrication system. Some rods have oil ducts drilled in rods, or tubes fastened on side of rod to lubricate pin; the lubrication system would then be a full-force-feed system.

[4] Babbitted rods are usually exchanged at car dealer's or at a rebabbitting service station. See footnote, page 801.

NOTE: Two types of connecting rod bearings are in general use on late engines. In one, *bearing metal* is applied directly to the steel forging. The other is the *precision insert type*, steel-back, in which it is not necessary to dismantle the engine and remove the complete piston and rod assemblies (from *Federal-Mogul Engine Bearing Service Manual*—see footnote 6, p. 786).

The full-floating piston pin (not illustrated) works freely in the connecting-rod upper end and in the piston bosses, and is not anchored to either. End motion is prevented by means of a retaining expansion lock ring in the piston boss. This type of pin is a popular design in aluminum-alloy pistons. It is usually fitted without bronze bushings.

Connecting-Rod Bearing Knocks

One method for determining a loose connecting-rod is explained in the *Automobile Digest* as follows:

"After continued use they become worn, producing a dull thud or pound, especially noticeable when the engine is suddenly accelerated or speeded up. This is due to the fact that the bearing becomes elongated, as shown in Fig. 43, since the pressure is in one direction only. For this reason the knock is dull, and is usually worse when the engine is idling.

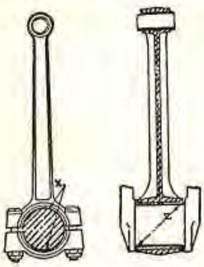

Fig. 43. This illustrates **how the crank-pin bearing wears.** At (X) is shown natural wear, while at (Z) is shown the wear caused by a bent or twisted rod.

"One method of **locating a worn connecting-rod-bearing** which has started to knock is by short-circuiting the spark plug, when two knocks will be noticeable, since the explosion pressure is eliminated. In addition to being caused by a worn bearing, the knock can also be caused by a twisted connecting rod, scored bearing, burned out bearing, or too much end play. In the case of a seized bearing or one that has been burned out, due to a lack of oil, the engine will also groan when starting cold.

"A worn piston-pin bearing can easily be distinguished by a sharp metallic knock occuring twice when the spark plug is short circuited. The knock will appear regularly, and is very sharp when the engine is pulling hard or accelerated." (See also pages 777–779 for testing for knocks.)

Removing Pistons and Connecting Rods

It is necessary to remove the pistons when working on the piston, or wrist pin.

Pistons and connecting rods can be removed on some engines from the top if it has a detachable cylinder head. It is **necessary** to remove cylinder head and oil pan (or lower half of crank case).

An example of removing pistons and connecting-rods from the top is shown in Fig. 44.

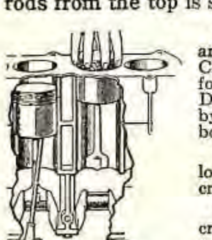

Fig. 44. Method of **removing pistons and connecting-rods from the top** on the Chevrolet engine (series V and X) is as follows: Remove the cylinder head. Drain the oil from the lower crank case by removing the drain plug from the bottom of the case.

Disconnect the oil pipes from the lower crank case. Remove the lower crank case.

Turn the crankshaft with the starting crank until the connecting-rod cap has reached the lowest point of travel.

Remove the cotter pins from the castellated nuts on the connecting-rod cap bolts. Mark each cap so that it may be installed in its original place and position.

Take off connecting-rod cap and remove the connecting-rod from the crankshaft (see Fig. 44).

Place the metal shims and connecting-rod caps in their respective positions and screw the nut on the connecting-rod bolts far enough to hold them in place.

With a hammer handle, long screwdriver, or rod, placed inside the piston from below (see Fig. 44) push up, forcing the piston and connecting-rod out until the bottom piston ring is above the top of the cylinder block, and has sprung out sufficiently to hold the piston and rod suspended in the cylinder wall. Grasp the piston as shown, and lift out the assembly.

Pistons and connecting-rods can also be removed from the bottom on some engines by removing the oil pan or bottom half of the crankcase and then remove the connecting-rod bearing cap from the rod attached to the piston which it is desired to remove.

The bearing cap is usually held by two bolts fastened by castellated nuts. When these are removed the connecting-rod can be swung to one side out of the way of the crankshaft and the entire assembly can be withdrawn from the cylinder.

Be sure to mark all parts when removing them, so that they can be assembled in their respective locations, as before disassembling.

Removing Piston-Pins and Bushings

Removing piston-pins and bushings is best done with a piston vise and press as shown in Fig. 51, or an arbor press. Care should be exercised to prevent distorting piston. A distorted piston can be tapped at its largest diameter with rawhide hammer until nearly round.

If a piston vise or press is not available, methods shown in Figs. 46–50 below can be used.

Where a piston pin is a shrunk fit, as in some aluminum-alloy piston bosses, the pin should never be driven out, but should be removed by immersing

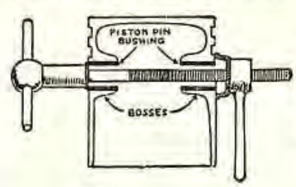

Fig. 46. One method of removing the two bushings from the piston bosses where the piston pin oscillates.

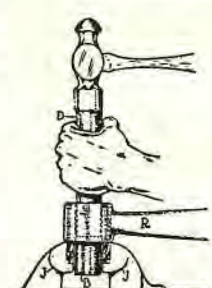

Fig. 47

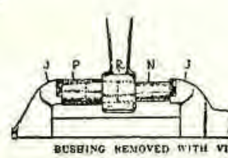

Fig. 48 (upper)

Fig. 49 (lower)

Fig. 47. **One common way to remove an upper connecting-rod (R), bushing (B),** in jaws of vise (J), with a drift or steel bar (D). Fig. 48. **A better way is to press bushing out of** connecting-rod (R), into pipe (P), with (N). Fig. 49. **Another plan:** (B) bolt, (W) washers, (P) pipe, (N) nut.

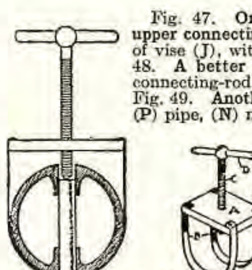

Fig. 50. **A piston-pin remover.** (A) is flat iron tapped to take screw (C). Flat-iron bands are attached so that they can be placed around the piston; then the screw is forced against the piston pin.

Fig. 50

the piston and pin in boiling water or heated oil for approximately one minute. This will usually provide sufficient expansion so that pin can be removed by pushing it out instead of driving out. **In replacing piston pin** the same heating process is necessary to expand piston-pin hole so that pin can be fitted. Pins must be removed or replaced quickly after parts have been heated.

Remarks on Fitting Piston Pins

To check piston-pins for wear, see page 798.

When bushing or piston pin in upper end of connecting-rod become worn, the usual practice is to ream the bushings oversize and fit oversize pins.

New piston pins of standard size (same size as pin removed) can be used if pin fits piston and rod properly. **Oversize piston pins** are usually fitted in used pistons.

When **new pistons** are installed, it is best to use new standard-size pins and bushings. **Bushings** sometimes contract after pressing in, and are **reamed** to fit pin.

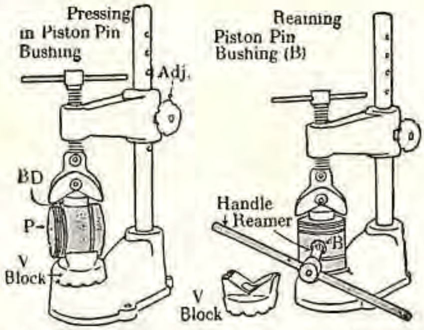

Fig. 51. **Universal piston vise and press,** with babbitt lined jaws designed especially for removing piston pins and bushings.

If reaming is necessary for bushings, the same device can be used to hold the piston for the operation. This device will also hold the piston while fitting rings to the piston, or for scraping carbon from the piston, or while the top, or upper part of the connecting-rod is being clamped to the piston pin.

This vertical vise can be used for many other jobs, as the "V" jaws have a babbitted lined surface which will not injure the finish of the piston. (See footnote, page 803, as to where material of this kind can be obtained.)

Fitting piston pins is a very important operation, and care should be taken to see that the holes through each boss are exactly in line with each other and smooth, and **if reamed,** they should be reamed at a 90° angle to piston skirt, otherwise the piston will cock in the cylinder, as shown in Fig. 76, page 803.

Reaming should be done very slowly, with a sharp reamer and very light cuts, and care should be taken not to remove too much metal and to avoid chattering.

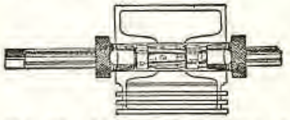

Fig. 52. **An adjustable piston-pin hole reamer.** This adjustable, piloted reamer is shown just finishing one side and entering the other. Two tapper **plug** pilots hold the reamer bar firmly and in proper line.

Fig. 53. **Bushings to go in the piston bosses on oscillating-type piston pins in cast-iron piston, or in the upper end of the connecting-rod on stationary type piston pins.**

Fig. 54. **A self-aligning piston-bushing reamer with pilots on each end to insure perfect alignment and a perfect fit the first time through. The spiral is fluted with steel blades.**

When reaming a split-end rod oversize for an oscillating piston pin, shim the split, draw the clamp bolt up tight and ream until the pin just slips in.

When reaming bushed rods, allow some clearance for oil film. A piston pin should be so fitted that it will just hold the weight of the connecting-rod and no more.

A loose-fitting piston pin with too much clearance will cause a piston-pin knock which will eventually mean that the pistons will have to be reamed and new oversize pins installed.

On the other hand, if it is too tight a fit, it will cause trouble, because there must be room for a film of oil on the pin. Piston pins fitted too tightly are likely to "seize" and score the piston. A well-fitted pin will last for some time.

Piston-pin locking: Exercise care in fastening the pin securely in the connecting-rod or piston, according to the type used. Securely lock the set and clamp screws. When cotter pins are used, be sure they are of ample size, and that they are spread apart after being inserted.

Piston and connecting-rod alignment: Assemble piston, piston pin, and connecting-rod and square them so that the piston is not cocked in the cylinder. Alignment instructions of the connecting-rod and piston assembly and connecting-rod and piston pin is shown in Figs. 72, 73, page 803.

Fitting Piston Pins

Piston-pin clearances given are approximate. No definite clearance can be given, as it varies with construction, design and lubrication systems and manufacturers differ. Therefore **follow manufacturer's instructions.** See page 795 for **explanation of types of piston pins.**

Fitting a stationary type piston pin to cast-iron piston: Fit in the plain cast-iron bosses with a light drive fit.

Fitting an oscillating type piston pin to cast-iron piston where bosses are bushed with bronze bushings: Fit in bronze bushings with a slight drag.

In the for example, the fit is such that rod will drop gradually when piston is held in both hands and given a quick shake, as shown in Fig. 57.

Fitting a stationary or full-floating type piston pin to aluminum-alloy piston: Aluminum expands more than cast iron and piston pins are accordingly **fitted somewhat tighter** where steel to aluminum contact is made, and care must be taken to secure a smooth reamed hole. Manufacturers differ as to fitting methods, as will be observed below, and it is advisable to obtain manufacturer's instructions. **The following method is recommended by one manufacturer:**

"While piston is cold, ream bosses as near piston-pin-size as possible, but not quite large enough for the pin to enter hole. Then **heat the piston in boiling water** (to expand piston-pin hole) and tap pin lightly into place with a small wooden mallet. If pin does not tap easily into place while piston is hot, increase the size of the boss hole (**when cold**) until it does."

Another manufacturer suggests this for set screw type piston pins: "Fit set screw type pins with .0005" less clearance on side where pin is anchored. This can be done by entering reamer on side opposite where pin is anchored; on semi-floating and full-floating pins use a hand push fit."

Fitting an oscillating piston pin to aluminum-alloy piston. This method is followed by some repairmen: A hole should be reamed so that the pins can be hand-pressed in by holding piston in one hand and pressing in the pin with heel of palm of other hand when piston is cool. The bosses are not bushed but plain.

Bronze bushings are not usually fitted to aluminum-alloy pistons. Due principally to the great difference of expansion between the two metals, the aluminum when hot, would work free from the bronze bushings, so that they would become loose.

Fitting Connecting-Rod Upper End

Fitting connecting-rod upper end to piston pins in cast-iron or aluminum-alloy pistons where connecting-rod is free to work on piston pin and a bronze bushing is provided in upper end of rod (bronze to steel contact): Fit with a slight drag. This fit can be the hand-pressed fit with palm of hand, as explained. If piston pin is found to be slightly too tight, it can be loosened by driving pin in and out of bushing with a mallet or tapping the rod around the bushing with a hammer.

Sideplay of upper end of connecting-rod between the rod and piston bosses varies; usually about $\frac{1}{8}$" is allowed. This endplay at upper end of rod is necessary on account of the endplay in the crankshaft and also on account of elongation of the crankshaft when heated.

Fitting Piston-Pins;

piston pin oscillating type. The connecting-rod clamps to the pin and the pin oscillates in the bushings in the piston bosses.

Before installing the old piston pins and rods in a new piston, check for wear and alignment.

Piston pins are checked for wear by measuring the diameter of the pin with a micrometer.

if the old pin is worn down .001" or more below the low limit, a new pin should be installed.

To check the play between the piston pin and the piston bushings: Hold the piston with the piston-pin perpendicular to the bench with the left hand (Fig. 55), while with the right hand, the connecting-rod (lower end only) is moved up and down, causing the pin to be rocked against one side of the bushing and then the other. If there is .002" or more play, a new pin should be fitted and, if necessary, the piston bushings should be replaced.

Note: Wash oil out of pin and bushing surfaces, as oil will cushion and the full amount of wear will not be discernible.

The pin is removed by running out the connecting-rod clamp screw, after which the pin may be pushed out. Every repair shop should be equipped with a piston clamp, or vise.

Fig.55

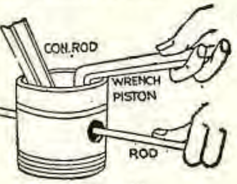

Fig. 56

If no clamp is available, the piston may be held by means of a rod (Fig. 56) through the piston pin while loosening or tightening the rod. The practice of holding the rod in a vise invariably results in a twisted rod.

The piston pin, when properly fitted, will wear very slowly, but when carelessly fitted, it will wear the bushing in a very short time, causing a noisy engine and excessive wear on crankshaft bearing.

The piston pins are usually fitted in the bushings by selective fit. A pin is tried in the bushing. If it turns freely, another pin is selected until one is found which requires a fair amount of effort to force it in and turn it. Since the piston pin is harder than the bushings, it is usually necessary to renew the bushings to insure a properly fitted pin.

The bushing can be removed on an arbor press by pressing bushing out from inside of piston. The piston is then turned over, and the other bushing is forced out in the same manner. When pressing in the new bushings, it is important to have them line up properly with the hole in the piston, as a cocked bushing requires considerably more pressure to force it in, throwing the piston out of round.

The bushing should be pressed in until about $\frac{1}{16}$" **of the bushing shows on the inside of the piston, or until it is** $\frac{1}{32}$" **inside the outside diameter of the piston.** When the bushings are in place, they should be line-reamed to size with a pilot-type reamer.

Reaming the piston-pin bushings: If a reamer[2] is used which has no pilot, only one of the bushings should be removed at a time, and the reamer should be inserted through the old bushing to act as a guide in reaming the new one. The old bushing is then replaced and the reamer is inserted through the reamed bushing as a guide in reaming this one.

If no piston clamp (Fig. 51) **is available** the reamer should be held in a vise and the piston turned by hand.

When the new pin has been fitted, as described, it is removed and oiled. It is well to rub a little oil in the bushings as well. Hold the rod in the piston and force the pin into place. Turn the pin until the groove (G) (Fig. 40, page 795) lines up with the connecting-rod clamp-screw hole, and insert the clamp screw.

Run the clamp screw down with a socket wrench; remove the piston from the clamp, and press the rod from one side of the piston to the other to **see that the pin does not extend outside** the diameter of the piston. If it does, remove the rod and pin and press the bushing on that side in a little farther. If it does not, set the piston in the clamp and tighten down the cap screw with a special wrench, and insert the cotter pin.

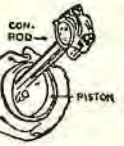

Fig. 57

Fig. 57. **The assembly may now be tried** as shown. The rod should drop gradually when the piston is held in both hands and is given a quick shake.

Piston Pins

While the standard pins can usually be secured from stock in .003", .005", .010" or .015" **oversize,** it sometimes is necessary to order special ones. That there may be no confusion in ordering special sizes, be sure to give the oversize above standard, the make of car, model, engine, diameter and length, slot or set-screw hole, width and depth of slot, diameter of set-screw hole, distance from center of set-screw hole to end of pin; and also state if the pin has oil holes or oil grooves.[1]

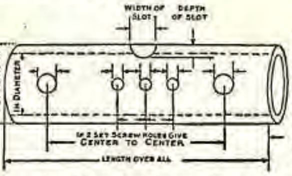

Fig. 58. A handy diagram to copy and fill in what is needed when ordering special piston pins. (By courtesy of Heald Machine Co., manufacturer of cylinder grinding machines, Worcester, Mass.)

Oversize identifications: The practice of painting the ends different colors has been generally adopted by oversize piston-pin manufacturers, in order to identify them, so that they can be readily distinguished from one another.

Remarks on Connecting-Rod Lower End

As in the case of the main bearings, there are caps fitted to the lower part of the connecting-rod (see Fig. 38, page 795), which in this instance have **removable split bearing halves** (11, 12) in both the connecting-rod bearing above the crankshaft and in the cap below the crankshaft.

On some connecting rods, the lower part of the connecting-rod and the bearing cap are **babbitted, or cast integral** (or cast-in) and when the lower part of the rod is worn or burned, a complete new connecting-rod with lower cap is necessary. Rods of this kind can be **exchanged** for new ones which is cheaper than refitting.

When a bearing is scored or burned, refitting of the bearing is the only remedy.

A scored bearing is one having the surface slightly roughened, but where the babbitt metal has not been burned or run.

A **burned bearing** is one having the surface badly roughened or where the babbitt has melted or started to run.

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[1] Piston pins, bushings, etc., oversize and standard, can be secured of automotive supply houses as listed on page 686.

[2] **Some of the manufacturers of piston-pin hole and connecting-rod bearing reamers** and boring tools, who issue instructive printed matter on this subject are Automotive Maintenance Mchy. Co., Chicago, Ill.; Foster-Johnson Reamer Co., Elkhart, Ind.; Shephard-Thomason Co., Los Angeles, Calif., Taft-Pierce Mfg. Co., Woonsocket, R.I. See also list of manufacturers on pages 790B, 803, 714, and automotive supply houses page 686.

Adjusting Connecting-Rod Lower Bearings

Loose connecting-rod bearings are detected by a kind of metallic sound or knock when the engine is running at idling speed or accelerated.

To test, in order to determine which rod is loose, a good method is to run the engine at idling speed and to disconnect one spark plug after another. The knock will either cease or will sound as if there are two knocks, when the cylinder is found in which the rod is loose (see also page 778 testing for knocks).

After determining that a connecting-rod is loose remove the oil pan. Turn the crankshaft (first remove the spark plugs to relieve the compression) so as to place the rod bearing in a convenient position for inspection. Take hold of the rod and, by a vigorous push up and down, ascertain whether there is play. If so, the looseness can be felt.

Do not, however, mistake the side play for looseness, as there should be an appreciable amount of **side play.** At the same time, too much, or an excess of side play indicates wear on the sides.

If the bearings are found to be loose, pull the cotter pins out and remove the nuts. The cap can then be removed.

Next, examine the bearing and see if it is cracked, worn thin, scored, or burned. If so, it will require new bearings and refitting explained farther on.

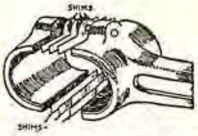
At the same time that the bearing is being examined, examine also the crankshaft bearing pin to see if it is scored or cut. If so it will cut the bearings, and the crankshaft should have the pin dressed down as explained on pages 791–793.

If the bearings are only worn, and have a clean polished surface otherwise, then they can be adjusted.

Adjusting: What has been said concerning the main engine bearings also holds good for the connecting-rod bearings. The two bearing halves may be brought closer together by the **removal of some of the shims** between them, or **dressed down** if shims are not provided. (See pages 784A, 785.)

In the majority of engines removal of lower half of crank case gives access to the connecting-rods.

Note. When **removing caps and connecting-rods, mark them.** Also be sure that the connecting-rod bearing caps are placed with the oil holes facing the direction in which the rod dips in oil troughs with an engine using splash lubrication, because oil is forced into these holes when the engine is running.



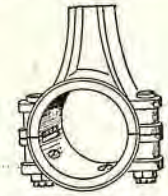


Fig. 59. **Connecting-rod lower bearing end with cap removed to show shims** placed between the upper bearing and cap. By removing a shim the cap is drawn closer to the upper bearing, and hence it would be tighter on the crank pin. The shims shown above are the loose-leaf type. The laminated type of shims is often used.

Fig. 60. **Connecting-rod lower bearing end of the shimless** type with cap drawn up. By dressing bearing cap and connecting rod, they can be drawn tighter to compensate for wear.

Fig. 61 (right). **When removing rod (R) or cap (C) examine for file marks;** if none, mark them. See also Fig. 68, page 802.

Adjusting Connecting-Rod Bearings Where Shims Are Used[1]

1. **Drain oil** and remove under hood.
2. **Remove spark plugs** (to relieve the compression when testing by cranking).
3. **Disconnect oil line** at rear of case, remove cap screws, and drop oil pan.
4. **(If cotter pins are used) remove,** back off all locking nuts one complete turn (using special wrench T269).
5. **Turn engine to position for adjusting connecting** rod, or lower dead center.
6. **Remove locking nuts and cap** from con.-rod.
7. **Remove equal amounts of shims from each side of rod** if loose shims are provided, but if not sufficient, remove strips from laminated shims. Replace cap and tighten nut.
8. **Turn engine to see if there is a slight drag on the crankshaft.** If there is no drag remove additional shims until a slight drag is detected.
9. **Replace one .002″ shim on each side** to give bearing proper running clearance.
10. **Replace cap and locking nuts;** tighten the nuts.
11. **Turn engine over to check running clearance** (.002″). Bearing should run free of drag, but with no appreciable looseness. See page 785, "testing after adjusting."
12. **Before proceeding to adjust the next rod again loosen locking nuts** one complete turn on rod previously adjusted.
13. **Adjust the remaining five rods using the same** method explained above.
14. **Tighten all locking nuts; test for running clearance** (.002″) and if cotter pins are used, replace them and spread the ends.
15. **Wash oil pan thoroughly and be sure sumps are filled.** Replace oil pan and oil line at rear of case.
16. **Refill** with 7 quarts of oil.

Caution: Loosen cap screws in cam gear-case cover and insert screwdriver between case and cover on each side to prevent injuring the gasket before letting pan down. **If any gaskets are injured during above operations, replace with new to prevent oil leaks.** Use a sheet of thin metal over face of gasket to prevent tearing it when putting on oil pan.

Adjusting Connecting-Rod Bearings Where Shims Are Not Used

If the connecting-rod bearings are not fitted with shims, then the bearing cap must be dressed down, as explained on pages 784A, 785.

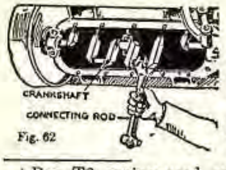
Fitting Connecting-Rod Lower Bearings

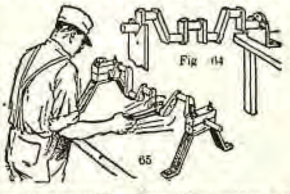
When the bearings in the lower end of the connecting-rod and cap are badly worn, cracked, burned or scored, it will be necessary to install new bearings if they are of the **removable type.**

If of the plain solid **cast-integral, or cast-in babbitted type,** a new connecting-rod and cap will be necessary, or they will have to be re-babbitted. Usually they are **exchanged** at the service station for a new rod.

In either case, it is necessary to fit the bearings to the crankshaft connecting-rod bearing pins.

In many instances, this work can be done under the car, by removing the oil pan, disconnecting the connecting-rod caps, and removing the rod and pistons from the engine. See also Fig. 44, page 796.





[1] Reo T6 engine used as an example. See illustration of this connecting-rod on page 784B (splash lubricated).

It is best, however, to do this work with the crankshaft removed, because at that time the crankshaft can be tested for alignment and crankpins can be examined more freely and the work will be better.

Two home-made methods are shown (Figs. 64, 65), **for supporting crankshaft while fitting the connecting rods.** The crankcase can also be turned upside down and the work can be done while working on the main bearings and while the engine is on the bench and after the main bearings have been fitted.[1]

Various Methods of Refitting Connecting-Rod-Lower Bearings

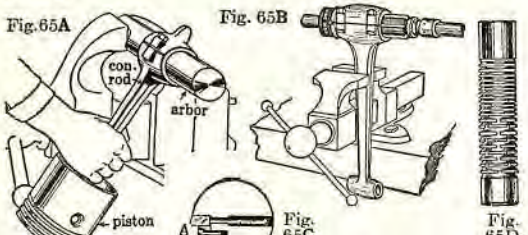
There are various methods for fitting the connecting-rod to the crankpin, which is similar to the main bearings:

1. By spotting-in and scraping.
2. By reaming.
3. By boring.
4. By broaching.
5. By burning-in and burnishing-in.
6. By lapping with a grinding compound.

Spotting-in and scraping: This work can be done with the **crankpin** to be fitted used as a gauge, and additional shims added for clearance after bearing has been fitted.

When fitting shimless rods, a good practice to follow is to **fit to a mandrel or arbor** the size of the crankpin diameter (Fig. 65A) and enough oversize to give the proper clearance to the bearing, approximately .001" per inch diameter. Measure crankpin with a micrometer and add the amount of clearance to crankpin diameter; this will give the proper diameter for mandrel. Care should be given to the finishing of mandrel to secure a smooth surface.

Spotting-in and scraping is usually done when rod bearing boring, or reaming fixtures are not available, and when very little metal is to be removed for fitting.



To spot-in and scrape proceed as follows: After sufficient shims have been removed from between the cap and rod, so that the bearing fits tight on the shaft (providing shims are used; if no shims, cap must be dressed down) the rod nuts are taken off and the shaft bearing, or arbor surface is given a very thin coating of "marking" compound (Prussian blue or lamp black)

Put the connecting-rod on crankshaft or arbor with the piston end hanging downward, and with all shims in place, and put on the cap and draw it up tight. Be sure that caps are fitted on according to the punch marks on the cap. Then swing it around the shaft twice in one direction.

Next remove the cap and examine bearing for blue spots. The "high spots" inside the bearing will be found marked in blue, showing that at these points the crank or arbor touched; the part which is white the crank or arbor did not touch. The problem is, therefore, to get the high spots down by **scraping,** until the bearing will mark for about three-fourths over its surface. **Remove high spots with scraper** as shown in Fig. 9, page 787.

This marking or "spotting-in" process is repeated from time to time till the whole surface is marked as shown at (D) (Fig. 11, page 787), and until all "high-spots" are removed and the bearing surface is smooth and touches the crankshaft at all points evenly. The upper part of the rod is scraped first, then the lower bearing cap.

After scraping is done, the burnisher shown in Fig. 10, page 787, may be run over the entire surface of the bearing to shine it up and smooth the surface.

When fitting is completed, test. With all nuts down, the connecting-rod should be just snug enough so that when the piston and rod are placed in a horizontal position they should, of their own weight, move to a vertical position with slight drag. If fitted too tight, seizure will result.

When testing the bearing, keep in mind that while it should have no appreciable amount of looseness, this does not mean that the drag on the shaft should prevent its free rotation.

Reaming:[2] This is a process generally used when fitting new bearings to crankpins that are true or have been ground true.

Connecting-rod bearing reamers, shown in Fig. 65**B** (adjustable flute type) and Fig. 65C (a fixed size non-adjustable reamer), eliminate the slow method of hand scraping. This gives a very smooth glass-like bearing surface. There are a number of other designs.

Some manufacturers claim proper alignment can be obtained by reaming without a fixture, whereas others claim that an aligning fixture is necessary when reaming. A connecting-rod bearing (Fig. 65B) is shown being reamed without a fixture by use of one centering bushing and a short reamer bar.

In Fig. 65C the Ammco reamer is shown; the body of reamer is ground to the diameter of size of crankpin, and cutting blade (A) is set to project .001" to allow for a diametrical oil clearance of .002". Reamers can be had for all makes of cars in standard sizes, undersizes and oversizes. Undersize reamers are used when crankpin has been machined undersize.

Boring:[3] This is a process similar to reaming, but differs in that only one cutting edge is used and the work is done with a special sharp boring tool mounted in an aligning jig or fixture.

Broaching: A broach for broaching connecting-rod bearings and piston-pin bushings is used considerably by some manufacturers. A type of broach (Fig. 65**D**) has been developed to meet the demand of garages and service stations that do not have sufficient work to warrant the purchase of a broaching machine.

Operation: Select the broach of the required size, insert starting end in the hole to be broached; place under arbor press, and press through as you would an arbor. Broaches are made in standard, oversizes and undersizes. Stroke of arbor press required is 11 inches. One type of press suitable for this purpose is shown on page 693, Fig. 9A. (The J. N. Lapointe Co., New London, Conn. is one of the manufacturers of broaches.)

Burning-in and burnishing-in: This subject is dealt with on page 789. In burning-in bearings, the operations are the same up to the point where actual scraping begins under the spotting-in and scraping method, the scraping being avoided by placing the crankshaft assembly in a burning-in machine.

Where a running-in machine is not available, connecting-rod bearings can be spotted and scraped (using thin layer Prussian blue on crankpin) until approximately 80 per cent of bearing shows contact with pin. Then adjust bearings with slight drag (testing each bearing separately); flood crankcase with oil and run in under own power.

Note: In some cases (after reconditioning bearings) it is advisable to remove oil pan and inspect **and adjust bearings** after approximately 1,000 miles of running.

[1] Another advantage in fitting connecting-rods in this manner, lies in the fact that the bearings are "spotted" to the shaft. The connecting-rod can be turned a complete circle, thus insuring a more perfect marking, or, in other words, the entire circumference can be "spotted." Crankshaft supports and other bearing fixtures can be obtained of firms mentioned in footnote, page 803.

[2] See footnote, pages 790**B**, 798, and 714, as to where to obtain reamers.

[3] Many of the concerns listed on page 790B supply boring tools and fixtures for boring connecting-rod lower bearings and also rebabbitting equipment.

Miscellaneous Pointers

When the bearing is being fitted to the shaft, clean and lubricate it thoroughly, so that there will be a film of oil on the bearing when engine is started. After fitting bearings, "run-in" engine bearings as explained on page 833A.

Oil grooves: Do not overlook the oil grooves when fitting the connecting-rod bearings. Remember that oil grooves wear thin in a worn bearing. Also see that all burrs and other obstructions are removed from oil holes.

When new connecting-rods are installed, the connecting-rod should be tested for alignment before and after it is fitted to the piston; see page 803.

When fitting a new connecting-rod to an old shaft, the crank pin is sometimes undersize and it is not only necessary to remove the shims, but also to dress off the sides (face) of the cap. **If a crankpin bearing is badly undersize,** it is necessary to dress the face of both the cap and the rod.

If, as already suggested, the shaft is badly undersize, and all connecting-rods require replacing, it is usually less expensive to install a new crankshaft.

Lapping with grinding compound: See page 790B.

Connecting-rod lower bearing clearance: This depends upon size of crankshaft crankpin, design of engine and lubrication system. About .001″ for each inch of crankpin or journal diameter is considered approximately correct, which space is occupied by an oil film on pressure lubricated bearings. See also page 783, testing resistance, etc.

Splash-lubricated bearings usually require a slightly closer fit than those with pressure feed; the fit might be termed a snug fit with some drag, whereas on **pressure-lubricated** bearings the fit must be free of drag. See page 783, and refer to testing resistance, etc.

Side play or clearance of lower connecting-rod bearings is usually about .002″ to .003″.

The fitting of aluminum-alloy connecting-rods to the crankpin bearings should be given careful attention. The clearance on this bearing fit, as stated by one manufacturer, should be about .0015″ on the diameter. See also page 808.

How Connecting-Rods are Babbitted

Connecting-rod bearings are, in many cases babbitted or cast directly into the rod and cap, termed **"cast-in type."** The cast-in type may be described as a **non-removable type** of cast bearing. As the name implies it is built by filling the bearing seats with molten babbitt metal by any one of several processes as mentioned on pages 781, 782.

It is always best to have the rods re-babbitted at the factory or service station. Some makers even **exchange**[1] the rods in order to facilitate service.

For example, the following wording is taken from the Oakland six instruction book:

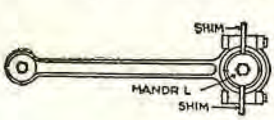
"The connecting-rod bearings are a high grade of babbitt cast directly into the rod, and are usec without shims. The high quality of babbitt and large bearing surface insure a very long life for this bearing and when it has become worn to a point where there is looseness producing a pound, we recommend that it be **exchanged** for a new rod at our service station. The upper end of the connecting-rod carries a bronze piston pin bushing."

At the present time the most widely used method of inserting or bonding the babbitt metal to lower end of rod and cap is by the **centrifugal process** wherein the rod is held stationary with the big end surrounding a rapidly revolving hollow mandrel provided with suitable outlet holes through which the molten babbitt is ejected on to the previously tinned surface of the big rod end. By regulating the temperature the babbitt metal cools just enough to adhere to the rod and allow building up to the desired thickness. Due to the high centrifugal pressure on the babbitt, there is little chance for air pockets and a dense, close-grained layer of babbitt of desired thickness is secured. This is termed a **"spun-bearing."**

Another method consists in pouring the molten babbitt **under air pressure** between a stationary mandrel and big end of rod. With the exception of the metal being forced into place by pressure the process is similar to gravity pouring with a ladle and stationary mandrel. The **above** two methods are usually **factory methods.**

Babbitting a Connecting Rod; Gravity Pouring

As an example of gravity pouring with a ladle and stationary mandrel the following is given:[2]



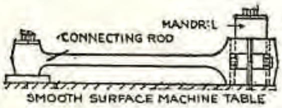


Fig. 66 (left). A simple method of holding the connecting-rod for re-babbitting the large end.[3]

Fig. 67. Method of grooving re-babbitted bearings.

To pour and bore these bearings requires some skill, and it is a difficult job to set up. A simple method is depicted in Fig. 66, in which a **machine table,** such as that of a shaper or milling machine, is used, as these have T-slots to fasten the work to.

To get the new lower bearing in line with the piston-pin bearing is not easy, but if the ends of the piston-pin hub are in good shape, one of these can be blocked up and bolted down on the machine table. Then with the babbitting mandrel held vertically and located from the center of the piston pin, the bearing will line up within scraping distance, the setting being obtained by measurements.

The babbitting mandrel can be made of wood, which will leave a fairly smooth babbitt surface. It must be bolted down to prevent shifting when pouring the babbitt. If a metal mandrel is used, it should be heated before using.

To form the two halves, a liner is inserted on each side that touches the mandrel, both halves being run at the same pouring.

The babbitt can be heated in a ladle, using a slow heat and stirring frequently. For best results the babbitt should be poured at the proper temperature, which is that at which it will char a pine chip, but will not ignite it (or a dull red, see also page 790).

When the metal has reached the pouring temperature (between 800° and 840° F.), the rod should be tinned and heated[4] somewhat. This prevents sponginess and blisters in the babbitt. Stir and skim off **dross** just before pouring, and pour rapidly.

Note: A popular babbitt formula contains 85 per cent tin, 7½ per cent copper, 7½ per cent antimony with a maximum of 1 per cent lead. The metal is usually **heated to 800° F.** while the tin melts at 450°. It will start to oxidize and form a dross

[1] See p. 690 under "Connecting Rods."

[2] From *Automobile Digest.* See also p. 790 on babbitting.

[3] **Machines for rebabbitting main and connecting rod bearings can be obtained of:** Automotive Maintenance Machinery Co., 2100 N. Commonwealth Ave., Chicago, Ill.; Freeport Machine Works, Inc., Freeport, Ill.

[4] **Tinning compound should be put on hot rods before babbitting.** The Metal Bond Mfg. Co., St. Louis, Mo., make such a compound, also brazing and welding flux.

on top which looks like dirt but is **tin. Each time you skim it you are reducing the percentage of tin, and the babbitt becomes harder and harder.**

After the bearing has cooled, the oil holes can be drilled, and then the final operation of fitting (see page 790A) can proceed. It will be necessary to cut new oil grooves, which can be accomplished with a hammer and cape chisel, as shown in Fig. 67.

Pointers on Connecting-Rod Bearings as Usually Found on Tractor Engines

Rods and caps should be marked: Before removing any of the connecting-rods they should be examined for identification marks (Fig. 68). The marks referred to are placed on the connecting-rod and cap, so that they may be reassembled in their original positions.

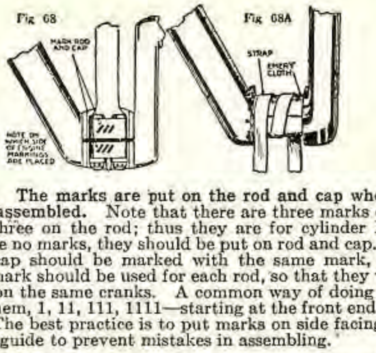
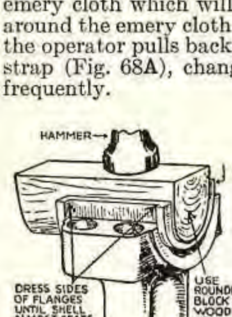


Fig. 68. **The marks are put on the rod and cap when the engine is assembled.** Note that there are three marks on the cap and three on the rod; thus they are for cylinder No. 3. If there are no marks, they should be put on rod and cap. The rod and cap should be marked with the same mark, but a different mark should be used for each rod, so that they will be put back on the same cranks. A common way of doing this is to mark them, 1, 11, 111, 1111—starting at the front end of the engine. The best practice is to put marks on side facing camshaft as a guide to prevent mistakes in assembling.

Fig. 68A. **Dressing-down a crankshaft connecting-rod bearing pin** which is slightly scored, without removing crankshaft.

Bearings must be fitted to a perfectly round bearing pin: When the connecting-rods have been removed, the shaft should be tried for roundness. This is easily done with a pair of calipers carefully handled. If the shaft is found to be out of round or scored, there is no use fitting new bearings without first dressing down the shaft.

This work may be done at the time, without removing the shaft if the shaft is not in very bad shape. Wrapping around the journal a piece of emery cloth which will cover it for the full length; around the emery cloth a strap is wrapped once, and the operator pulls back and forth on the ends of the strap (Fig. 68A), changing position of emery cloth frequently.



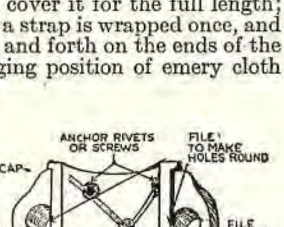


Fig. 69. When bearing flanges are too thick dress with a file and use a half-round block.

Fig. 70. Connecting-rod bearing cap, with bearing half.[1]

Fig. 71. A type of connecting-rod of heavy construction, usually found on tractor engines.

Fit backs of bearings to seats: Inspect bearings for oil and set screw holes to locate bearings to match holes in bearing seats. When flanges are too close to permit bearing to seat properly, dress off sides of seats, however bearing must fit very snug. Tap bearing in place with hammer and a block of wood. Avoid distorting bearing (Fig. 69).

Bearing anchored to prevent turning: With bearing properly seated, insert anchor screws or rivets and tighten in place; screws should be peened with a hammer or punch, on the end of threads to avoid coming loose.

Bearings that do not have anchor screws or rivets should be carefully fitted so that the edges of bearing have a full and rigid contact against the shims when cap is bolted in place.

Bearings that are full halves and that do not use anchor screws, rivets, or shims should also be fitted with a full and rigid contact at the edges when cap is bolted tight. To secure this rigid contact, allow bearing halves to project slightly, about .002" above the edge of seats (see also Fig. 3G, page 784A).

Fitting bearing to shaft: Face off sides of bearing flanges, allowing enough clearance for side play (about .003"). Scrape bearing **fillet** (rounded edge of babbitt lining) to fit fillet on shaft (rounded corner of crankpin). In order to do this enough babbitt metal is removed by scraping fully to install bearing to secure full contact with crankpin. Operator is now ready to "spot" bearing for a final fit.

To spot and scrape: Coat the crankpin with a thin layer of Prussian blue (a very thin coat applied with tip of finger and rubbed all around journals is sufficient; too much gives poor and uncertain spotting).

Insert the same thickness of shims in each side of bearing, allowing the bearing to have a tight fit when cap is bolted tight in place; turn rod two or three times around shaft in one direction only; remove cap and "spot" with bearing scraper; remove with a slight cut only the "high spots" marked by the Prussian blue; deep cuts exaggerate the rough surface and will result in indefinite "spotting-in."

Assemble and bolt cap in place and repeat "spotting-in" operation until approximately 80 per cent of bearing shows full contact with journal.

Assembling bearing: Clean off journal and bearing faces and inspect oil holes and grooves. Remove cuttings to prevent clogging of oil holes and grooves; cut grooves deeper if too shallow; apply oil to bearings; install or remove the same thickness of shims on opposite sides of bearings to adjust them; bolt cap in place, allowing oil clearance (see page 784A).

Always **adjust bearings with shims** when shims are used. When **shims are not used, file or dress off** faces of caps when too loose, **or scrape** bearing for clearance if too tight, but **never tighten or loosen a nut or capscrew to adjust a bearing,** as caps should always be drawn or bolted tight. Now install new cotter pins.

Bearings should never be adjusted so tight that shaft cannot be turned with starter or with starting crank. The only exception to this is when the bearings are to be burned-in or run-in on a running-in machine; refer to page 789.

Main bearings: The main crank-shaft bearings are fitted in much the same way, except that all the upper bearing halves must be fitted at the same time. Fitting one bearing at a time would be pretty sure to result in getting one lower than the other, which would cause the shaft to bind when the caps were put on. The caps may be fitted one at a time.

The job of fitting bearings calls for care, precision, and a certain amount of mechanical ability. The work outlined above may easily be adapted to almost any kind of engine bearing.

[1] See also Index: "Adjusting truck-engine bearings."

ALIGNMENT OF PISTON AND CONNECTING-ROD

When new connecting-rods are installed, the connecting-rod should be tested for alignment before and after it is fitted to the piston. The rod may be slightly twisted or bent and good results will be obtained only by having the piston pin parallel with the crankshaft bearing (Fig. 73) with the proper clearance between the piston pin bosses on the piston and the end of the connecting-rod.

After fitting the piston to the connecting-rod, a further check can be made by the use of connecting-rod fixture shown in Fig. 72, or if the fixture is not at hand by clamping the connecting-rod to an arbor as illustrated in Fig. 75 and testing for alignment with a combination or carpenter's square.

After having fitted the bearings, as previously explained, the rod bearings should now be tested for **parallelism.** The piston pin and the crank-throw must be parallel, and the bearings that they move in must also be parallel, or binding and rapid wear will take place. This should be done before and after scraping the bearings (Fig. 72).

If the connecting-rod is distorted or bent, to even the slightest extent, it will cause a knock or "piston slap" and wear on one side of the cylinder wall, and will also cause the rings to stick and leak; therefore, before assembling, some means must be found of determining if the piston is in perfect alignment with the connecting-rod, crankshaft, and cylinder.

Very often, knocks that develop in engines (after they have apparently been thoroughly overhauled), will be found to be due to the fact that the **connecting-rods are slightly bent sidewise,** or got out of true when fitting the cylinders down over the piston, or when removing and replacing them. One cylinder will get a slight lead, or one ring does not properly enter, the cylinders are twisted, and in an effort to align them, the rods are bent. When the engine is finally assembled, it is very noisy, due entirely to the fact that one or more of the rods have been bent sidewise, and when the force of the explosion is exerted on the piston head, the wrist-pin end of the connecting-rod is driven sidewise against the piston boss.

There are three disalignments possible in the piston and connecting-rod: piston pin not parallel with crankpin; rod bent, or improper offset in "offset" rods; twist in rods. Before replacing these parts they should be tested on a device as shown in Figs. 72 and 73.

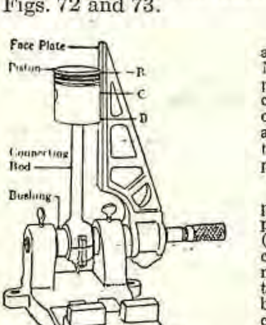


Fig. 72. **A connecting-rod and piston aligning jig or fixture.** Note that the test is for the purpose of ascertaining if the **connecting-rod is bent sidewise or if cross bore of piston is accurate** (meaning that the piston-pin when inserted will be parallel to the crankshaft).

If all of the skirt (**C** to **D**) of piston comes flush with the face plate and if they touch at points (**C** and **D**), then the piston and connecting-rod are in alignment. If, however, the piston touches at the bottom at (**D**) but not at the top (**C**), then the connecting-rod is bent to the left. If it touches at the top (**C**) and not at the bottom (**D**), it is bent to the right. Note that the test is made on an arbor and bushing the size of crankpin. After testing one side, remove connecting-rod and reverse and test the other side. **If bent, straighten with bar** (Fig. 74)

Note: Tapered pistons are smaller at top than at skirt. For example, a Ford piston is .010" smaller at top; therefore there should be a clearance of .005" at (**B**) between top of piston and face plate. The bottom, or skirt of piston (**C** to **D**) should fit snugly against face plate without any clearance.

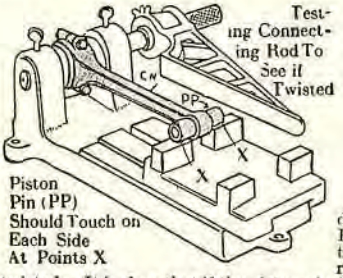
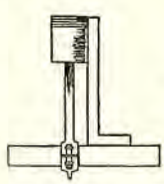


Fig. 73 (left). Same device as shown in Fig. 72 being used to test the **connecting-rod to see if it is twisted.** It is clear that if the piston-pin (PP) should not touch the surface blocks at both points (X), the connecting-rod is twisted and should be bent back with tool (Fig. 74).

Fig. 74 (right). **Straightening bar**[1] **for a bent or twisted rod.**



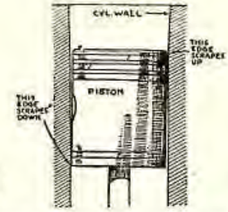


Fig. 75 (left). **A ground arbor and a square can be used to check up the alignment of the connecting-rod and piston assembly** if a special fixture is not available. This should be done both before and after scraping the bearings. A spirit level should be used to level top of piston. Blade of square should touch piston skirt at exact center.

Fig. 76 (center). **The illustration is exaggerated in order to show how a piston that is cocked as a result either of the connecting-rod being out of alignment with the piston,** will scrape oil up on one side and down on the other side of the cylinder walls. Bearing at lower end of rod will also be cocked or cramped to one side.

Fig. 77 (right). **The spade type or flared-end connecting-rod.** In order to get a better distribution of the load on the connecting-rod bearings, some of the engine makers flare the ends of the connecting-rods as shown. This naturally results in such a bearing wearing less, because the load imposed upon it by the explosion stroke is taken over a greater spread, than where the I-Beam part of the rod is brought to the cap end in approximately a right angle, or a small fillet.

The connecting-rod has come in for a good deal of attention during the last year or so. In nearly every case makers are now finishing their rods much better. Some go so far as to machine the rods all over, and take great care in balancing them. Heretofore some makers have weighed their rods, and if they were within ½ oz. of each other, they passed inspection. These same makers now carefully balance the rotating ends of the rods and the reciprocating ends, because it is of prime importance to get the rotating weights alike as well as the reciprocating weights.

[1] **Service station tools and equipment can be secured of such concerns as:** Automotive Maintenance Machinery Co., Chicago, Ill.; Shepard-Thomason Co., Los Angeles, Calif.; Storm Mf'g Co., Minneapolis, Minn.; Bench or surface plates for testing bearing caps and other such parts can be obtained of such firms as those mentioned above. See also list of auto supply houses, page 687, and ads in trade magazines. See pages 714 and 790B for a list of concerns who supply reamers.

IMPORTANCE OF OIL PRESSURE IN RELATION TO CRANKSHAFT BEARINGS

As an example, we will use the Oldsmobile eight-cylinder V-type engine, model "45-B."

Oil-pressure regulation: The oil regulator is shown in Fig. 80. Note the position of the oil-pressure adjusting screw and the ball-check valve. Dirt beneath this valve will cause a drop in pressure, and may be removed by snapping the ball up and down a few times with a piece of wire inserted through the oil passage.

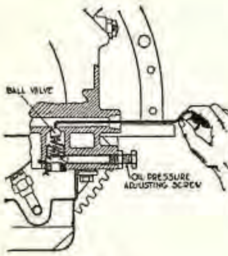


Fig. 80

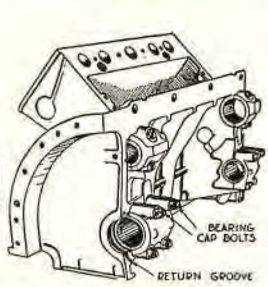


Fig. 81

Fig. 80. Oldsmobile (eight-cylinder, V-type engine) oil-pressure regulator.

Fig. 81. The main bearings are bolted to the left cylinder block. Note the return oil groove. This should be free to permit the oil return.

The oil-pressure regulator is on the front left-hand side of the engine, as shown in Fig. 80. If the oil-pressure gauge on the dash registers below 5 lbs. at 10 m.p.h., it is necessary to regulate the oil pressure. The following is the method:

1. Screwing the oil-pressure adjustment screw inwards should raise the pressure, and remedy the conditions. When the engine is steadily raced, a maximum pressure of 25 lbs. should be shown on the gauge.

2. If this is not the case, remove the oil line from the pump to the regulator, and also the elbow attached to the regulator. Then with a 3/16" wire or rod, bent at right angles for ⅜", reach into the oil passage and depress the ball valve a few times. This will release any dirt beneath the seat which has caused low pressure.

After replacing the parts, it will be necessary to adjust the oil-pressure screw as directed. It is also advisable to drain the crank case and flush it out with kerosene, when conditions are as described.

A medium-weight oil should be used, and, as is common with the present-day low-grade gasoline, it will be best to drain the oil, flush out the base, and replace new oil every 500 miles. Five quarts of oil are needed to completely replenish the oil supply.

Should a crankshaft bearing ever burn out, it will be necessary to see that all oil passages are tested for clearness before replacement is made.

If any of the oil passages in the crankshaft are stopped, a ⅛" twist drill may be used to remove the babbitt.

Testing should not be done with an air hose. The best method is to clean the end of the oil passage and blow by means of the mouth; the mechanic can thereby feel exactly the condition of the oil passage.

Cleaning oil lines: Usually a short-length twist drill is used for clearing babbitt out of the crankshaft after a bearing is burned out. Most tool stores carry long-shank twist drills, with which this work can be carried out better.

This precaution applies equally well if a connecting-rod bearing burns out. Before the new bearing is installed, all oil passages should be **cleaned with compressed air.** Very probably one will find a thick, black, pasty substance in the oil pipes connecting the crank cheeks, and also in the drilled passages in the crankshaft. This is carbon, road-dirt, and oil emulsion formed by the mixture of oil and water—the water being one of the products of combustion or having entered the crank case through a leaky head gasket.

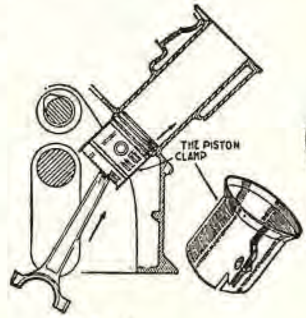


Fig. 82

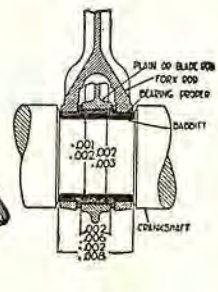


Fig. 83

Fig. 82. A piston clamp, as shown, facilitates piston and ring replacement through the crank case.

Fig. 83. These are the running clearances that should be observed when refitting the connecting-rod bearings.

If air is not available, use a tire pump by removing the connection and applying the end of the hose to the mouth of oil holes.

Connecting-rod bearing clearances: In fitting the connecting-rod bearings, it is essential that the correct clearance be observed in order to give proper action. If the mechanic uses those methods common in fitting the connecting-rod bearings on four-cylinder engines, the bearings will be drawn too tight and will cause future trouble.

The plain, or **blade rod** shown in Fig. 83 bears on a bronze bushing, which in turn runs on the crankshaft. If this bearing does not have from .002-.003" clearance, the bushing will expand faster than the plain rod and cause binding. This condition will be indicated by a burning out of the babbitt around the center of the bearing proper.

The following is the proper method of fitting the plain or blade-rod bearing to obtain the proper clearance.

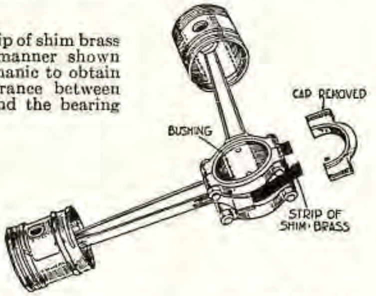
1. Fit the babbitted bushing to the crankshaft bearing, and bolt the fork rod tightly in place.

2. Procure a strip of shim brass ¾" wide and .001" to .0015" thick, just long enough to lap around the plain rod bearing on the bronze bushing (see Fig. 84).

3. Bolt the plain rod in position and adjust until, when the bolts are tight, the plain rod may be turned, but not loosely. Then if the brass shim be removed, the plain rod will have the proper clearance.

The side clearances may be checked up by means of a thickness gauge. It is essential that the clearance shown be followed. An absolute check on the bearing fits may be determined by using an inside and outside micrometer, and the careful mechanic will use this method instead of guessing.

Fig. 84. A strip of shim brass applied in the manner shown enables the mechanic to obtain the proper clearance between the blade rod and the bearing proper.



Adjustment of main bearings on the Oldsmobile model "45B" is described below and serves as an example of how bearings are adjusted on the average eight-cylinder V-type engine:

1. Remove the oil pan, place a jack under the flywheel "take the strain"—noting carefully if the crankshaft has any motion in the bearing. If such motion exists, remove the main bearing cap and take an equal number of shims from each side of the bolts, usually about two.

2. Examine the cap carefully to see that the crankshaft has a good bearing. In some cases the lining of the bronze bearing has been partially ruined, from lack of oil, which later causes leakage from the rear end of the engine.

3. Use air hose or a tire pump to blow through the drain hole which brings back the oil from the rear of the rear main bearing into the oil pan; this is a "cored" passage beneath the bearing, and connects with a groove in which a collar formed on the crankshaft revolves, throwing off the oil. There may be dirt or a stoppage at this point, preventing a proper return of the oil to oil pan.

4. When all of these points have been taken care of, replace the bearing cap and tighten up firmly. Crank the engine by hand. If it is not stiff, but has more "feel" to it than existed before you made the adjustment, this will indicate that the bearing is a close and proper fit. If it is still quite free, it would be advisable to check the bearing again, and see that it is not loose.

Note. In removing shims, be sure to take the same thickness from each side.

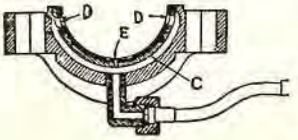


Fig. 85. Method of oiling the main bearings on the Mitchell. The space back of the bearing forms a reservoir, the oil being forced through holes (D) and (E) under pressure.

RELATION OF VIBRATION TO BALANCE

Centrifugal force and the force of inertia are the two main forces causing engine vibration. Both affect those parts having rotary motion, and inertia affects those parts having a reciprocating motion.

Vertical vibration is a "vertical or up-and-down vibration" of the reciprocating parts at certain angular positions of pistons and connecting-rods, and is more common in a 4-cylinder engine. A **vibration balancer** reduces this vibration. (See page 780.)

Torsional vibration is a twisting vibration. It is sometimes noticeable in 6- and 8-cylinder automobile engines with long crankshafts. Assume that the crankshaft is made of rubber. When the front cylinder fired, it would tend to turn the front of the crankshaft very rapidly, but the inertia of the flywheel would tend to prevent this rapid increase in speed at the rear of crankshaft.

Therefore the result would be a "winding-up" of the rubber crankshaft. As the force exerted by the front cylinder decreased, the rubber crankshaft would "unwind" again. This repeated "winding" and "unwinding" sets up a twisting or torsional vibration.

While, of course, the steel crankshaft is not as elastic as rubber, it is sufficiently elastic to permit torsional vibration.

It is obvious that the shorter the distance between the flywheel and the farthest removed cylinder, the less will be the winding effect. Hence a flywheel mounted at both ends of the crankshaft, as on the Rickenbacker (termed **tandem flywheels**), accomplishes the same result as making the crankshaft only half as long, as far as torsional vibration is concerned, and would decrease the torsional vibration. A stiff crankshaft decreases twisting or torsional vibration, but has the disadvantage of adding weight **to the engine.** A slipping flywheel or **vibration damper** is another method of reducing torsional vibration. (See page 780.)

Crankshaft whip, or a tendency to "whip" around at high speeds, is a term used to express what sometimes occurs to long crankshafts, especially those with bearings out of line. Some methods to decrease whip are: (1) using a stiffer crankshaft; (2) placing the main bearings closer together; (3) placing counterweights on the crank throws.

Periodic vibration. A vibration is said to be periodic when it recurs at equal intervals. Thus, during two revolutions of the crankshaft, certain vibrations occur; if, during the next two revolutions, these same vibrations are repeated, they are said to be periodic.

Balancing is the effort to reduce the effects of vibration. There are two main classifications: (1) balance of rotating parts; (2) balance of reciprocating (up-and-down motion) parts.

A part or combination of parts may be perfectly balanced when at rest, but not when the engine is running at a high rate of speed. This leads to a further classification: (1) **static balance,** which means balance when at rest; (2) **dynamic balance,** which means balance when in motion. An engine may have perfect static balance and yet not have dynamic balance.

To obtain static balance of rotating parts (crankshaft and flywheel) it is necessary to machine them so that the weights are equal in all directions from the center when at rest.

To obtain static balance of the reciprocating parts, it is necessary to have the parts equal in weight, that is, all pistons with rings and wrist pins equal in weight, and all connecting rods equal in weight.

Dynamic balance of the rotating parts (crankshaft and flywheel) is perfect when the centrifugal forces are equal in all directions at any point.

One method of aiding dynamic balance is by placing counterweights on the crank throws. Another method is the divided flywheel (one in front and one in the rear)

OIL TEST FOR ENGINE BEARINGS[1]

A bearing test successfully used in the air service and also in the maintenance stations of some of the prominent automobile manufacturers for several years is an oil test for determining the condition of the bearings on a pressure-lubricated engine with a drilled crankshaft.

The test is made by disconnecting the regular oil pump and passing oil through the system by means of pressure.

If the bearing clearance or seal between crankshaft bearing pin and bearing is as it should be, very little oil will leak through.

If the clearance is too great, a greater quantity of oil will pass from between the bearing and journal.

If an oil passage was clogged the indication will be that there will be a great difference in the number of strokes on test pump, and no oil would leak from bearing.

If one bearing did not get any oil it would be necessary to trace the oil passage from the oil pump through the oil manifold, making sure that all these passages are clear. This could be most easily done with an air hose and a small tube that could be fitted tightly into the oil holes in the crankshaft.

As an example, the Packard oil test method will be used.

Packard Oil Test for Engine Pressure-Lubricating System

Purpose: The test tank should be used in making an engine inspection, as it is possible to determine very accurately the **condition of the bearings.**

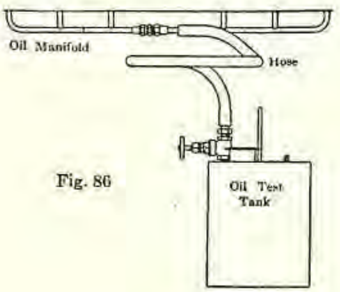


Fig. 86

It is very valuable in correcting over-oiling, because it tells the mechanic whether the difficulty lies in the fit of the bearings or in the pistons and rings.

It should also be used for checking bearing work after an engine overhaul and if properly applied will indicate if the bearing has too much diametrical clearance or if the oil passages are clogged or partially clogged.

In making a test with this tank (Fig. 86), **the following procedure should be observed:**

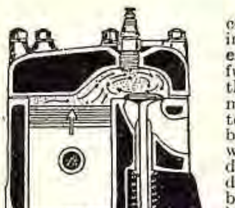
1. **Drop bottom** half of crankcase.
2. **Disconnect oil manifold** from oil pump.
3. **Fill test tank** two-thirds full of oil out of engine, unless it is so thin as to be of little value in making the test. Engine should be warm just prior to being pulled down to make the test.
4. **Connect test-tank hose** to engine oil manifold.
5. **Keep tank pumped up** to 30 pounds minimum pressure (use a hand pump).
6. **Gauge on instrument board should register approximately same as gauge on test tank, except** when cylinders 1 and 6 are on upper dead center, as in this position there is a direct flow of oil through camshaft to lubricate the front end chain and sprockets.
7. **Crank engine over** by hand crank.
8. **Flow of oil from connecting-rods and main bearings should be in drops before reaching floor.** With the full metered bearings as now used the oil should leak from the bearings in a fine stream, but will form drops before it hits the pan on the floor. In other words, the oil stream would not be continuous to the pan.[5]

   A stream of oil from the bearing to the oil pan would indicate too much clearance and it would be necessary to take up on the bearings. There are no shims on the Packard six or eight, therefore this dressing is done by rubbing the cap over a piece of emery cloth laid on a surface plate.

In refitting the main and connecting-rod bearings, they should be set up with a minimum clearance of .001″, and if this is done, the crankshaft may be turned over freely with the hand crank after all main and connecting-rod caps are drawn up and the cotter pins in place.

It will thus be seen that by the use of the hand crank and the oil test tank, a positive check can be obtained on the condition of all bearings, the hand crank checking for tight bearings, and the test tank indicating when the bearings are too loose.

THE RICARDO CYLINDER HEAD[1]



Purpose: To produce complete combustion of all the gases entering combustion chamber. In an **engine with an ordinary head** the fuel charge separates after it enters the combustion chamber, which permits the **outer layer** of this charge to cling to the walls to cool and become stagnant, or slow to ignite, while the other part is burned. These dead, stagnant gases fail to burn during the explosion period—they burn afterwards or during the exhaust stroke (known as after-burning); therefore this heat and energy is wasted. **After-burning** causes high power losses, excessive engine temperatures, which in turn cause detonation,[4] more commonly called "pinging" or "knocking."

The illustration above shows a sectional view of Ricardo cylinder head, indicating by arrows the swirl of the gas mixture just prior to the passage of the ignition spark.

Turbulence is produced by the **piston forcing the gas up into the combustion chamber and causing a rapid swirling of the main body of the charge,** thus distributing the flame rapidly throughout the mixture.

Principle of Ricardo[2] head: The fuel charge (owing to the shape and design; see illustration) enters the combustion chamber, during the compression stroke, as a swirling, intensively turbulent, wholly combustible uniform mass. This **turbulence[3]** or the swirling motion of the fuel charge is of the utmost importance. Because of it, **the outer layers of the fuel charge are dug off the combustion chamber walls and hurled into the** energy-producing explosive mass, and thus the great bulk of the gas is reached more quickly by the spark and 8 to 12 per cent of otherwise wasted fuel is made to burn in time to contribute power to the piston rather than to heat the exhaust.

Fig. 88. (A) Indicates a dark stagnant layer in a lazy moving mixture approximately $\frac{1}{16}$ inch thick, constituting in a combustion chamber between 8 and 12 per cent of the total volume of useful fuel. This layer burns too slowly to contribute its power to the piston before the exhaust valve is open.

Fig. 89. (B) Indicates the practical elimination of this dark, stagnant layer, due to turbulence in a Ricardo head by driving this gas layer out into the body of the flame. Thus the 8 to 12 per cent of otherwise wasted fuel is made to burn in time to contribute power to the piston rather than heat to the exhaust.

When operating an engine equipped with a Ricardo head, the spark should not be advanced too far. The fuel mixture in a Ricardo head burns much faster than in the conventional head, and because of this increased combustion speed, the explosion does not need to occur so soon.

The advantages claimed by the manufacturers (Waukesha Motor Co., Waukesha, Wis.) is that more power with much less fuel, more speed, quicker acceleration, easier and quicker starting, fast getaway, and elimination of engine pinging and **detonation[4]** (even with less expensive grades of gasoline) are the result of the use of this head.

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[1] See pages 1052–1054 for **piston clearance, compression-ratio,** and other subjects formerly on this page.

[2] Invented by Harry Ricardo, Shoreham, England.

[3] See also page 115, relative to producing turbulence in the intake manifold.

[4] The definition of **detonation** is given on page 1075.

[5] When the oil line is coupled up and the oil is turned on to the bearings, it is possible to obtain an extreme leak from individual bearings when stopped in certain positions in addition to the main position of one and six up; in other words, the check should be made by slowly turning the crank and not when the crank is standing still in any one particular position.

INSTRUCTION No. 70

PISTONS: Types, Construction and Fitting; Piston Clearances; Standard and Oversize Pistons; Installing and Fitting Pistons. RECONDITIONING CYLINDERS: Different Methods of Finishing Bores of Cylinders; Cylinder Reconditioning Devices, Etc.

PISTONS[1]

The piston and piston rings act as a seal when compressing the gases. The piston transmits the energy of the expanding gases through the connecting-rod to the crankshaft; it functions also as a guide for the piston pin. The piston and rings should, therefore, fit the cylinder walls as closely as certain limits permit.

Owing to heat generated in the engine the pistons expand: therefore it is necessary to fit the pistons in the cylinder with a **clearance** that allows expansion and provides space for the oil film.

The head or **top part of a piston** (being next to the combustion chamber) is **subjected to greater heat** than the skirt, therefore **greater clearance** is given by the manufacturer at the top.

Piston heads are made flat, crown or dome-shaped, bevel or chamfered, and concave or hollow head. The majority are flat head.

Piston rings are fitted to grooves in the piston. The usual practice now is to fit 3 or 4 rings above the piston pin. The **purpose of the ring** is to fill up or seal the gap clearance between the cylinder wall and the piston, preventing the gases escaping into the crankcase and an excess of oil working into the combustion chamber. As these gases are under pressure, it is necessary that the rings fit snugly not only around the cylinder wall, but in the grooves of the pistons as well; otherwise the gas and oil work through, behind the rings.

Piston material: Pistons are made of cast iron or aluminum alloy, semi-steel, and duo-metal.

Pistons are usually made of cast iron, and this type is the one in general use. When heated, cast-iron pistons expand, but not as much as aluminum-alloy pistons.

Aluminum-Alloy Pistons

Aluminum-alloy pistons are used in a great number of engines. They expand more than cast-iron pistons, but since they cool more rapidly than cast iron, they permit a higher compression pressure. (Higher compression increases heat.)

By reducing the weight of reciprocating parts, quicker acceleration is also made possible.

They give longer life to the bearings by reducing the bearing pressure, especially at high speeds.

The inertia of the reciprocating piston is reduced considerably. This cuts down side pressure, or thrust, on the walls of the cylinders and reduces friction and the consumption of lubricating oil.

The great heat conductivity of aluminum alloy lessens the carbon deposit on the piston head, and the deposit is more easily removed.

It is claimed that in cases of extreme heat the lynite piston will not "score" or cut the cylinder walls.

It is a proven fact that the lighter the piston, the quicker it will operate. Therefore **greater speed and flexibility are the result.**

The main disadvantage, with the aluminum-alloy piston of the solid skirt or trunk type, where no provision is made for maintaining constant clearance, **is the "slap"** which often occurs, as explained on page 779.

As the aluminum-alloy piston expands two or three times as much as a cast-iron piston when heated, it would be necessary to give two or three times the clearance, therefore the clearance of an aluminum piston when cold is considerably more than that of a cast-iron piston; consequently, until the engine is warmed up, there is more or less slapping noise. As the heat increases, the piston expands and the noise disappears.

During this expansion period, raw gasoline is drawn from the cylinder, past the pistons, into the crank case, thinning or diluting the oil. Methods have been devised to overcome this objection as will be explained.

A long step in advance is the constant-clearance type of aluminum piston. Briefly, this is a piston which does not expand in the same way as an iron piston. Usually the skirt of piston is **cut or split,** so that when the piston does expand it simply closes this cut and does not, therefore, change its diameter. Hence the clearance substantially remains the same at all temperatures.

Where the constant-clearance type of piston is used, it is generally made with an opening on each of the two thrust sides of the piston extending circumferentially around the piston excepting for a small portion where the piston pin bosses are located.

The object of this **head slot** is to separate the upper portion of piston, or heat portion, from the skirt and the load resulting from the gas pressure is transferred directly from the piston head to the piston bosses.

When split-skirt type of pistons are installed in cylinder blocks, the split side of the piston must be placed on the side of engine having lesser thrust (see pages 809, 811, 814, 780, explaining).

An example of the constant-clearance type of piston is that shown in Fig. 1. In order to use small clearances and still avoid any trouble due to expansion of the metal, the **piston skirt is split along one side and slotted near the top** and joined to the head only above the piston pin bosses. The pistons are given a closer fit in the cylinder, even when cold. There is, therefore, no undue noise in the engine when first starting up. When heated, the sides expand circumferentially and along the diagonal split without increasing the outside diameter.

Interior ribbing provides exceptional strength and eliminates binding of the piston pin. Besides eliminating the effects of expansion of the piston, the slots act as oil drains.

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[1] **Note: Pages 807–824; There may be a slight discrepancy between the index and the text. See footnote, page 809.**

The layout for making this piston (Fig. 1) has been arranged in the belief that piston wear, oil pumping, and failure of the piston rings to make proper contact with the cylinder walls are due largely to misalignment. This **misalignment causes the piston to cock in the cylinder,** so that one side of it becomes a scraper, giving unequal lubrication around the walls, as shown in Fig. 76, page 803.

Fig. 1. **Aluminum-alloy pistons of the constant clearance type with a split skirt.** Pistons of this type can be given less clearance. With the use of aluminum pistons which cool readily, the use of larger valves and higher compression is permissible.

The piston, Fig. 1, is the McQuay-Norris (see also Fig. **6A,** page 811, for description and clearances). The piston, Fig. **1A** (right), is the Permite. These pistons can be supplied finished or semi-finished and are exact factory duplicates for replacement in standard sizes and oversizes from .003" to .060".

The skirt of the piston is split at an angle, so that it does not work vertically in the cylinder, but with a **sliding** motion.

The piston and rod assembly should always be given a final check on the **alignment** of the piston to make certain that the latter will operate on a true axis, as explained on page 803.

Aluminum-Alloy Pistons and Connecting Rods[1]

The numerous advantages obtained by using forged aluminum alloy connecting-rods in place of steel rods are due mainly to the saving in the weight of the reciprocating parts, and to the higher heat conductivity of the aluminum alloy as compared with steel (see also page 795).

The wear on the crankpin bearing is caused by three forces, centrifugal, inertia, and explosion pressure.

Centrifugal force results from the weight of the large end of the connecting-rod and is acting throughout the entire revolution of the crankshaft.

Inertia forces act mostly at the top and bottom of each stroke due to the weight of the complete rod and piston which have their direction of motion changed from going up to going down and vice versa.

At the end of the compression stroke, once every four strokes, the **compression and explosion** exert great forces in opposite directions.

Therefore, any saving in the weight of the large end of the connecting rod **decreases the wear due to the centrifugal force,** and any saving in the total weight of the rod and piston **decreases the wear due to the inertia forces** at the top and bottom of each stroke. Reduction in wear means that you can drive thousands of miles more before it will be necessary to adjust the connecting rod lower bearing when using aluminum-alloy rods.

[1] From literature of the Piston and Mfg. Co., Most connecting rods, at present, are light-weight forged steel.

The lighter weight of the aluminum-alloy rod also **decreases the whipping effect of the crankshaft at higher speeds,** and together with the lighter piston lessens the vibration.

Another great advantage giving longer life to the engine and more comfort in driving is that the **vibration** occurring at common speeds of about 20 to 25 miles per hour in light cars with steel rods and iron pistons does not occur until a speed of about 35 to 40 miles per hour when aluminum-alloy rods and pistons are used.

The fitting of aluminum-alloy connecting-rods to the crank pin bearings should be given careful attention. The clearance on this bearing fit should be about .0015" on the diameter. This should be accomplished by adjusting the shims so that when the nuts on the connecting rod bolts are tightened the rod fits firmly and can just be turned; then loosen the nuts about 1/6 turn before locking with cotter pins.

Examples of Aluminum-Alloy Pistons

A few examples of the aluminum and alloy type of piston will follow.

Fig. 2.
Note the spiral slot which, the manufacturers claim, controls expansion and contraction due to changes in engine temperature thereby maintaining a **constant clearance.** The spiral slot also assures constant lubrication between piston and cylinder wall therefore decreasing wear.

The base metal of this piston is aluminum which dissipates heat faster than cast iron, preventing carbon collection and detonation.

A lighter and cooler running piston makes higher compression permissible. This piston, its makers state, due to the spiral slot, can be fitted to a close clearance. With a close clearance, compression leaks and piston slap on starting are greatly eliminated, and the other advantages of the aluminum alloy piston are likewise obtained.

Above pistons are furnished "semi-finished" which can be finished to any size from standard to .065" oversize.

When ordering finished pistons, size of cylinder bore should be given, correct clearance will be allowed when pistons are ground. If you order a 3¼" piston .010" **oversize,** the finished oversize piston allows the specified clearance. Also mention name and model of car, or engine and number of cylinders.

Aluminum-alloy pistons are of the **constant clearance type,** having a split skirt. Being made of an alloy of aluminum, copper, and several other elements in very small quantities; it is one-third the weight of cast iron and three times a better heat conductor.

Printed matter **states:**

"When the cylinders of an automobile engine become worn out of round enough so that refinishing is necessary, it should be done by a shop with the proper equipment. Grinding the hole to a smooth finish will give a satisfactory surface for this metal. If the hole is bored or reamed it should be honed to a mirror-like surface to insure proper results. If the piston is being installed in the original bore, which probably is well glazed up, it will give wonderful results if the cylinder is not too badly out of shape.

"We do not recommend that these pistons be lapped in by using an abrasive mixture. When this is done the cylinder and the piston are charged with the abrasive and the lapping action continues after you have apparently washed all the abrasive from the surfaces. This also holds good for cast-iron pistons.

"Clearance allowance on round split-skirt Lynite pistons should be .001" per inch of diameter of piston.*

"When installed, the following clearance for the split-skirt Lynite pistons should be allowed:*

Cyl. Dia.	Skirt Clearance	First	2nd and 3rd	Fourth[1]
3.0"	.0030"	.015"	.010"	.0625"
3.5"	.0035"	.017"	.012"	.0625"
4.0"	.0040"	.020"	.014"	.0625"
4.5"	.0045"	.023"	.016"	.0625"
5.0"	.0050"	.025"	.018"	.0625"

"**Installing:** It is **important** that the split side of piston be installed on the drivers side of the car, as this is the side of minimum thrust.

"Lynite pistons are carried in stock in standard, .003", .005", .010", .015", .020", .031" and semi-finished. Semi-finished pistons may be finished as large as .060" oversize. Piston pins, where desired can be fitted at 25c. each plus cost of pin, and on request step cut piston rings can be furnished for pistons using same.

"Width and depth of ring grooves are very closely machined, wrist pin holes guaranteed square with side walls of the pistons and are bored to required diameter allowing 0.003" to 0.005" for reaming."

"**Clearance allowance on aluminum-alloy pistons of the solid skirt or trunk type** (No. L54) should be .006" from the bottom of the lowest ring groove to the skirt and should be ground .012" taper from the bottom of the lowest ring groove to head.

Fig. 2A. Nelson-Bohnalite piston of an improved light alloy design of the narrow-steel strut type (do not confuse with the "wide-steel strut type"). This piston differs from the split-skirt type, as it is made with special alloy steel struts so placed in the piston that they control expansion and maintain satisfactory clearance under various engine operating conditions. With well-finished cylinder bores, these light alloy pistons are fitted with less clearance than is used in fitting cast-iron pistons.[2]

On the bearing side of the piston two horizontal saw slots are used and the skirts are partially cut to enable the control members (the struts) to give the proper expansion to the skirt.

The struts are placed in the direction of the resultant thrust on the piston skirt and comprise an important portion of the piston in this direction. They are located to allow for finishing the piston skirt, piston-pin holes and drilling necessary oil holes.

The section in the head portion of the piston is comparatively heavy which promotes cooling because Bohnalite conducts heat three times as fast as cast iron. The piston-pin bosses are joined to the head and skirt portions by heavy ribs, which envelop the central sections of the struts.

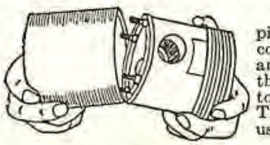

Fig. 3. The Marmon two-piece piston (1920–1926) is a combination piston: the head and body are aluminum, and the skirt is cast iron. A .0025" to .003" clearance was given. The one-piece piston was later used by Marmon.

Light Iron or Semi-Steel Pistons

Where iron or semi-steel pistons are used, there has been a tendency to get them very light. In fact, some of the semi-steel pistons weigh little more than aluminum-alloy pistons. Flexible pistons of this type have the advantage that they will shape themselves into the cylinder bores in which they are working. In other words, the pistons will conform much better to the shape of the cylinder, should the latter wear oval.

One of the things in favor of the semi-steel piston is that owing to the nature of the metal it can be machined to much closer limits than can cast iron. There is, therefore, a reduction in weight which is a desirable feature in any of the reciprocating parts.

Light-Weight Gray-Iron Pistons

One example of design or construction of a light-weight gray-iron piston is shown in Fig. 4. The system of ribs or webbing extends across the head and down the skirt of the piston. These ribs or braces give the piston strength and permit of the walls between the ribs being made very light.

Fig. 4. The De Luxe light-weight gray-iron piston. A clearance of .001" to each inch of bore is recommended.

Cast-Iron Pistons

We shall now confine our attention to the cast-iron (or gray iron) piston. Some manufacturers add just enough steel to the cast iron to give it certain physical properties. Pistons should be heat-treated and seasoned before machining in order to prevent warping when heated in the engine.

The cast-iron piston expands under heat, as do all other types—some more or less than others—and the extent of this is, of course, governed by the amount of heat generated in the engine.

The diameter of the top of the piston is usually smaller than the bottom, or skirt, because the piston is subjected to greater heat at the top; consequently there is greater expansion at this point.

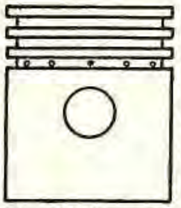

Fig. 5. Example of a gray cast-iron piston. The safe average diametrical clearances with the cylinder are as follows for the bores shown: *2 1/2 to 3"*, top land .011", 2nd land .008", 3rd land .006", skirt .003"; *3" to 3 1/2"*, top land .012", 2nd land .009", 3rd land .006", skirt .00325"; *3 1/2 to 4"*, top land .014", 2nd land .010", 3rd land .007", skirt .0035"; *4" to 4 1/2"*, top land .016", 2nd land .012", 3rd land .008", skirt .004", *4 1/2 to 5"*, top land .019", 2nd land .014", 3rd land .009", skirt .00475"; *5" to 5 1/2"*, top land .022", 2nd land .016", 3rd land .011", skirt .00575"; *5 1/2 to 6"*, top land .026", 2nd land .019", 3rd land .013", skirt .007". Slightly closer clearances can be used if the pistons are carefully run-in.

Most makers of pistons are now polishing the heads of the pistons. It is well known that carbon or soot will not so readily adhere to a polished surface, and while it is somewhat more expensive to finish pistons in this manner, it is worth it.

Questions and Answers on Pistons

Q. 1: What troubles result from too loose a piston?

Ans.: In addition to a "slap" and the wear of the cylinder wall, there is a third trouble resulting from the gasoline passing into the crank case and diluting or thinning the oil, thus injuring the bearings. Piston will also pump oil, causing carbon, smoke and fouling of spark plugs.

Q. 2: What is meant by "squaring" the piston?

Ans.: When fitting the piston and connecting-rod assembly into the cylinder, if not done carefully, the connecting rods may become slightly bent. If one side of the connecting-rod bearing is higher than the other, the piston will be at an angle. It is very important that pistons be in perfect alignment and nearly equal weight. See Index "Alignment of piston."

Q. 3: What are pistons usually made of, and what is meant by "seasoning" and "heat-treating"?

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* **Note.** This instruction has not been revised for some time. **Follow manufacturer's latest instructions for fitting and clearances.** See paragraph at bottom of left column next page. *For literature on pistons* see page 690. See also page 58, Addenda, for the "Lo-*Ex*," "T-*slot*," "*cam-ground*" pistons and pistons with the "*alumilite*" finish; also, "*tin-plated* cast-iron pistons." See also page 828.

[1] By "first," "2nd" and "3rd," and "fourth" is meant ring lands, that is, the material between each ring groove.

[2] **The skirt and land clearances** of this piston are the same as in table, p. 811 (taken from the instruction sheet of McQuay-Norris Mfg. Co., St. Louis, Mo., sole replacement distributors).

Ans.: Pistons made of cast iron usually are not machined for a long time, to allow them to set so that they will not change their shape after being machined. The result of this is that they do not warp out of shape when heated, thus permitting minimum clearance, and reducing "slapping" when cold. Heat-treating is supposed to have the same effect as long seasoning.

Q. 4: How are pistons machined?

Ans.: They are turned down to within .005" of size, then ground to exact size on a special grinding machine. On high-grade engines the pistons are seasoned or heat-treated, then turned and ground to fit each cylinder individually in order to prevent warping out of round when heated. Piston rings are sometimes also heat-treated as well as cylinders. On some engines they are not always heat-treated or seasoned; are made in quantities, and the assembler fits the pistons to the cylinders, termed a **selective fit.**

Remarks on Piston Clearance[1]

The clearance of pistons or the running allowance is the difference between the inside diameter of a cylinder bore and the outside diameter of piston, termed diametrical clearance (explained on page 827).

A piston does not fit the cylinder wall tightly. If it did, it would **seize** and stick when it was heated, as it expands with heat. For this reason **clearance** must be allowed between cylinder wall and piston.

The piston rings fit tight, however, but, being split and flexible, they fit the cylinder at all points—or at least they should.

More clearance is required at the top of a piston, because here the heat is greatest, and there is therefore greater expansion at the top.

If pistons are fitted very close to the cylinder they will run quietly but **may heat and stick** and cause engine to slow down or stop if driven at a high speed, and this may result in a **scored cylinder wall.** Pistons fitted too tight will **wear cylinder wall rapidly.**

New or reconditioned engines should be driven at moderate speed for the first 1,000 miles in order to work or run-in the pistons, bearings, etc. See pages 833A and 824B for reason.

If pistons are fitted moderately loose, they may "slap" until heated up.

If pistons fit too loose, a "piston slap," oil leakage and dilution of oil with gasoline will result.

The amount of clearance depends upon the speed of the engine, the efficiency of the cooling system, the type of water circulation, and the length of the water jacket. If the engine is "hot-running" or heats quickly, clearance is increased proportionately. If it is "cool-running," give less clearance. The clearance needed will vary, depending on the conditions mentioned.

Air-cooled cylinders usually expand outwards, which equalizes with the expansion of the piston. Therefore the same clearance can generally be used as in water cooled engines.

Cast-iron pistons require about one-half the clearance that those made of aluminum-alloy with solid skirt require, because they do not expand so much under the same degree of heat.

No hard-and-fast rule can be given as to the amount of clearance which should be allowed between the pistons and cylinder walls.[1] There are many conditions to be taken into consideration, including the construction and speed of the engine, the style and material of the pistons, the service given the engine, after grinding, and even the characteristics of the driver himself. For example, a smaller clearance might be given, providing the driver gave the engine time to run in properly.

Even the manufacturers themselves are divided on this point, each having his own pet theory as to what the clearance should be. A manufacturer states that they give more clearance on truck engines than on passenger car engines, and still more on tractor and fire-apparatus engines.

Where engines run for long periods under full power they require more clearance than others, and, of course, the heating of the engine, the cooling surface, etc., as previously stated, are factors governing the clearance to a certain extent.

For example, in fire-apparatus engines, where they are run at times for long periods, pumping water at full power, it is clear that greater heat will be generated; there will consequently be greater expansion. Thus in such cases it is necessary to **allow more clearance.**

It is clear that a close-fitting piston is desirable and the idea is to not give any more clearance than necessary. But bear in mind that the piston clearance is measured when piston is **cold,** and as the piston **gets hotter than any working part of engine** (except exhaust valves) and expands considerably faster than the cylinder bores, it is **very necessary to provide sufficient clearance to allow for expansion at maximum running temperatures** without excessive friction, and to retain an oil film between piston and cylinder wall. **The best method of determining what piston clearance to allow is to obtain the manufacturer's instructions.**

As a general rule, it is safe to allow .001" **to each inch diameter of the bore on cast-iron pistons.** (The regrinding concerns—and the **manufacturers themselves, shade this a little sometimes**).[2]

For example: If a piston is to be fitted to a cylinder of 3" bore, the skirt of the piston should be measured as .003" less in diameter than the bore. Thus, in the case supposed, when the cylinder bore is 3" in diameter the piston should be .003" less, or 3" —.003" = 2.997" (two inches and nine hundred and ninety-seven one-thousandths), measured at the skirt.

How a Piston Tapers

The clearance of a piston, or running allowance, as previously stated, is the **difference** between the inside diameter of a cylinder bore and the outside diameter of the piston.

The clearance of a piston is measured at the skirt for all general purposes, but there are clearances called **land clearances** which the maker gives a piston, explained in text on next page.

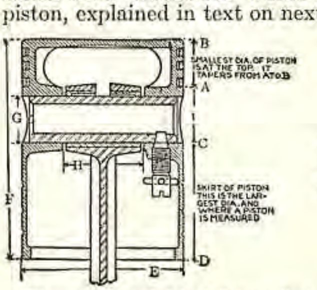

Fig. 6. This illustration shows how a piston tapers and also gives the measurements to be given when ordering.

When ordering finished pistons, first give the make and model of car and then the **exact micrometer reading of the cylinder bore,** and in turn the manufacturer will furnish piston to fit, allowing the proper clearance. Factory duplicate pistons are usually carried in standard sizes and oversizes of .005" to .040".

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[1] **The S. A. E. has never adopted any standards for piston clearance** because the difference in materials, in cooling, and in design both of pistons and cylinders, affects the amount of clearance necessary. **Obtain manufacturer's instructions.**

[2] **A clearance of .00075"** (three-quarters of one-thousandth) of an inch for each inch diameter of piston can be used, provided that fitting of the piston rings and pins is an A-1 job, and provided that, when assembling the engine, every precaution is taken in regard to squaring up or **aligning** the pistons and rods. In **addition,** the driver should operate the car at moderate speed the first few hundred miles with plenty of oil.

If necessary to order by measurement, then give the exact skirt diameter (E), length (F), distance between piston bosses (H) and the distance from center of piston-pin hole to outer edge of head, which is called the **compression distance**. This is important as it may affect the compression if it varies. See also page 813 on how to order pistons.

The smallest diameter of a piston is at the top and the largest diameter at the bottom.

Theoretically, the piston should be ground tapered from the bottom to the top, but commercially the piston is ground straight on the part from point (D) to point (A) (Fig. 6).

This portion of the piston from the lower ring groove to the bottom of the skirt has the tightest clearance and the biggest diameter and it is usually ground to one diameter.

From point (A) to point (B) each land[1] between the rings is cut under the skirt dimension which, in general, might be considered a gradual taper to the top or point (B), or simply made smaller in diameter successively to the top. (See also Addenda, page 58.)

Piston Clearances; Iron

Skirt-clearance for iron pistons: The piston skirt is usually made smaller than the cylinder by an amount equal to approximately .001″ per each inch of diameter of the piston.[4]

Land clearance (approximate) **for iron pistons:** The **third land** from the top is usually made .002″ smaller per diameter inch,[1] the **second land** from the top, .003″ per diameter inch; and the **top land** .003″ or .004″ per diameter inch.[4] (See also Fig. 5, page 809.)

Piston Clearances; Aluminum

Skirt and land clearances for split-skirt aluminum pistons (safe average clearances) are shown in the table[2] below.[4]

Diam. Cyl.	Top Land	2nd, 3rd, 4th Lands	Oil Land	Skirt Cl'nc.[2]
2½″ to 3″	.019″	.014″	see[3]	.002″
3″ to 3½″	.023″	.016″	"	.002¼″
3½″ to 4″	.028″	.019″	"	.002½″
4″ to 4½″	.034″	.023″	"	.003″
4½″ to 5″	.041″	.028″	"	.003¾″

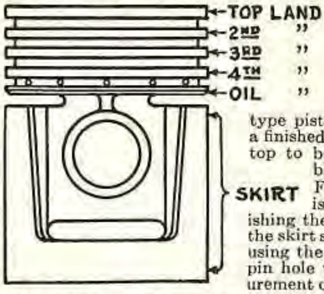


Fig. 6A. Showing the lands between the piston-ring grooves. This illustration is a McQuay-Norris all-aluminum split-skirt type piston. A vertical slot in a finished piston is opened from top to bottom with a hacksaw blade after finishing. See Fig. 1, page 808, for finished piston. When finishing these pistons to size, grind the skirt straight as usual, always using the diameter at 90° to the pin hole to determine the measurement of the skirt.

All clearances shown refer to the difference between the cylinder bore and the piston diameter.

The aluminum piston should be installed in the cylinder block with the vertical slot bearing on the left-hand side of the cylinders when viewed from the driver's seat, as this is side of lesser thrust (explained on page 814).

Skirt-clearances given aluminum-alloy pistons with solid skirt (now seldom used) are about twice (or more) the clearances given cast-iron pistons (varies with different manufacturers and class of service). It is advisable to fit pistons with **clearances recommended by the manufacturer.**

Piston Clearance; How Measured

Method of measuring piston clearance: Place the **inside micrometer caliper (IM)** in the cylinder, as indicated in Fig. 7, and determine **the inside diameter of the cylinder** (see also page 703).

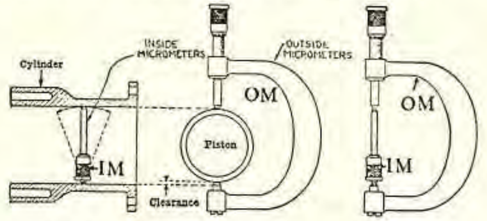


Fig. 7 Fig. 8 Fig. 9

Then place an **outside micrometer (OM)** over the piston, as shown in Fig. 8, to determine **the outside diameter of the piston.**

Then with the outside micrometer (**OM**), measure the inside micrometer (**IM**) as shown in Fig. 9. The reading in Fig. 8 subtracted from the reading in Fig. 9 is the **clearance.** A quicker, but less accurate, method would be to subtract the measurement found in Fig. 8 from the measurement noted in Fig. 7. See also Fig. 11.

In the absence of suitable micrometers, and if the pistons are to be ordered, cut a $\frac{1}{16}$″ bar of steel, filing both ends smooth so as to fit the cylinder at its **smallest point,** and number each bar for each cylinder. Send these bars to the piston manufacturer, and give make of engine, etc. (See also under Fig. 6.)

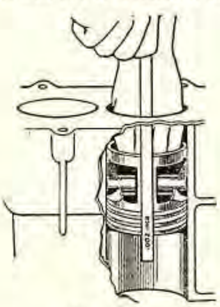


Fig. 10

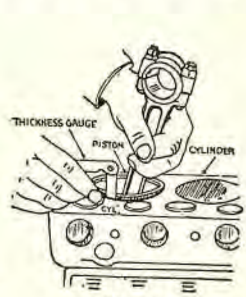


Fig. 10A

Another method of testing piston clearance between a piston and cylinder wall with a thickness gauge is shown in Fig. 10. The piston on the Chevrolet series (1936), as an example, should have .002″ clearance.

For a properly fitted piston, some resistance should be felt, that is, you should feel the gauge "binding" on the piston and cylinder. When measuring the clearance between piston and cylinder walls, always do so at **right angles to the piston pin and on a line with it** as shown in Fig. 10.

Free-fit and tight-fit piston clearance: Frequently instructions advise fitting a piston, say .003″ **free or loose-fit,** and .004″ **tight-fit.**

This means that the piston is placed in the cylinder and a thickness gauge (also called a "feeler") is placed alongside the piston, between it and the cylinder wall (Fig. 10).

The piston should fit free, or loose, or fairly snug with a .003″ gauge, and tight with a .004″ gauge.

[1] **"Lands"** refers to the material between each ring groove (as in Fig. 6A). **On pistons having four rings,** the fourth ring land is usually given the same clearance as the second and third land.

[2] **From instruction book** for finishing and installing McQuay-Norris aluminum pistons (split-skirt type).

[3] **Oil land clearance** (Fig. 6A) is 1/32″ less than standard cylinder-bore diameter. This extra clearance is used to allow the oil to be freely scraped from the cylinder by the lower ring.

[4] **Always obtain manufacturer's latest instructions** on fitting clearances and for **machining** semifinished pistons. When fitting to close clearances, it is very essential to caution the driver against driving the car at high speeds for the first 500 miles, and to use plenty of oil during that breaking-in period. **See paragraph** lower left column page 810. See also **"Note"** bottom of page 809.

How to Determine if Cylinders Are Tapered or Out-of-Round

To determine the condition of the cylinder, as to size and taper, use a piston and feeler stock of sufficient thickness to fill up the space between the cylinder wall and the piston (Fig. 10A).

Insert the piston and gauge at the top of the cylinder, as shown. If the piston binds at the bottom of the cylinder, and is free at the top, you will know that the cylinder is **tapered.**

To determine if the cylinder walls are out of round, insert piston with gauge into cylinder bore, noting the clearance (Fig. 10A).

Remove piston and turn one-quarter turn with the gauge in same position of the piston and again insert in the cylinder. If the clearance is not the same, the cylinder is **out-of-round.**

Fig. 10B. **Thickness gauge or "feeler" with 9" long and ½" wide leaves, suited for determining proper clearances when fitting pistons.** Starrett No. **172D** with eight leaves .002", .003", .004", .005", .006", .008", .010", and .015".

If a thickness gauge is not at hand, a 1" strip of heavy tough wrapping paper can be **"miked,"** that is, its thickness can be measured with a micrometer and then the paper can be used to test the clearance when fitting pistons, by laying it in the cylinder between the piston and cylinder wall.

As an example of the thickness of papers: Newspaper thickness is approximately .00275"; a sheet of this paper, .002" to .0025"; a postal card, .009".

Another test to determine cylinder taper is to insert a piston ring and slide it up and down the full length of cylinder. Measure ring gap at various points with thickness gauge. Subtract smallest gap from largest gap. This *difference,* divided by 3.1416, is the taper in thousandths of an inch.

More accurate methods to determine if cylinder bores are out-of-round or tapered are by the use of an **inside micrometer,** Fig. 7, or a **cylinder dial gauge,**[1] Fig. 11.

Fig. 11 (left). Cylinder gauge.

Fig. 11A (right). Transferring cylinder measurement from cylinder gauge to an outside micrometer.

To measure taper, turn knurled rim of dial (Fig. 11), so that hand registers at 0 and move the gauge up and down the cylinder bore its full length; rotate the gauge in the cylinder bore about 90° and again move it up and down. The maximum reading on the minus (−) side should be added to the maximum reading on the plus (+) side to determine the number of thousandths of an inch of taper.

To measure out-of-round, proceed as above; but instead of moving gauge up and down, hold it at some particular height and rotate it around the cylinder bore. The total movement of hand represents the number of thousandths of an inch out-of-round. This measurement should be made at several places in the cylinder, particularly near the top of ring travel.

After all the foregoing readings have been noted, the largest diameter of cylinder is found by transferring the gauge to an outside micrometer (Fig. 11A) and opening or closing outside micrometer until cylinder gauge shows the highest plus reading found during both foregoing tests. See also pages 703, 704.

The remedy for tapered or out-of-round cylinders is to regrind, bore and finish hone, or hone, as explained on pages 814–814B.

Piston Replacement

The three following conditions make it necessary to replace a piston: (1) scored pistons; (2) leaky pistons; (3) worn pistons. (See also discussion of this subject on pages 814–815.)

The scored piston, if it is not too badly scored, may be dressed off with a mill file. However, this practice is not recommended unless the mechanic is skilled in the use of a file. Again, a scored piston usually means a scored cylinder, which requires enlarging the cylinder, and fitting an oversize piston.

Leaky pistons are found by setting the piston bottom side up in a pan of gasoline, or by pouring about 1" of gasoline into the interior of the piston. The gasoline will seep through any leak.

Worn pistons cause excessive wear on the walls of the cylinder and cause a knock or slap. A cylinder may be made to hold compression by fitting tight rings on a badly worn piston, but because of the wear on the block, such practice is false economy.

On the Ford Model "T" the cast-iron piston is fitted to cylinder bore with .003"–.004" clearance. **Instructions are to renew the piston if clearance is over .006".** (See also p. 823.)

Pointers on Fitting Pistons

Fitting new pistons is often resorted to when there are compression leaks, or so-called piston slaps, whereas, in reality, the difficulty is due to improperly fitted or worn piston rings, carbonized pistons, or improperly seated valves. Generally speaking, the pistons should not be replaced until the engine has been in service a long time, and the cylinder walls have worn so that the **pistons slap badly** when ascending grades, or on hard pulls, and then oversize pistons should be fitted, after having reconditioned the cylinder bore, if necessary.

Do not confuse carbon knocks or valve clicks with piston slaps, and remember that a cold engine will usually have a slight metallic clicking which will disappear as soon as the engine heats up.

With a clean engine, that is, carbon removed from piston heads, and valves properly seated, and properly fitted piston rings in cylinders and grooves of piston, and cylinder bore round, smooth, straight, and in proper alignment there is little need to consider replacement of pistons, unless, as stated previously, there is a bad piston slap or the ring grooves are badly worn.

If it is necessary to replace the pistons on account of piston slaps due to excess clearance, and it is found that by fitting a new piston to a proper clearance at the upper part of the cylinder where the piston rings bear on the wall and the wear is the greatest, that the piston binds or does not have sufficient clearance at the lower part of the cylinder, then the cylinder should be reground or honed, and oversize pistons should be installed.

If a piston is fitted to a worn cylinder, it will be found that the **wear is where the rings travel** (Fig. 32, p. 833). (See p. 814 why cylinder wears taper.)

Thus, if the piston is fitted with proper clearance at these points, it may have considerably **more clearance when up into the cylinder,** and this is one reason why worn cylinders should be properly enlarged and oversize pistons fitted, if worn excessively.

When worn, cylinders are usually out of round, and in the majority of cases tapered, thus leaving a space between the rings and the cylinder walls at certain points in the stroke.

There is usually a slight shoulder or ridge above the piston-ring travel in a worn cylinder bore and a lesser one below. See also page 833.

[1] The gauge (Fig. 11) is the Starrett No. 452 cylinder gauge (L. S. Starrett Co., Athol, Mass.). Another is manufactured by B. C. Ames Co., Waltham, Mass.

These shoulders should be removed before a new piston can be properly fitted. In many instances this can be removed with a **hone.**

Installing new piston rings or pistons will not always overcome leaking by of gases if the cylinder walls are worn out of round or are tapered. An examination should be made to determine whether this condition exists, as the new piston rings will only touch the high spots in the cylinder, leaving a space between the rings and cylinder.

When removing a piston, always replace it in the same cylinder from which it was removed, as each cylinder usually varies in bore to a slight extent.

Installing Piston

When installing new pistons, select pistons which will all be **equal in weight** in ounces.

Inasmuch as there is sometimes a slight variation in the diameter of the pistons, they should be carefully measured.

Pistons of the same length as the old ones should be selected. If the distance from piston pin to top of piston is any greater, the compression pressure will be raised and likely cause a knock; if distance is less, the compression pressure will be lowered.

The pistons should next be checked for roundness as they occasionally become out of round due to rough handling in shipping. The pistons are checked with 3″ to 4″ micrometers (shown in Fig. 11A), the measurements being taken at different points around the skirt of the piston (see Fig. 6).

If the piston is out of round, it can be trued up by lightly tapping it with a rawhide mallet on the side of the skirt which shows the greatest diameter.

After piston is assembled to connecting-rod by fitting it to the piston pin, then fit rings to cylinder bore, then fit the rings to piston grooves.

For piston-pin discussion, see pages 796–798.

Piston-pin locking: Exercise care in fastening the pin securely in the connecting rod or piston, according to the type used. Securely **lock the set and clamp screws.** When cotter pins are used, be sure they are of ample size, otherwise the cylinder walls may be scored, as explained on page 814.

Piston and connecting-rod alignment: When assembling piston, pin and connecting rod, square them so that the **piston is not cocked** in the cylinder. Alignment corrections are made by carefully bending the connecting rod. See pages 802, 803.

Always lubricate pistons and pins and work-in engine lightly for several hours before putting it under load.

After new pistons are installed, caution driver to run car slowly—under 25 m.p.h. for at least 500 miles. See pages 833A and 824B—why.

When installing aluminum pistons with split skirts in the cylinder block, the vertical slots should be installed on the side of lesser thrust as explained on pages 807, 814 and 780.

How Pistons Are Marked; Standard and Oversize Pistons

Pistons are usually stamped on the head, and this stamp indicates the diameter at the skirt. For example, a **standard size** piston for, say, a 4½″ bore cylinder with a .003″ clearance may be stamped 4.497″, meaning that 4½″ in decimals is expressed as 4.500″ and 4.500″−.003″=4.497″. This method of marking, however, does not hold true in all instances, as manufacturers have different methods.

When an **oversize piston** is ordered from the manufacturer of a car, the probabilities are that it will be stamped for the oversize only. For example, suppose the cylinder diameter was 4″, and the standard clearance was .003″, the **standard piston** would then measure 4″−.003″=3.997″.

Suppose the cylinder was worn and the piston was loose, and you ordered a piston .005″ **oversize.** This would mean that the piston would measure at the skirt .005″ more than the standard size. It may be marked simply .005″ OS ("OS" stands for oversize), or it may be marked the actual measurement, as 4.002″. The 4.002″ is arrived at by adding .005″ to the standard size of 3.997″.

Another example: Suppose it is necessary to remove .027″ in order to properly clean up a Ford cylinder (3.750″ bore). Referring to Ford parts list, we find that the piston which would more nearly correspond to .027″ would be .03125″ oversize. It would then be necessary to enlarge cylinder to 3.78125″ (3.750+.03125) and install .03125″ oversize pistons (3.77825″ diameter) (see also **page** 823). On most other cars the nearest standard oversize is .030″. (Applies to Model "T" Ford).

Standard and Oversize Pistons

Pistons can be purchased in **"standard"** and **"oversize"** diameters.

A standard size piston is the original diameter of the engine cylinder, less the standard clearance.

An oversize piston is a piston larger than the original or standard size of piston.

The oversize piston is fitted to a cylinder when the cylinder is worn, or is enlarged, by re-boring, re-grinding, or reaming, as explained farther on.

In many instances, when a cylinder is worn and the piston is loose, an oversize piston of .0025″ or .003″ is ordered, and it is then "lapped" in, as explained on page 815.

S.A.E. standard oversizes for piston and piston-rings shall be 0.005″, 0.010″, 0.015″, 0.020″, 0.030″, and 0.040″. Larger oversizes, when necessary, shall be held to multiples of 0.010″.[1]

Finished pistons are usually furnished complete, minus rings and pins, unless otherwise specified.

When a finished standard-size piston is ordered, clearance is usually allowed for. See also Fig. 6, p. 810, for information to give when ordering.

When ordering finished standard oversize pistons, select nearest size as above. Shops where pistons are finished usually order semi-finished pistons and grind them to fit the job (see also page 819).

When ordering a piston finished to standard, a size equal to the diameter of cylinder bore, less proper clearance, is supplied.

When ordering oversize pistons, you will receive that oversize above the standard piston, and clearance will be allowed for.

Miscellaneous Oversize Engine Parts

Some of the other oversize parts are such as mentioned below:

Oversize piston pins are cheaper to use than it is to re-bush a piston. Simply ream the bushing when a piston pin is loose, and fit an oversize pin. See page 797.

Oversize valve stems are necessary when stem and guide are worn. The guide is reamed oversize, and a 1/64″ oversize valve-stem is fitted. See page 776A.

Oversize piston rings can be obtained of any supply house or piston-ring manufacturer. See pages **833A, 833B.**

Oversize valve tappets, oversize cylinder head bolts and other oversize parts can be secured of auto supply houses.

[1] **Other sizes,** although not recommended by S.A.E. can be obtained, as .0025″, .003″, .031″, .033″, .045″, .0625″.

Questions and Answers on the Standard Bore of Cylinder, Standard Size of Piston, Standard Clearance of Piston, Oversize Pistons, and How a Piston Is Measured

The Ford* Piston as an Example

Q. 1: What is meant by a "standard bore" of a cylinder?

Ans.: The bore or diameter of the inside of a cylinder as it comes from the factory. On the Ford it is 3¾″ or 3.750″, expressed in decimals (three inches and seven hundred and fifty one-thousandths of an inch).[1]

Q. 2: What is meant by a "standard size" piston?

Ans.: The diameter of a piston to fit this standard size bore, less the clearance. The actual diameter of a Ford "standard" piston is supposed to be approximately 3.747″ at the skirt.

Q. 3: What is meant by a "standard clearance" of a piston?

Ans.: The clearance adopted by the manufacturers. On the Ford, the standard clearance between the cylinder wall and piston should be .003″ to .004″.

Therefore if the cylinder is 3.750″ in diameter and the clearance is to be .003″, the piston should measure at skirt, 3.750″−.003″= 3.747″.

Q. 4: How is clearance measured?

Ans.: By measuring the clearance between piston and cylinder wall. A thickness gauge, shown in Fig. 10**B**, page 812, can be used.

If in checking pistons for wear, there is more than .006″ clearance, the old pistons should be discarded after removing the piston-pin and connecting-rod, and new oversize pistons installed, as will be explained farther on.

When checking, the thickness gauge should be tried at several points between piston and cylinder bore, especially around sides of the two oil pockets on the piston.

Q. 5: Suppose piston is out-of-round, would clearance be the same at all points between piston and cylinder bore?

Ans.: No. Check by inserting thickness gauge between piston and cylinder wall. While holding thickness gauge stationary, turn piston and check a quarter of a turn at a time. If piston shows out-of-round, remove piston and lightly tap it with a rawhide mallet on the greatest diameter of the skirt, to true it up.

Q.6: Where is a piston measured?

Ans.: At the skirt.

Q. 7: How much smaller is a piston at the top than at the skirt, and why?

Ans.: On a Ford, the piston is .010″ smaller across the head. The reason for the piston being smaller at the top is the fact that cast iron expands when heated, and the heat is greater at the top where the combustion takes place. There is also more metal surface at the top.

Q. 8: What is meant by an "oversize piston," and when is it used?

Ans.: A piston which is larger than the "standard size" is called an oversize piston. It is used when the cylinder is worn or rebored.

Q. 9: Do some of the manufacturers adopt a "standard oversize piston"?

Ans.: Yes. The Ford has adopted five: a .0025″ (two and one-half one-thousandths); a .005″ (five one-thousandths); a .010″ (ten one-thousandths); a .03125″ (thirty-one and one-quarter one-thousandths), and a .033″ (thirty-three one-thousandths of an inch).

Q. 10: When are the ".0025″ and .005″ oversize pistons" used?

Ans.: When the cylinder bores become slightly worn, the .0025″ or .005″ (according to the amount of wear) can be fitted by slightly enlarging[2] cylinder.

Q. 11: What is the diameter of a ".0025″ oversize piston"?

Ans.: The standard size plus .0025″; or 3.747″+ .0025″=3.7495″.

Q. 12: How much would the cylinder be enlarged to take this .0025″ oversize piston?

Ans.: The standard bore of 3.750″+oversize .0025″ =3.7525″.

Q. 13: Would this leave .003″ clearance?

Ans.: Yes. If the cylinder was enlarged to 3.7525″ and the diameter of an .0025″ oversize piston was 3.7495″, the difference would leave .003″ clearance.

Q. 14: What is the diameter of a .005″ oversize piston?

Ans.: The standard size plus .005″; or 3.747″+ .005″=3.752″.

Q..15: How much would the cylinder be enlarged to take this .005″ oversize piston?

Ans.: The standard bore 3.750″+oversize .005″= 3.755″.

Q. 16: Would this leave .003″ clearance?

Ans.: Yes. 3.755″−3.752″=.003″.

Q. 17: When is the .010″ oversize piston used?

Ans.: When cylinder bore is worn or scored more than .005″ it will be necessary to enlarge cylinder.

Q. 18: When is the ".03125″ oversize piston" used?

Ans.: When cylinder is scored or cut or worn considerably over .010″, the cylinder bore must be enlarged.

Q. 19: What is the diameter of a ".03125″ oversize piston"?

Ans.: The standard size plus .03125″; or 3.747″+ .03125″=3.77825″.

Q. 20: How much would the cylinder be enlarged to take this ".03125″ oversize piston?"

Ans.: The standard bore of 3.750″+.03125″= 3.78125″.

Q. 21: Would this leave ".003″ clearance"?

Ans.: Yes. If the cylinder was enlarged to 3.78125″ and diameter of an .03125″ oversize piston was 3.77825″, the difference would leave .003″ clearance.

Q. 22: When is the ".033″ oversize piston" used?

Ans.: When the cylinder becomes worn after it has been enlarged for the .03125″ oversize piston. The .033″ oversize piston is fitted. Some

[1] On all engines the bore may vary even as much as .002″. We shall assume that it varies one one-thousandths on the Ford; thus the cylinder bore may be 3.750″ or 3.751″ or 3.749″. Therefore in working out the answers to these questions, we shall assume that the bore is 3.750″, although, as stated, almost all cylinders vary at least .002″.

[2] reboring is recommended as shown on pages 823, 824, when stock is to be removed from cylinder bore.

*Applies to Model "T" Ford.

times cylinders are badly scored and require enlarging by reboring to this size.

Q. 23: What is the diameter of an ".033" oversize piston"?

Ans.: The standard size 3.747"+oversize .033"=3.780".

Q. 24: How much would the cylinder be enlarged to take this .033" oversize piston?

Ans.: The standard bore of 3.750"+.033"=3.783".

Q. 25: Would this leave .003" clearance?

Ans.: Yes. If the cylinder was enlarged to 3.783" and the diameter of an .033" oversize piston was 3.780", the difference would leave .003" clearance.

Q. 26: How are oversize pistons marked?

Ans.: They are marked with the oversize mark, as .0025", .005", .010", .03125", or .033". OS is often used as an abbreviation for oversize.

Q. 27: Is it advisable to fit pistons of the same size to all cylinders?

Ans.: Pistons vary slightly in size; therefore the fit of piston to cylinder should be a **selective fit.** The main points to consider are fitting the pistons so that they will have .003" **clearance,** and selecting pistons which will insure all four of them being approximately the **same weight.** This can be ascertained by weighing them on a scale. This will insure proper clearance and better balance. The proper procedure is to **bore the cylinders to fit the pistons,** as explained on page 823.

Q. 28: What is meant by a "balanced engine"?

Ans.: This is a broad subject, but if all pistons are the same size, and all cylinder bores are uniform, then the cylinders will come nearer getting a uniform charge of gas. Balance is aided if all connecting-rods weigh the same, and the crankshaft and flywheel are perfectly balanced, and all corresponding parts of each cylinder are of the same weight and size. Reciprocating parts should be light as possible.

Q. 29: How can pistons be fitted to worn cylinders where no enlarging devices are available?

Ans.: By lapping cylinders with an old piston and lapping compound to a diameter that will give .003" clearance for the new pistons (see page 815, explaining the lapping process); then thoroughly clean all compound from cylinders and fit the new pistons and rings, and then run-in in oil.[1, 2]

If cylinder walls are out of round, or tapered more than .005" (as explained on page 816), it will then be **necessary** to enlarge them.

Q. 30: How are piston pins checked for wear?

Ans.: By measuring the diameter of pin with micrometers. The diameter of the pin is .740" to .741"; if the old pin is worn down .001" or more below the low limit, install a new pin.

Q. 31: How is the play between piston pin and bushing checked?

Ans.: By holding the piston with piston pin perpendicular to the bench and moving the lower end of connecting-rod up and down in such a manner as to cause the pin to be forced first against one side of the bushing and then against the other side. (Do not confuse with side clearance between connecting-rod and pin bushing which must have $\frac{1}{32}$" to $\frac{1}{16}$" play.) If there is .002" or more play a new pin should be fitted. If this does not overcome the trouble it will be necessary to install new bushings (see pages 797, 798).

Q. 32: What about "oversize piston rings" when fitting oversize pistons?

Ans.: Oversize piston rings should also be fitted. For instance, if a .0025" oversize piston is fitted, fit .0025" oversize piston rings; in like manner the fitting of rings should be correspondingly the same for the .005", .010", .03125"", and .033" oversize pistons.

Q. 33: How much "clearance" should be allowed at the "gap of the ring"?

Ans.: .010" to .015" on all rings; or see page 827.

Q. 34: How is the clearance measured at the gap of a ring?

Ans.: Place the ring in the cylinder and measure the gap with a thickness gauge. If the gap is too small, file.

Q. 35: How are the rings installed?

Ans.: In **piston-ring grooves** that have had all **carbon removed** from them. (See p. 833.)

Q. 36: Should a ring have equal pressure or tension at all points of its circumference?

Ans.: By all means. See the discussion on the subject of "Piston Rings," pages 825–832.

Q. 37: What test should be made on a crankshaft?

Ans.: Examine for cracks and scores; if badly cracked or scored, install a new shaft; if slightly scored, see page 791. Check journals for wear and out-of-round with a micrometer, as shown on page 791. If main bearing journals show more than .0015", or connecting-rod crankpins more than .002" out-of-round, install a new shaft. If shaft is sprung more than .015", install new shaft; if less, straighten in straightening press (page 792). Flywheel flange must run true with bearing journals (see page 790A). If not true it will cause vibration, and wear out bearings.

Q. 38: What test should be made of piston and connecting-rod assembly before installing into cylinder?

Ans.: Test for alignment, as explained on page 803, to see if the assembly is slightly sprung or twisted; if so, it can be corrected by straightening the connecting-rod with a straightening iron. Also check for worn or cracked babbitt in both cap and rod; if babbitt is badly worn or cracked, a new cap and rod should be installed.

Q. 39: Should engine be run-in after installing new pistons and rings?

Ans.: Yes. See pages **833A, 833B.**

See pages 833A, 833B 824B and 633 **on the subject of "running-in a new engine" and "glazing the cylinder walls,"** which also applies to reconditioned engines. See page 833**A, B** on "**procedure of installing piston and rings and precaution to take afterwards." See also pages** 828, **814B.**

Some of the piston manufacturers are: Aluminum Company of America, Gulf Bldg., Pittsburgh, Pa. (Lynite); Aluminum Industries, Inc., Cincinnati, Ohio (Permite); Arrow Head Steel Products Co., Minneapolis, Minn. (Arrow Lite, Arrow Head); Bohn Aluminum and Brass Corp., Detroit, Mich. (Nelson Bohnalite, Bohnalite. Sole distributors to replacement trade, King Quality Products Co., St. Louis, Mo.); DeLuxe Products Corp., LaPorte, Ind.; Detroit Auto Piston Co., Detroit, Mich.; King Quality Products Co., St. Louis, Mo.; McQuay-Norris Mfg. Co., St. Louis, Mo.; Ohio Piston Co., Cleveland, Ohio; Ray Day Piston Corp., Detroit, Mich. (Ray Day, Pepper, Oil Master); San Diego Machine Co., San Diego, Calif. (Realite); Sealed Power Corp., Muskegon, Mich.; United Engine & Machine Co. (San Leandro) Oakland, Calif. (Dual-Flex, Silv-O-Lite).

See page 833B for an assortment of pistons, piston pins, piston rings, and bearings which the average service shop should carry in stock. **See page** 690 **for** *piston and piston ring literature.*

[1] See footnote 2, page 813A.

[2] If lapping (or honing) is done it is very important that care be taken to prevent grit lodging in crankcase and working parts. It would be best to remove cylinder block to the bench.

RECONDITIONING CYLINDERS

What constitutes a perfect cylinder? A cylinder block, before it is machined ready for use, has holes in it which represent the cylinders, but are considerably smaller than the size required. For instance, if the cylinder is to be 4" in diameter, when machined and ready for use, the original hole will be about ¼" smaller. This is because it is impossible to cast a perfectly smooth and true surface, and the holes, or cylinders, must later be bored out by machinery.

A cylinder-boring machine is used for this, and generally two cuts are made in the cylinder, a cut which removes all the material except just enough to be taken off in the finishing cut, which is a very fine cut. Sometimes a third cut is necessary to obtain the exact size, and when this is completed the cylinder walls are perfectly straight from top to bottom.

The cylinder is then reamed or ground and then honed to a polish finish. The cylinder is then perfectly round and the surface of the wall is nearly as smooth as polished glass. **A cylinder in this condition is said to be in perfect condition.**

For a finish of a cylinder there are five operations that can be performed on the cylinder bores, namely: (1) rough bore, (2) semi-finish bore, (3) reamed, (4) ground, (5) honed. Some manufacturers omit grinding.

The Lycoming cylinder blocks are first rough bored, then flycut, rough reamed, finished reamed, and then rough and finished honed. Continental engines are also bored, reamed and honed.

Reconditioning a cylinder bore means making the cylinder bore perfectly true and having the cylinder bores parallel and perpendicular to the base (explained on page 822, Fig. 25).

Conditions which necessitate reconditioning of cylinder bore arise when the bore is worn, out-of-round, tapered or scored.

Why Cylinders Wear Tapered, Out-of-Round or Oval

Why cylinders wear tapered: A depression will, in time, wear in cylinder wall **where the piston rings travel** (from **A** to **B**, Fig. 11C). This wear is a uniform kind of wear; however, it will probably be found, in most cases, that the wear will be greater toward the top and less at the bottom, one reason being that more oil is splashed on lower cylinder walls. The wear being greater at the top, it results in a taper.

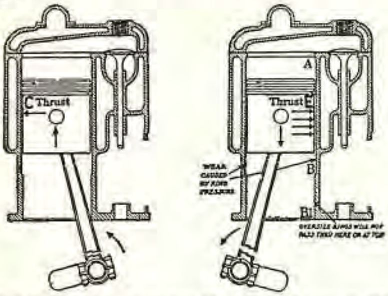


Fig. 11B (left). **Compression thrust,** as shown at (C), is near the top when on compression stroke, going up, due to the angular position of connecting-rod. (View is rear of engine as when seated in car.)

Fig. 11C (right). **Explosion thrust,** as shown at (E) is near the top when on power or explosion stroke, starting down. The resistance of connecting-rod opposes the force of explosion thrusting the piston against cylinder wall with great force. (View is rear of engine.) (See also pages 779, 780.)

If, on observing the piston rings, a black spot is found on the ring and it is not smooth, either the ring has lost its pressure or distorted at this point, or the cylinder is out of round. The result is that the cylinder leaks compression, pumps oil, fouls the spark plugs with oil, and consumes oil and gasoline all out of proportion to the power delivered.

The lower part of cylinder (**B** to **B1** Fig. 11C) may be true, but it will be observed that this leaves a shoulder below (B) and at (A), and it would be difficult to fit a proper oversize ring. Where wear does not exceed .002" to .005" and walls are not greatly out of round or tapered, the shoulder can be honed to a size corresponding with the wear to obtain a uniform size throughout the cylinder from top to bottom. If greatly out of round or tapered, it will be necessary to bore, ream, or grind. (On some engines where the ring slightly overlaps the top of cylinder wall, as in Fig. 33, page 833, there would be no shoulder at **A**.)

Why cylinders wear oval or out-of-round: The wear is greater on the two sides at right angles with the crankshaft.

This wear is the result of the **thrust** of the piston against one side of the cylinder wall on the **compression stroke** as at (C), Fig. 11B (due to connecting-rod being at an angular position as it pushes the piston against compression resistance.

As the piston and crank pass over dead center on **power stroke** and explosion takes place (Fig. 11C), the piston is forced against the opposite wall of the cylinder (E, Fig. 11C) with **greater thrust force.**

Inasmuch as the **explosion pressure is about three to five times as great as the compression pressure the thrust** at (E) is much greater than at (C). For this reason pistons with split skirts are always installed with the split at the left side as at (C), as this is the side of lesser thrust.

This alternate thrust action of the piston from side to side may in time cause oval or out-of-round spots toward the top. This wear is always greater near the top where the closest fit is needed most. Cylinders are often found worn .005" to .010" or more at the top, whereas the wear may be only .001" or less at the bottom.

Connecting-rods that are bent or twisted will cock the piston (see Fig. 76, page 803) in such a shape that the cylinder walls will be worn **out of line with the crankshaft** and hollow places in cylinder may be found that are sometimes as much as .010" deep. Thus the importance of properly aligning the connecting-rod (see page 803). A cocked piston usually leaves a shoulder about half-way around cylinder bore where piston stops on down stroke and a depression at top on opposite side.

If cylinder bore is not square with the crankcase, or if piston-pin hole is not bored square with the side of the piston, or if the holes in the ends of the connecting-rod are not parallel with each other, this will cause piston to become cocked, resulting in excessive wear on cylinder walls, or the same conditions as mentioned in paragraph above.

Cylinder Scores

There are two general kinds of cylinder scores, namely: (1) a piston-pin score; (2) a seized piston or piston ring score. Scores or cuts in cylinder wall permit a leak between the wall of cylinder and piston ring.

The piston-pin score is usually a long score on cylinder wall, the length of piston-pin travel. This kind of a score is nearly always **caused by a loose piston pin,** and the reason is as stated below.

All pistons are fastened to the connecting-rods by means of a piston pin securely anchored to the piston or to the connecting-rod. A set screw or lock ring is used to keep the piston pin from moving. If the mechanic should **fail to tighten set screw or lock ring properly**, or if they should work loose, the piston-pin would move from side to side and thus cut or score the cylinder walls where the end of the piston pin would touch it.

Some pistons are fitted with bronze bushings into which the piston pin works. Occasionally these bushings work loose, due to vibration, and score the cylinder walls in the same manner as a loose piston pin, but generally not as deep.

The seized piston score is where the piston is "seized" or stuck to the cylinder wall. This kind of a score may be a general score at different points on the cylinder wall, and very likely the piston itself will also be scored. Seized pistons do not always score the cylinder. In many instances the deposit from the piston will be left on the walls of the cylinder, which can be removed by lapping or honing.

The **cause of a seized piston is usually excessive heat or overheating,** and the overheating can be caused by lack of lubricating oil in engine, wrong grade of oil, dirt in the oil, highly diluted oil (gasoline in it), lack of water in cooling system, or pistons having insufficient clearance, or running a new engine at too high a speed for a long period of time. (The remedy for a seized piston will be given farther on.)

A leaky piston ring will sometimes cause scores. Cases have been known where the cylinder was getting plenty of oil, yet, if the rings were loose, the flame from the combustion would work past the loose ring and prevent it from receiving proper lubrication, causing it to heat and cut the cylinder.

Another point worth mentioning here is that on a new engine, especially where there is a lower oil-control piston ring placed in the skirt of piston, it is advisable to put a small quantity of high-grade cylinder oil in the top part of cylinder (also in the gasoline—see pages 833A, 833B), because the upper rings may not get sufficient lubrication and plenty of lubrication and moderate speed are necessary when working in a new engine.

A slightly scored cylinder can be reconditioned by honing if not over .005" deep, or by grinding, boring, or reaming if over .005" deep.

The practice of enlarging .030" to .040" is quite universal and it is practical to enlarge to .060", and many cylinders will even stand ⅛" (.125") with safety.

A point to bear in mind is that if a cylinder is enlarged ⅛" or .125", this would mean that only 1/16" or .0625" is taken from each side of cylinder.

Another point to bear in mind is that the larger the bore, the heavier the piston will be, and this tends to increase vibration (see page 808 about inertia forces).

The thickness of cylinder walls usually runs from 3/16" (.1875) to 5/16" (.3125") thick. Once in a great while, due to a shifting core when moulding, some cylinder walls may be very thin, possibly not over ⅛" at this point. This is mentioned so that the repairman can use **caution** when figuring on enlarging cylinders.

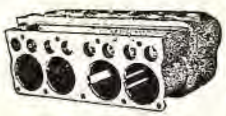
A deep piston pin score in the cylinder can sometimes best be repaired by one of the filling processes: for example, if the cylinder bore was enlarged all around to remove a very deep score, it might leave too thin a wall and the strength of the cylinder would be impaired.

Repairing scored cylinders by filling: One method is by fusing silver nickel alloy into the scores electrically and refinishing to the original size. This is called the Lawrence process.

Another process of repairing scored cylinders by fusing electrically is the McQuay-Norris process. The equipment used is called a score-filling machine and consists of a table, condenser, and electrode. The electrode is a special alloy metal which is fused into the score by an electric arc. The cylinder is then refinished. This process **can also be used for repairing cracked cylinder water jackets** (McQuay-Norris Mfg. Co., St. Louis, Mo.).

Another method of filling scores is the Eagle patented process, whereby the scores are dovetailed and a strip of copper alloy is inlaid and rolled into same as shown in Fig. 11D. This method is entirely mechanical, and the manufacturers claim it can be applied without enlarging the diameter of the bore or heating the cylinders, and the original pistons and rings can be refitted if not damaged.

In case where scores are unusually wide which would prevent the filling from being properly anchored, or where it was so deep that it was almost cut through, or is cut through, **a sleeve can sometimes be fitted** and thus a cylinder that would be thrown away could be reclaimed.



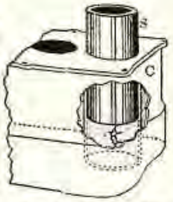


Fig. 11D. (left). **Repairing scored cylinder by filling** with the Eagle process. The score is dovetailed or grooved with a special tool to take the copper. The soft copper alloy is shaped to fit the groove, also with a special tool. The copper is then inlaid into the dovetailed groove. The copper which then sets above the cylinder bore is rolled down with a steel roller which swedges the copper tightly into groove, then a cutting tool planes the copper to a finish.

Fig. 11E. (right). **Cylinder sleeve (S) as applied to a cracked or broken cylinder (C).** To fit, proceed as follows: Bore out the cylinder larger in diameter, then turn and bore a semi-finished **cast-iron cylinder sleeve** to proper size, allowing grinding stock inside and .005" for press fit on outside. Press sleeve into cylinder, using a mixture of litharge and glycerine as a seal against water leaks. Grind to proper size. This method is called the replacement sleeve method. Sleeves, etc., can be obtained of Eagle Machine Co., Indianapolis, Ind. Another concern supplying sleeves and equipment for repairing piston-pin scores is the Storm Mf'g. Co., Minneapolis, Minn.

Remedy for a seized piston: Occasionally the repairman receives a call to start an engine that has the symptoms of a seized piston, and that has resisted the best efforts of owner of the car to start it. At such times the repairman must exercise the utmost ingenuity, for the owner has generally tried all the easy methods before he arrived.

In such cases, the first thing to do is to make sure that it is the engine and not some other part as the transmission or the rear axle, that is at fault. The rear wheels should be jacked up, the emergency brake released, and the gear-shift lever placed in neutral. The wheels should turn freely, and there should be no binding in the rear axle system.

The spark plugs should be removed, or the compression cocks opened, to relieve the compression. Then if the crank cannot be turned over by hand or by means of the starter, or by the two working together, the car may be towed with the gears in high and the clutch disengaged. As soon as the car has attained some momentum, the clutch may be allowed to engage gently, care being taken not to allow a sudden motion which might strip the gears in the rear axle, or even break a shaft.

If this does not free the engine, kerosene can be poured into the cylinders and allowed to remain for a couple of hours. This will have a tendency to dissolve any old oil which may have gummed the pistons to the cylinder walls. Then the car may be towed again, and an attempt made to turn over the engine by engaging high gear. The engine can be turned over more easily in high than in low gear because it does not have to revolve so rapidly.

After succeeding in turning over the engine, open the drain cock in the bottom of the crank case and drain out the mixture of kerosene and old oil thoroughly. Then the new oil should be added, the radiator should be filled with hot water in order to expand the cylinders, and the spark plugs should be replaced. After starting, the engine should be run slowly under its own power for some little time, in order that the new oil may work to all parts.

If piston is seized badly, it is best to tow car in and remove pistons and examine and recondition cylinder walls. Usually, the pistons do not always cut the cylinder, but a deposit from piston is left on the cylinder walls which can be removed by lapping, or, better, by the use of a hone.

The first troubles usually caused by worn or scored cylinders are fouled spark plugs and excessive carbon deposits resulting from oil leaking past the piston and rings. Compression also escapes by the worn

Cylinder sleeves or liners. Some engines are originally manufactured with replaceable sleeves or liners. They may be either of the "dry" or "wet" type. See Supplementary index under "*Cylinder sleeves or liners.*" **To repair** a scored or cracked cylinder block that was not originally equipped with sleeves requires the use of a properly fitted "dry" sleeve. **For literature** write: Aluminum Industries, Inc., Cincinnati, Ohio; Sealed Power Corp., Muskegon, Mich. Also sold by jobbers and motor-truck dealers.

parts, causing loss of power and wasting gas and oil. A very annoying knock or clatter, known as **piston slap,** soon develops. The longer the engine runs, the worse this condition becomes.

A **piston slap** not only causes a knock, as explained on pages 779, 780, and 812, but in all probability the cylinder will be worn at the upper point, on one side, owing to the explosion pressure forcing the piston, at an angle, constantly against the wall of the cylinder, thus causing **cylinder to become out-of-round.** This permits gasoline to pass between the rings and cylinder wall into the crankcase, which washes the oil from the cylinder walls, a major cause of rapid piston ring wear.

Cylinders wear taper where the piston rings travel, and the greatest wear is near the top of the ring travel. (See also p. 814.)

When To Enlarge Cylinders

The amount of out-of-round or taper requiring enlargement of cylinders varies according to the design of engine. **A practical method of determining when cylinders are sufficiently worn to require enlargement** is to note whether *oil consumption* is excessive, and whether *piston slap* is noticeably violent.

Excessive oil consumption is determined by too frequent filling, pistons pumping oil, oil-soaked spark plugs (indicated by excessive oil in the combustion chamber), and by "blow-by." A blow-by test can be made by listening for a hissing sound, as explained under "testing for piston-ring leaks," pages 768 and 829. Excessive oil consumption can also be caused by worn connecting-rod bearings. See footnote, page 826. A compression test will indicate if the rings or valves leak. See Addenda, page 41.

A prominent piston-ring manufacturer recommends: **If cylinder is tapered** under .005", instal new rings; if tapered .005"–.010", enlarge if possible, otherwise use spring-expander rings and perhaps piston expanders; if tapered over .010", completely recondition by enlargement and installing new pistons, rings, piston pins, etc. See also page 828 and footnote 2, page 825. Recommendations differ. Write for *piston-ring literature* as given on page 690.

Cylinders out-of-round .003" or more usually require enlargement.

The reason that more taper than out-of-round is permissible is that the piston-ring gap aids the ring in conforming to a tapered cylinder. *For example,* **if a cylinder is tapered .003" but is not out-of-round, the gap will open wider when piston is at top of stroke than when it is at the bottom but will still make contact with the round cylinder. The extra wide gap does not usually cause serious trouble. When, however, the cylinder is .003" out-of-round, as illustrated in Fig. 23, page 831, the gap will not permit a round ring to fit the out-of-round cylinder, and therefore "blow-by" or oil pumping may occur.**

The mileage at which it is necessary to instal new piston rings and to enlarge cylinders will vary materially with the type of engine, the care it has had, and the type of service in which it is operating. Unless oil and gasoline consumption become excessive or the engine loses power, an **inspection** of the rings and cylinder bores is not necessary until after about 30,000 miles of service. The conditions found during this inspection, together with the value of the car and the amount of money that the owner is willing to spend, will determine whether to completely enlarge cylinders or whether to use spring-expander rings and piston skirt expanders. (See page 828.)

If the cylinder is badly worn out-of-round (and it is usually out-of-round and tapered when worn), then it will be necessary to **enlarge** the cylinder bore and to **fit oversize pistons** and **oversize piston rings.**

When a cylinder is cut or scored, but not worn, and is not out-of-round, then the score or cut can be "sleeved," as stated on page 814A. In this instance the original or **standard-size piston can usually be refitted,** as the sleeve is usually bored, honed, or ground to standard size.

How Much To Enlarge a Cylinder

To determine how much to enlarge a cylinder, depends upon how much it is tapered, out-of-round, how badly worn, or how deep the cut is. Usually, one of the dimensions of the S.A.E. standard oversize pistons will meet the requirements. One must be careful, in enlarging a cylinder, to see that the wall of the cylinder is thick enough to stand it.

Oversize Cylinders

With a view to eliminating all unnecessary expense and delay, **the following standards have been adopted for oversize pistons by the Society of Automotive Engineers,** and pistons to correspond can be obtained from most engine and piston manufacturers. See page 813.

5 one-thousandths of an inch (.005") large for 1st
10 one-thousandths of an inch (.010") large for 2d
15 " " " " " (.015") large for 3d
20 " " " " " (.020") large for 4th
30 " " " " " (.030") large for 5th
40 " " " " " (.040") large for 6th

The meaning of 1st, 2d, 3d, and 4th is this: If the cylinder is scored or cut, say, .009" deep, then bore it to fit a .010" oversize piston. (Or enlarge the bore to the original diameter, + .010".) If cut .011", then bore it for a piston .015" oversize—but not between the two.

For example: Suppose that it is found necessary to remove .023" in order to eliminate scores, taper or out-of-round condition. On referring to the table above, we find the nearest standard oversize to be .030". It would then be necessary to enlarge the cylinder by .030". If the original bore was 3" (3.000"), it would have to be enlarged to a diameter of 3.000"+.030" or 3.030" (see page 813 for S.A.E. standard oversize pistons).

Remarks on Enlarging Cylinders

First, examine the condition of the cylinders and see if the cylinder walls are perfectly smooth and free from scores or scratches. **Second, measure or test cylinders** for taper and out-of-round, as explained on page 812.

Having done this, determine **whether the cylinders need repairing.** If the scores or scratches are very slight, they may be remedied by *honing* but if they are too prominent they must be *enlarged* and oversize pistons fitted.

When a cylinder requires enlarging it is understood immediately that the **old pistons are useless,** so far as this particular job is concerned. Honing, reboring, and finish honing, reaming or grinding; whatever the method may be increases the size of the cylinder and **new oversize pistons and rings** are necessary.

The cylinder with the greatest amount of wear is enlarged first, as it determines the size to which the other cylinders are to be enlarged.

Before starting to enlarge cylinders, the cylinder bore should be tested to see if it is at right angles with the base of the block.

When reconditioning a cylinder while on chassis by boring, honing, etc., **protect the bearings and crankshaft** with a cloth wrapped around them.

Resurfacing Cylinder Blocks and Heads

Cylinder blocks and cylinder heads sometimes warp, even on new engines. After severe heating this has been known to occur (usually due to cylinder castings not being properly heat-treated and seasoned, see Question 16, page 817). The result is that the cylinder-head gasket will constantly blow out and in some instances leak water on to hot piston head and crack it. In cases like this the cylinder head can be resurfaced or cylinder block machined on the top. If very much metal is machined off, an extra thick gasket will be necessary in order to prevent increasing compression.

Remarks on Fitting Piston and Rings

Next in order are the pistons and rings. Very much the same can be said of the pistons as has been said of the cylinders. Their wearing surfaces should be perfectly smooth, the same as the cylinder wall, but if their surface is badly scored or scratched there is no repair for them. See page 812 for fitting pistons and pages 829–833 for fitting piston rings.

There is one of two methods to be followed for fitting pistons when enlarging cylinders: (1) by enlarging cylinder to fit certain oversizes of pistons; (2) by grinding and fitting pistons to fit enlarged cylinders.

The best plan is to take the cylinder with the greatest amount of wear and enlarge it to the nearest standard oversize, and then enlarge the others to the same diameter; then procure oversize pistons ground to proper clearance to fit. In this way all cylinder bores and piston clearances will be equal.

Piston rings lose their pressure after long use, and cease to have enough strength to press or **expand** against the cylinder wall all around. As a result oil is permitted to pass by them and to enter the combustion chamber. Besides, compression sometimes is lost because the gas is permitted to escape past the rings; in many instances due to a loose fit of ring in **piston groove.** Excessive oil coming up into the combustion chamber is one of the first indications of poorly fitting rings. The gap between the ends should be the correct gap, as explained on page 828.

In the case of fitting patented rings, some manufacturers have a specially machined ring for each type of engine, and it would be well to specify the make and model of engine when ordering.

If the cylinder has been enlarged, the amount of oversize should be stated or give the exact micrometer reading of cylinder bore. See also pages 828 and 826 on oil control rings.

For the care of a new or reconditioned engine and glazing of the cylinder walls see pages 824B, 833A.

Lapping Cylinders

Cylinders which are out of round or tapered to an extent not exceeding .003″ may be improved by lapping. This process is one of the oldest methods employed in re-conditioning cylinders and is very tedious. Only a very small quantity of material can be removed from cylinder.

The lapping tool consists of an old piston that has been split with a hacksaw and mounted on a handle as shown in Fig. 18. The old piston is kept coated with a fine lapping compound. The tool is moved up and down and given a spiral motion thereby cutting away the material of the cylinder. At each stroke, the handle is slightly rotated so that the split will not continually be in contact with the same part of the cylinder thereby assuring uniform grinding at all points and hindering the formation of spiral cuts.

The lapping process is continued until the cylinder has been ground to proper shape as indicated by an inside micrometer or dial gauge. **The compound is then thoroughly washed from the cylinder** with kerosene. New oversize pistons and rings are fitted.

Where cylinders are lapped while in the chassis, caution should be used to **protect bearings** and thoroughly clean afterwards. **Oil pan** should always **be removed.** It is best to remove **cylinders to the bench.**

Many manufacturers strongly advise against the use of powdered emery, carborundum, ground glass, or other hard abrasives on cylinders or pistons. They claim that it will lodge in the pores of the cylinders and will continue grinding. For this reason, some manufacturers of lapping compounds[1] claim to produce abrasives that are only slightly **harder than iron and that are soluble.**

There are cases when the scoring of a cylinder is so bad that lapping or honing would be useless, and the cylinder must be reamed and honed, reground or rebored. Wherever there is any metal to be removed from cylinder bores the most satisfactory results are obtained by removing the cylinder block and turning it over to a shop that is specially equipped for this class of work.

Lapping Piston and Rings to a Cylinder

Lapping piston and rings: When new pistons and rings are installed in a cylinder which has been worn slightly out of round, the practice is to "wear in" or "lap in" each piston assembly for a few moments by moving the piston assembly slowly up and down in its proper cylinder after carefully coating the cylinder wall with a fine "lapping compound."

When this practice is employed, **care must be used to remove all particles of grit from the cylinder wall or the piston assembly** by a liberal washing in kerosene of all parts to which the "lapping compound" has been applied.

Thorough workmanship also demands that the rings be removed from the pistons before washing, in order that no particles may find lodging behind the piston rings. These particles of grit might later find their way out and perhaps severely score the cylinder wall or ruin the bearings in the engine. Replace each ring in the groove from which it was removed. Same applies to piston pins.

Lapping Slightly Scored Cylinders

If the cylinders are slightly scored, they can be lapped with an old piston. It is not desirable to use a new piston, because it will be worn away. For the same reason new rings should not be used in the piston during the lapping process.

Aluminum pistons cannot be treated in the same way as cast-iron pistons, because they are too soft. High spots on the pistons may be removed by means of a semi-cylindrical brass lap into which the piston fits, or carefully filed.

Lapping Only Rings to Cylinder

If the cylinder surfaces are in good condition, only the rings need be lapped. The purpose in lapping the rings is to make them fit against the cylinder surfaces at all points.

The lapping process consists in moving the rings back and forth in the cylinders in connection with a lapping compound. The abrasives should be the finest obtainable.

When the rings bear all around, the work is finished. This can be seen with the naked eye. See also above, under "Lapping Piston and Rings."

Note: It is advisable not to use any compound in which there is emery, as it tends to imbed itself in the parts and is difficult to clean out. A mixture of rotten stone ground to a paste with oil and applied to the rings serves very well for lapping and can be cleaned off more readily. See also pages 772, 790B on compounds.

The practice of lapping piston rings is not as popular at the present time as in the past, rings are now lathe or velvet finished and seat quicker.

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[1] **Some of the manufacturers of lapping compounds are:** Clover Mfg. Co., Norwalk, Conn.

mention *Dyke's Automobile Encyclopedia*); Pep Mfg. Co., 33 W. 42 St. New York, N.Y.; Zip Abrasive Co., Cleveland Ohio:

Lapping Methods and Devices

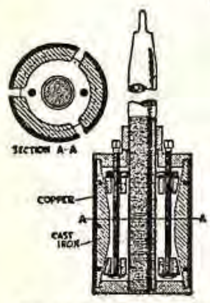
Lapping new pistons into cylinder for clearance is done when the **new piston** will go into the cylinder but with not quite enough clearance.

Lapping the cylinder for a new piston is done when the piston is slightly too large to go into the cylinder. An **old piston** is split so that it will expand and the cylinder walls are lapped down with it so the new piston will fit with proper clearance.

Lapping the cylinder for a slight score is done with an **old piston** split, and **oversize piston** must then be used.

Lapping rings into the cylinder can be done with new or old piston.

The following illustrations give an idea as to the different devices used for lapping a cylinder.



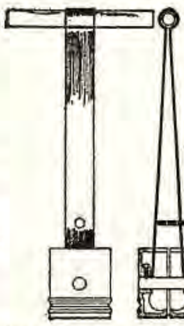
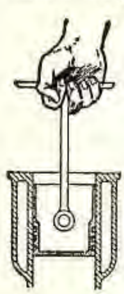


Fig. 12 (left). A simple design of an **expanding lapper**. Such a tool as this may be used in the drill press, an up-and-down and rotary motion being applied at the same time.

Fig. 13 (center). **An expanding piston lapper which may be used for lapping rings or cylinders.** The two operations should not be simultaneous, however. When the cylinders are slightly scored, the marks should be removed first, and then the new rings should be lapped in. Note the screw for expanding the shank against sides of piston.

Fig. 14 (right). **Piston lapping handle.** It is made of ordinary ½″ pipe, a T at the lower end slipping over the wristpin of the piston. The wristpin used in lapping should be made of fiber, as a metal one is likely to score the cylinders.



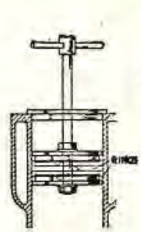


Fig. 15. **Rings may be placed in an old piston.** A new piston should not be used because it will wear away to some extent, and this is objectionable.

Fig. 16. **When no piston is available the rings may be lapped between two blocks** of wood as shown.

Fig. 17

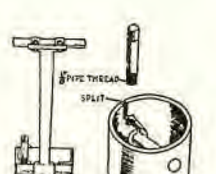


Fig. 17. **Another method** is to cut off the head of the piston and to use the wristpin for a handle.

Fig. 18. **An expanding cylinder lap,** made from a worn-out piston. The head of the piston is removed. One wristpin bearing is tapped; the piston is then split, as shown in the right-hand cut, so that a tapped plug screwed into the tap hole will cause the piston to expand. An old connecting-rod and handle are then provided as shown in the left-hand cut.

Honing Cylinders[1]

The process of honing was originally created to replace lapping by providing a less laborious and more dependable method. At the present time, hones have been improved to such an extent that they are considered satisfactory for correcting taper, out-of-round, burned and slightly scored cylinders to an oversize not exceeding .010″ in diameter.[2] For larger oversizes, honing is neither practical or efficient. Another use of honing is to remove the shoulder caused by ring wear which causes "ring knocks."

A hone consists of a steel frame supporting grinding stones which are pressed against the cylinder wall by springs (see Fig. 33, page 824A).

A **lubricant** (usually kerosene) is used and hone is revolved and moved up and down within cylinder until desired amount of material has been removed. **The time of a run** is 30 to 60 seconds, after which hone should be removed for measuring. The hardness of metal is what determines the cutting speed of a hone, in addition to the pressure applied. A manufacturer states that a cutting speed of .002″ per minute is the average.

Two or more grades of **stones** are provided, the coarser being used first for removing quantities of material such as removing large tapers (.005″ to .010″); a medium grade for small tapers (.003″ to .005″) and the fine stone which is 2″ longer than coarse stone is used for finishing or polishing. Stones for polishing are seldom used to remove over .001″ to .001½″.

The hone is often revolved by an electric drill as illustrated in Fig. 19. A ½″ heavy duty drill is generally used but a ⅝″, or even a ⅞″, is preferable.

To support drill and hone while honing and thus saving operator's back a Ford inner tube or a flexible coil spring can be used to suspend the drill and hone above cylinder.

Hones for service shop use are also operated by special drill stands and also by automatic honing machines with an automatic reverse which gives a uniform feed up and down the cylinder. One device of this type is made by the Storm Mfg. Co., Minneapolis, Minn.

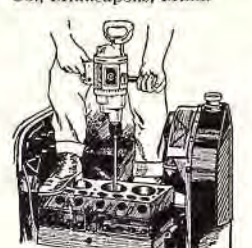


Fig. 19. Honing a cylinder in chassis by means of a hone and an electric drill. Great care must be exercised when honing or lapping, especially where engine is in chassis, that **grit does not get into crankcase and bearings resulting in damage to them. Parts should be carefully protected and cylinder and all parts cleaned thoroughly. Oil pan should always be removed. It is best to remove cylinder block if possible.**

Hones are used in service work to remove tapers and oval conditions. One of the most common uses of a hone is to **finish or polish a cylinder** after it has been enlarged by boring or reaming. Many **automobile engine manufacturers finish or polish cylinders by honing,** as the surface produced is very smooth. The hones are placed in multiple drills. No correction of taper or out-of-roundness is required of the hone in factory production as the cylinder holes are true. See page 824-A, explaining the operation of a hone.

[1] See footnote pages 694, 824B for list of concerns specializing on cylinder reconditioning tools.

[2] By enlarging .010″ in diameter, it is necessary to remove .005″ of metal all around the cylinder. See difference between radial and diametrical clearance, page 827.

Questions and Answers on Enlarging Cylinders

Q. 1: When should a cylinder be enlarged?

Ans.: When it is badly scored, or worn out-of-round more than .003″ or tapered more than .010″. See pages 814B, 814–814A, 812.

Q. 2: How can you tell if it is out of round?

Ans.: By measuring as described on pages 811, 812, 814-B.

Q. 3: Suppose it is not out of round but deeply cut, should it then be enlarged?

Ans.: If cut too deep for safe enlargement, resleeve (see p. 814A).

Q. 4: How much should it be enlarged if out of round?

Ans.: Enough to have it perfectly true. See page 814-B.

Q. 5: How is a cylinder enlarged?

Ans.: By grinding, boring, reaming, honing or lapping.

Q. 6: Which is most commonly used?

Ans.: Grinding. Boring, with a special boring machine, then finish by honing.

Q. 7: How is a grinding machine operated?

Ans.: Grinding is done on a special grinding machine, employing a wheel made of abrasive material revolving at a high rate of speed on the end of a rigid spindle. The spindle at the same time moves in a circular path, so that the revolving wheel travels around the hole. The path of the spindle is adjustable to the diameter of the hole. The cylinder is held stationary, and a multiple cylinder block can be ground without removing it from machine, thus insuring all cylinders being perfectly round, smooth, straight, and square with the base of the cylinder casting. Grinding gives a true, smooth surface and no matter how hard or soft the material, the grinding wheel will grind it just the same. A lathe tool cannot leave a cylinder as smooth as a grinding wheel. Some grinding machines are portable.

Q. 8: How are cylinders bored?

Ans.: By placing them in a lathe; by placing them in a drill press; by placing them in a special boring machine, or attaching a portable boring tool. When placing a cylinder on the face plate of a lathe, a long boring bar is used. The cylinder, unless clamped securely, will move and ruin the job. Other disadvantages are that the boring bar is likely to vibrate or slide over a hard spot without cutting. The cylinder must be reset on the face plate, if a multiple cylinder block, thus requiring skill to bore each cylinder square with its base. A lathe tool cannot leave a cylinder as smooth as a grinding wheel. When placed in a drill press, the cylinder does not revolve, and can be held more securely, but otherwise there are the same disadvantages. When placed in a special boring machine, the work can be done better than on a lathe or drill press, as the cylinder is held securely in place and the boring-bar spindle is heavy and rigid. Cylinders are then usually finished by honing.

Q. 9: How are cylinders reamed?

Ans.: Cylinders can be reamed on a drill press (see page 694), or by a reaming outfit which can be attached to cylinder block (pages 824-A, 714). The possible disadvantage of reaming (with some types of reamers) to enlarge a cylinder, is the tendency of some reamers to follow the course of the old hole, thus preventing it from making a new and perfect hole. It is also necessary to take a deeper cut than would be necessary if grinding. Reaming worn or scored cylinders can be done without removing engine from chassis, and thus costs less. In factory production some manufacturers bore, then ream, then hone, but have special rigid machines.

Q. 10: Is it necessary to fit larger pistons when a cylinder is enlarged?

Ans.: Yes; oversize pistons must be fitted as directed on pages 813, 814-B, and oversize rings must be fitted to pistons (pp. 828, 813).

Q. 11: Would you advise sending a cylinder block to a specialist to regrind and have the pistons fitted to the cylinders, or fit the cylinders to the pistons?

Ans.: Grinding is considered the best, especially if cylinders are badly worn. Grind the cylinders to equal bore and grind oversize pistons to fit each individual cylinder. See answer 2, p. 824.

Some machinists claim that cylinders can be ground more accurately than pistons can be ground, and for this reason, the final or finish grinding on the cylinders is done after pistons are finished, so that each individual cylinder bore is finish ground to fit each individual piston. See also p. 824B.

Q. 12: What are the symptoms of a worn or cut cylinder?

Ans.: Lack of power, heavy fuel and oil consumption, smoke, fouled spark plugs, and a piston slap. See answer to question 1, page 809.

Q. 13: Where do cylinders usually wear?

Ans.: In the space where the rings travel. If the piston is loose, then the constant pressure from explosion force will wear the cylinder on one side, near the top, owing to piston striking the cylinder wall at an angle. See pages 814–814B, 833, 780.

Q. 14: Isn't it possible to fit oversize rings to a worn cylinder?

Ans.: Yes, but it is not altogether satisfactory. If the cylinder is oval, then no round ring can fit it. (Also applies to pistons.) See p. 828.

Q. 15: Is it advisable to lap oversize pistons to a worn cylinder?

Ans.: The piston or lapping tool is sure to follow the old hole. While lapping may improve conditions temporarily, it is not recommended if other methods of enlargement are available. The cylinders become charged with abrasive that cannot be entirely removed by washing, and lapping continues as the engine is operated. New pistons, with proper clearance, should be installed after lapping.

Q. 16: Are all high-grade engine cylinders heat-treated or seasoned?

Ans.: Yes. Heat-treated, or seasoned castings are used and ground pistons are fitted to each individual cylinder. This prevents warping out-of-round when heated. Almost all cylinders, in factory production are first bored to within about .005″ of size, and then ground, or reamed and honed. See answer 4, p. 810.

CYLINDER, PISTON, AND CRANKSHAFT GRINDING AS A BUSINESS

The following material is taken by permission from the copyrighted booklet issued by the Heald Machine Co., Worcester, Mass., manufacturer of cylinder-grinding machines. This book discusses the following subjects:

Cylinder Regrinding as a Business: A treatise on the Field and Advantages; Equipment and Component Parts; Reasons, Advantages and Methods of Refinishing Cylinder Bores; Facts Worth Considering.

Reground cylinders fitted with new pistons and rings will give the engine as much power and pep as when it was new. It cuts the oil and gas consumption, and stops excessive smoking.

It has been shown that quite a virgin field presents itself in the smaller shops, because on a small investment they can often place themselves in the class with the larger shops. Many of the small shops are fully equipped with the exception of a grinder.

There is no business today that has the possibilities and which fits so nicely into a small machine shop, automobile repair shop, or a concern doing welding as the regrinding of worn, out-of-round or scored cylinders.

The field for regrinding: There are over 17,500,000 commercial and pleasure cars registered in the United States. Truck and tractor cylinders on an average will require attention once a year. Passenger cars should be overhauled at least once every two or three years. Figure out for yourself what your chances are when properly equipped for such work. Consider the fact that 3 four-cylinder blocks a day will bring profitable returns.

The car manufacturers and engine manufacturers have long since recognized this as the best method of finishing cylinders. Many of the repairmen advocate it; but to the owner it still means an unnecessary operation—only another way to add a few more dollars to his already overtopped garage bill.

It is, however, so vitally important in helping the engine to function properly that careful thought and study should be given it by every driver.

Prices Charged for Regrinding

As for prices that are charged for regrinding, they vary in different sections of the country, as well as in the localities in the same sections. It is best to get several price lists from the nearest concerns doing business, and to charge according to the conditions in your particular city. Never cut prices under a competitor, as regrinding is a quality proposition and it will cheapen your work and eventually be a losing proposition.

On the other hand, remember you cannot make a fortune overnight. Excessive prices will simply be an incentive for your customers to buy new blocks or to refinish by the boring method.

This schedule of these job prices was prepared some time ago, but are approximately a correct average.

On Fords, Chevrolets, and other mass-production cars sometimes prices are a little off these list prices, about 30 per cent off.

Approximately $10.00 per hole includes the price of the pistons and pins, or in other words this is a fair average of what it would cost to do the complete job, grind the hole, fit the pistons, pins and rings.

See page 683 for list of concerns who do cylinder grinding, engine rebuilding, carry engine parts, such as pistons, rings, etc., and also conduct rebabbitting service.

Average Prices in Different Parts of the Country for Regrinding Cylinders

Size	Cyl.	East	South	High Middle West	Low Middle West	Far West
Under 3"	2	$22.50	$24.00	$23.00	$17.00	$28.00
	4	43.00	41.50	45.00	34.00	42.00
	6	58.00	60.00	64.00	51.00	60.00
	8	74.00	77.00	83.00	66.00	76.00
	12	109.00	100.00	120.00	101.00	107.00
From 3" to 3½" dia.	2	22.50	27.00	24.00	18.00	32.00
	4	46.00	45.00	48.00	36.00	50.00
	6	59.00	64.00	68.00	53.00	71.00
	8	75.00	79.00	87.00	68.00	90.00
	12	114.00		131.00	106.00	128.00
From 3⅝" to 4" dia.	2	24.50	29.00	28.00	23.00	36.00
	4	44.00	49.00	54.00	42.00	58.00
	6	66.00	70.00	76.00	63.00	81.00
	8	82.00		104.00	85.00	104.00
From 4⅛" to 4½" dia.	2	25.00	35.00	32.00	24.00	43.00
	4	50.00	55.00	60.00	46.00	69.00
	6	68.50	77.00	84.00	68.00	97.00
From 4⅝" to 5" dia.	2	28.00	37.00	35.00	26.00	49.00
	4	53.00	62.00	67.00	50.00	79.00
	6	72.50	82.00	93.00	73.00	111.00
From 5⅛" to 6" dia.	2	28.00	40.00	42.00	26.00	60.00
	4	55.00	66.00	78.00	50.00	93.00
	6	72.50		130.00	73.00	136.00

Prices without pins — Prices with Pins

Parts to Carry in Stock

For small concerns starting in the re-grinding business, it is more desirable at first to buy pistons, rings and wrist pins in various sizes from the manufacturers of these parts, confining all the efforts to re-grinding and fitting up the component parts. In this way a large volume of business can be done with a very small organization, and thus a very tidy profit can be made.

A certain amount of stock of all these parts should be carried, depending on the class of trade, the distance from the source of supply, and the size of the shop.

Pistons; Rough, Semi-Finished, and Finished

Pistons can be carried in three different stages of completion: rough, semi-finished, and finished, depending on whether the equipment of the shop will take care of the rest of the finishing operations.

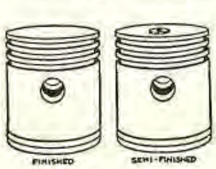


Fig. 20

Finished pistons are furnished finished complete, minus rings and pins; but these in many cases will be included, if so ordered. They usually come in oversizes of standard, .005", .010", .015", .020", .025", .030", and .040", and some manufacturers supply sizes from .003" to .060". **When ordering finished pistons,** the exact micrometer reading of the cylinder bore should be given and proper clearance will be allowed by the piston manufacturer.

Semi-finished pistons are finished with the exception of the outside diameter, which is left large to be ground down to the required diameter, and the wristpin holes which are rough-reamed and must be finished-reamed. **When semi-finished pistons are ordered,** instructions as how to finish are usually supplied by the piston manufacturer.

Finishing Semi-Finished Pistons

There is one operation on pistons that can be nicely taken care of by practically all re-grinding concerns, and that is the finishing of the outside diameter. Orphan cars afford a big field for grinding pistons and rush jobs can always be taken care of and furthermore, when the **piston is ground to fit the bore** a good job is assured. **The best plan, however, would be to bore the cylinders to one size and then grind the pistons to fit the cylinder bore.** All cylinders and pistons would then be equal in bore and would have the same weight.

Most piston manufacturers will furnish them finished or semi-finished. By using a semi-finished piston, which usually comes 1/16″ oversize, and grinding it down to fit the bore, not only will it increase production, but it will allow the carrying of a larger supply on the same investment.

Finished pistons will change, even when bought from the best of manufacturers, and will frequently be found out of round. (A slight tap with a wooden hammer when fitting out-of-round pistons to holes will usually bring them back.)

In finishing the outside of the pistons a suitable external grinding machine must be obtained, as the cylinder grinder is of no value for such work. In securing such a machine, it is well to keep in mind two facts: that the length of a piston seldom exceeds 6″ or 8″, and the diameter, even on the larger sizes, does not ordinarily run over 5″. Therefore a small-size external grinder that will swing 6″ or 8″ with sufficient length between the centers is very satisfactory.

The pin holes in semi-finished pistons come rough-reamed with .002″ or .003″ left for finish-reaming. Any good adjustable hand-reamer will take care of this.

Remember, that in **finishing the outside diameter,** the lands should be relieved and made smaller than the skirt by at least .008″ or .010″. The excess heat and solid metal cause greater expansion at this point. See also, pages 809, 811.

Always measure a piston below the wristpin hole at the skirt, and not above it on the head.

For fitting piston, see pages 812, 815.

For fittings piston rings, see pages 829-833.

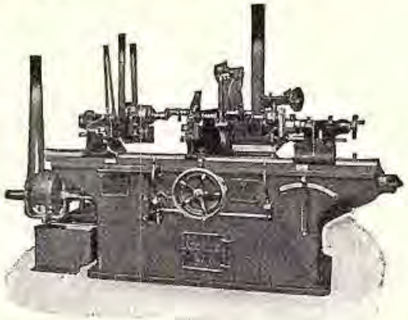


Fig. 20A. Landis 4-A special grinding machine grinds semi-finished pistons to exactly fit the bore. Grinds pistons, piston pins, crankshafts, etc., but not cylinders and cams on camshafts. This machine has a capacity of 16″ swing and 66″ between centers.

Crankshaft Grinding[1]

An allied line which fits in very nicely with cylinder grinding is that of crankshaft grinding. Too much cannot be said about the importance of keeping a crankshaft in perfect condition. The crankshaft, virtually the backbone of the engine, when sprung out of alignment or when its journals are worn out of round, will soon wear the main bearings and connecting-rod bearings which bear directly on the shaft; consequently it will cause the engine to knock.

It is impossible properly to fit a set of bearings to a shaft which is out of round or out of alignment, and the extra time consumed in obtaining even a fair job would more than pay for re-grinding the shaft.

There has, however, been a great deal of misunderstanding regarding actual crankshaft grinding.

By the old method of filing, lapping, and polishing[2] a shaft—a slow and expensive operation, which is often misconstrued as grinding—it is impossible to obtain accurate results. This work should be done on machines built especially for crankshaft grinding.

Equipment Required[3]

To do re-grinding, or to fit pistons, rings, and pins successfully, one must have the proper equipment. We have listed below the machines and accessories that make up such a shop. Prices for these will vary, especially if second-hand tools are used. Therefore it is hard to state any given value. All local machine-tool dealers will be glad to fill these in, and the amount of capital required can be determined at that time.

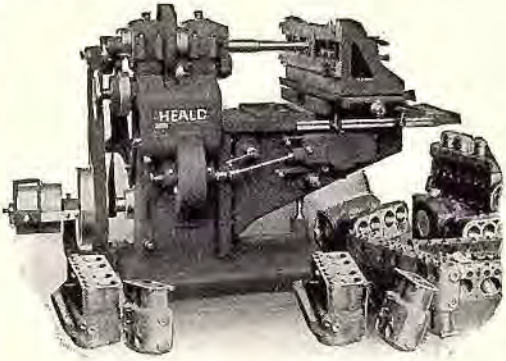


Fig. 21. A Heald cylinder grinder.

Machines Needed for the Average Shop

One style No. 55 or 50 Heald cylinder grinder.
One small external grinder.
One 14″ lathe.
One sensitive drill press; one back-geared drill press.
One 10 h.p. motor.
One emery stand.
Expanding reamers, sizes ⅝″ to 1½″.
Shafting hangers and belts.
Benches and tools.
Supply of pistons, rings, and pins.
Office equipment.

This comprises a fully equipped shop planning to use semi-finished pistons. For anyone just starting in, it is possible to do away with part of this equipment. By using finished pistons, it will not be

[1] Some of the concerns making machines for grinding pistons, etc., are Landis Tool Co., Waynesboro, Pa.; Van Norman Machine Tool Co., Springfield, Mass.; Simplicity Mfg. Co., Port Washington, Wisconsin (for lathe attachment).

[2] **Crankshaft journals can be honed** and the manufacturers state that doing so is an equivalent to 3,000 miles of actual wearing-in, and that both connecting-rods and main bearings get a tight fit and remain tight without tak'ng up for a longer period of time.

[3] From copyrighted booklet of Heald Machine Co., Worcester, Mass.

necessary to have an external grinder; and while two lathes are much more convenient, a 14" one will handle the work very nicely, and for the work which you would ordinarily use the back-geared drill press for, such as drilling wristpin holes, a lathe will answer the purpose.

When to Grind

Passenger cars: Cars that do not run tight, that use an excessive amount of gas or oil, lack power or pep, or smoke, need overhauling. A disagreeable piston slap is a sure sign of worn cylinders. This is usually heard on hills, or when the engine is laboring hard.

After it is taken down, it can best be determined whether it needs to be re-ground or not. If found scored, out of round, or with excessive clearance between the piston rings and cylinders, the cylinders certainly need re-grinding.

All cars that have been run two or three years should be pulled down, re-ground, and fitted with new pistons and rings.

If the cylinders have been welded for any purpose, such as a score or a crack, they must be re-ground. Welding distorts and changes the shape, in addition to leaving excess metal. Regrinding is the quickest and most practical method to finish welded cylinders.

With commercial cars or tractors, the same reasons for re-grinding hold true as with passenger cars. They are usually worked constantly to their full capacity, and are required to perform tasks which require every ounce of power.

Tractors, in particular, are subject to excessive wear, owing to the conditions under which they must work, and to the dust and dirt working into the engine. Re-grinding should be done at least once a year.

Why Engine Cylinders Should Be Re-Ground

It is essential, in order to have an engine run properly, that the cylinders be re-ground so that they do not vary more than a .001" as to roundness. The hole must be straight and absolutely square with the base of the cylinders, otherwise there will be a noticeable loss of power and pep, excessive use of gas and oil, piston slap, continual fouling of the spark plugs, and general troubles of all kinds.

Compression

It is necessary that a cylinder bore be straight and round to obtain the proper compression. You cannot fit a ring and have it tightly seal a cylinder with an out-of-round hole or one which has been enlarged at the top, either by error or inaccurate machining. Compression means a live engine, and rings must fit the hole. See also page 764.

Waste of Oil and Gas

When an engine has lost its compression, and knocks on the hills, etc., the owner usually makes the mistake of trying to cure the trouble by enriching his mixture. While this will temporarily cure the trouble, an excess of raw gasoline in the cylinder, on the compression stroke, is forced past the rings, thinning the oil and destroying its lubricating qualities, and possibly resulting in scored cylinders.

This gasoline eventually reaches the crank case, where it thins the oil to such a degree that it is useless as a lubricant. Old and worn cylinders are not the only places where this happens, as it also occurs in many engines where the holes were inaccurately finished.

Thus not only is excess gas being used in proportion to the power secured, but a large share of oil is going off in smoke, or is being rendered useless, thus requiring constant renewal.

Missing

Ill-fitting rings not only allow leaking of gas, but on the suction stroke air is sucked up from the crankcase, thinning the mixture and causing the engine to skip. This is particularly noticeable when traveling at idling speeds or starting on cold mornings.

Carbon

When the oil gets by the piston rings into the combustion chamber and is burned by ignition, it gives off a bluish smoke, leaving carbon formed on the head of the piston and in compression chamber.

Carbon holds heat, and if the compression is high, it will often explode the mixture prematurely. This is called pre-ignition, which opposes the driving forces of engine and causes undue wear on pistons and bearings, and it very often results in a broken piston pin, bent connecting rods, or a scored cylinder. Of course, burned oil soots the spark plugs and requires constant cleaning to keep a hot spark.

Engine Knocks

Engines that have thick carbon deposit will result in knocking on the slightest pull. This condition is all caused by oil leaking past the rings into the combustion chamber, where it is carbonized.

Are Re-Ground Cylinders, with Pistons Ground to Fit, Better than New?

When the statement is made that a re-ground engine which has been fitted with new pistons and rings is better than it was originally, few people can understand why. It is a well-known fact among those connected with the metal industry that castings change shape after they are cast. This is caused by strains and stresses resulting from the heavier walls of metal cooling last and shrinking from the already cooled lighter walls.

These strains can be relieved if the castings are seasoned for a long time, or by heat-treating processes.

Castings that are immediately machined and put to work in a car change more or less, owing to the heating and cooling of the engine, which acts as a heat-treating operation. Therefore, an engine which has been run several hundred miles is thoroughly seasoned and is in ideal condition to be re-ground and fitted up.

Once having been relieved of all the strains and stresses, the castings will retain their shape continuously after grinding, if properly machined and fitted up.

Actually, of course, an engine does not have any more power after re-grinding than that for which it was originally designed.

The fact, however, that the casting is seasoned, and that each hole has had individual attention, often gives better results than a general-assembly proposition.

DIFFERENT METHODS OF FINISHING BORES OF CYLINDERS[1]

Methods of Finishing Bores

There are five methods of enlarging cylinders: (1) by boring; (2) by grinding; (3) by reaming; (4) by honing; (5) by lapping.

Remember first and last that cylinder reconditioning by any method is a precision proposition, and that too much care cannot be applied to the task.

The prime object of either operation is to **finish** the cylinder, so that it is absolutely round and straight, and then to fit the cylinders with new oversize pistons and rings.

Reboring Cylinder[1]

Boring is done by a steel-cutting tool in the same manner as that in which a lathe cuts. It produces a porous-like surface which is subject to rapid wear.

When a cylinder is re-bored, the tool must get under the hard surface skin of the worn and polished cylinder wall, and as a result a heavy cut, as compared with grinding, must be taken. Therefore, the cylinder bore is enlarged more than is necessary and the walls are often reduced in thickness to a greater degree.

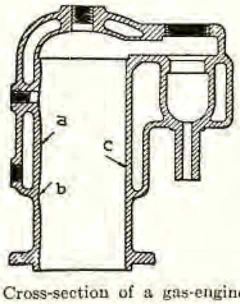


Fig. 22. Cross-section of a gas-engine cylinder.

With the re-boring method, a considerable amount of pressure will be exerted on the walls of the cylinder. Since these walls are not very thick and are reinforced only by the water jacket in certain places, it will be found that the walls where they are not reinforced will spring away from the cutting tool, when it springs back after the tool passes on, leaving an elevation, shown at (**a**). Where the walls are reinforced, the tool will take a slightly heavier cut, as at (**b**) (Fig. 22).

There are also hard and soft spots in the iron, and the cutting tool will bite into the soft spots and spring away from the hard ones.

This condition makes it difficult to produce a true round hole within exceedingly close limits of accuracy by the boring tool method. If the cylinder bore is out of square with the base, reboring will not always correct this error as the tool has a tendency to follow the worn hole.

Reaming Cylinder[2]

Reaming is similar to boring, except that a number of tools set in one head are used instead of a single tool. What has been said about the disadvantages of boring applies equally well to reaming.[2]

When the pistons and rings are assembled in cylinder, **after boring or reaming,** Fig. 23, they will rest on minute hills of metal. About half the bearing surface is thus lost, owing to the depression of metal between each hill. A full bearing surface is not realized until from .002″ to .005″ of metal has been removed by the pistons and rings. This causes a very rapid wearing of the cylinder walls until they are worn to full contact.[2]

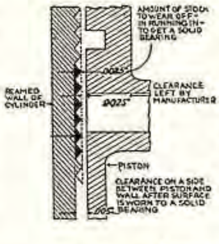


Fig. 23. Showing uneven surfaces left on walls of cylinder after boring or reaming (exaggerated) (from Heald booklet).

Lapping Cylinder

Lapping the holes of worn cylinders will not make them round or straight, because the lapping process is good only for polishing surfaces, and even after hours of work, but little material is cut away, leaving much of the lapping compound imbedded in the walls. It is an expensive operation, and the degree of accuracy and success to be achieved depends entirely on the skill and experience of the workman.

A worn cylinder is always larger at the top than at the crank end, owing to the friction of the rings and also to greater heat and poorer lubrication. Therefore, the grinding machine can be used to cut away the material necessary to get a round and straight hole for the entire length.

When lapping is done, two metallic surfaces are rubbed together with oil and abrasive material between them. This will charge the surfaces with grit.

Grinding in a machine with a hard, vitrified grinding wheel running at a high speed to cut the metal away is an entirely different proposition, and is the only way to secure the best results.

Finishing by Grinding

In finishing a cylinder by grinding, an abrasive wheel held by a very rigid arm moving at high speed cuts away the metal freely without putting undue pressure on the cylinder walls. The feed of the wheel into the work can be adjusted so that it will remove the metal rapidly if a large amount is to be taken off, or so lightly that it is practically immeasurable.

The grinding wheel revolves in a perfectly true circle and cuts away the iron until a round and straight hole is produced, without either high or low spots, and having a beautiful, smooth, and mirror-like surface throughout.

The work is held on an angle-plate attached to the cross-slide of the machine; the main table, traveling lengthwise, moves automatically. When a hole is finished, movement of the cross-slide gives the proper position for the next hole.

The block remains set during the entire operation, insuring the bores being absolutely parallel to each other and at right angles to the base, this being assured by the angle-plate mounted on machine at 90° to the grinding spindle.

[1] **The following discussion (pages 821, 822) of the advantages and disadvantages of each method** is taken from the instruction book of the Heald Machine Co.

[2] **In factory production,** some of the leading engine manufacturers use the reamer considerably; the cylinders are first bored, then reamed, and then honed, or ground to a finish. **In service work,** where cylinders are **reconditioned,** they are usually ground to their required oversize, or a reamer is used for this purpose and they are then honed to a finish (Author).

By this method all the disadvantages of boring or reaming are absolutely overcome. The high-grade cylinder-grinding machine produces a true, straight, accurate bore, the usual limits of accuracy being no more than one one-thousandth of an inch. The bore is absolutely square with the flange, the surface produced is hard and glass-like, and the amount of stock taken out is only a fraction of what would be necessary in re-boring.

New Rings No Help

A large share of repair shops are still advising new rings when an owner is confronted with engine troubles. He believes it is a cure, but it is only temporary, since in most cases the carbon has been cleaned out, valves have been ground, and the engine has been generally tuned up. It therefore seems to have overcome the ailment. It is not lasting, however, for no matter how expensive or complicated the rings may be that are used, with or without compression guaranteed, a round ring will not fit an egg-shaped hole; and if the engine has been run considerably, that is the shape it will probably have.

Thousands of strokes of the rings up and down the cylinder, while aided by road dust and other abrasives which are sucked into the cylinders with the mixture, will gradually wear down the cylinder wall.

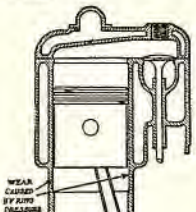


Fig. 24. Showing the points where rings usually wear cylinder walls.

This wear is greater on the two sides at right angles with the crankshaft. It is the result of the pressure of the piston against one side of the cylinder wall on the compression stroke, and on the opposite side of the cylinder wall on the power stroke.

No ring will fit such a shaped hole, so there is bound to be a chance for gas to escape and a long time needed for the rings to wear in, if they ever do so.

Therefore, as the **cylinders are worn only the length of the ring travel, it leaves the lower and upper ends smaller.** To put a ring of the proper oversize in the worn part through the smaller hole is impossible.

The only cure for a worn cylinder—and it takes but a few thousandths of an inch to show appreciative loss of power—**is to have the cylinders reconditioned and fitted with new pistons and rings.**

Fig. 24, which has been somewhat exaggerated, shows the wear in a cylinder which may have been made by various causes. Note how the gaps in the rings are spread, allowing gas to pass up through or around the rings.

New rings in such a worn cylinder would do no good, unless they were of the correct size to fill this hole. This is impossible, since rings of the proper size would not pass through the space either at the top or bottom of the cylinder. It will require grinding to take out sufficient stock to allow proper oversize pistons and rings to be inserted.

At Right Angles to the Flange

What is meant by "square with the flange," is indicated in Fig. 25.

It does not matter so much if the holes lean to the right or left side of the engine, but they must not lean to the front or rear with respect to the crankshaft.

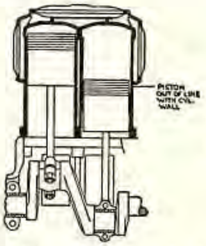


Fig. 25. Cylinder bore that is at right angles with the base, and one that is not. The right cylinder is at rear of engine. The cylinder bore is leaning to the rear.

The right-hand side of the cut shows how the piston is often cramped in the cylinder by being out of square.

This may be caused in several ways. First, the bore in the cylinder may not be square with the crank case. Second, the piston-pin hole may not be drilled square with the sides of the piston. Third, the holes in the ends of the connecting rod may not be parallel with each other. Any one or more of these may result in excessive wear on the cylinder walls, or in pistons "seizing."

Thin Cylinder Walls

Occasionally the shifting of the cores, when molding the cylinders, leaves a thin wall. In re-grinding such cases, if the wheel should break through, of course the man doing the work cannot be held for this misfortune. Furthermore, should there be a deep score and the owner wished it ground out and not filled, he must assume all the responsibility of weak walls.

It would be better business for all re-grinding concerns to refuse to touch such jobs, if, in their opinion, there is a doubt as to the strength of the wall after grinding. See Fig. 11E page 814A describing installation of cylinder sleeves.

New Pistons and Rings Necessary

If the cylinders are re-ground, new pistons and rings must be installed. The amount of stock to be removed in order to bring a bore back to a true round hole is usually at least .010" and, if the cylinder is scored or badly worn, will go from .030" to even .040". Such clearance would never allow the use of the old pistons.

Many a perfect re-grinding job has been spoiled when the engine is being assembled.

Great care should be taken first to wash the cylinders and pistons, rings, etc., carefully with gasoline. Be sure that every particle of abrasive material and foreign matter is removed.

Make certain that the **wristpin fits both the rod and the piston,** and see that it is securely fastened on. Better go over this an extra time and make sure, for a loose pin or screw will ruin the entire job the first time the engine is run.

Measure the pistons for roundness after assembling with the connecting rods, to see that they have not been distorted. A slight tap with a wooden hammer will help to make piston round.

After reassembling the pistons on the crankshaft, test them to see if they are absolutely square. Do not take it for granted, because the connecting-rods were straight before it was pulled down, that they will be so when you reassemble them. There are many chances and reasons for their having become twisted or out of square. This could happen in taking off the block with the pistons still connected to the crankshaft, when it is an easy matter to bend or twist the rods. Again, in scraping in the connecting-rod bearing or in tightening the caps, a slight variation at this end will increase many times at the piston end.

That the **pistons should be square** (see Fig. 25) is highly important; if they are not, the cylinders might just as well not have been ground, for the pistons hitting on the sides will give all the troubles of an out-of-round hole.

Put plenty of oil on all the pistons before assembling in the cylinder.

The rest of the assembling is purely a repairshop job, but every detail should be thoroughly gone into as if it were a brand new car. In fact, the vital parts are new and with very close limits; therefore, they should receive careful attention.

Be sure that the crankcase is well filled with a good light or medium oil, and that the lubricating system is working perfectly. Run the engine slowly for one half-day, giving it time to cool naturally.

RE-BORING OF CYLINDERS TO FIT THE PISTONS; FORD SERVICE METHOD

The preceding pages are devoted to cylinder grinding taken from the booklet of a prominent cylinder grinding machine manufacturer.

The following describes the method of re-boring the cylinders to fit the pistons as performed on a combination machine[1] recommended by the Ford Motor Co. for dealers and service mechanics.

The method of boring the cylinders "all one size" and hoping to find stock finished pistons to fit them (selective fit), is not always considered practical, because pistons may vary from the size with which they are marked.

Note: Stock finished pistons are subject to seasoning and are often distorted by handling.

Pistons should be carefully measured and if the variation exceeds .001″, the cylinders should be bored to fit their respective pistons.

Procedure

The cylinders are measured with a cylinder gauge (see Fig. 11, page 812) **to determine what size they should be rebored and the oversize piston to use.** The amount cylinder is out of round, tapered, or worn is indicated by the hand on the dial. Scores can be noted by visual inspection.

For example, suppose that we find it necessary to remove .027″ in order to properly clean up the cylinder. On referring to the Ford parts price list, we find that the piston which would more nearly correspond to this measurement would be .031″ oversize, which would in this case be the size to install.[2]

Fig. 26. Miking and chalk marking pistons.

The pistons should next be checked for roundness as they occasionally become out-of-round due to rough handling in shipping. The pistons are checked with a 4″ micrometer (E, Fig. 26) ("miking" is the term used for measuring with a micrometer), first for roundness, by measuring them across the skirt in the direction of the wrist-pin; then at right angles to it.

If the piston is out-of-round, it can be trued up by lightly tapping it with a rawhide mallet on the side of the skirt which shows the greatest diameter.

The pistons are then chalk marked for their respective cylinders, 1, 2, 3, 4 **and then measured for actual diameter, and also to check the size as stamped on it,** because pistons do not always measure exactly as marked. The measurement is made across the skirt with a 4″ micrometer as shown in Fig. 26.

For example, the Ford cylinder bore diameter is 3¾″ or 3.750″. The diameter of a **standard piston** with .003″ allowed for clearance should be 3.750—.003″=3.747″. The diameter of a .031″ **oversize piston** should then be 3.747″+.031″=3.778″. (See also page 813A discussing this subject.)

Therefore, if all of the .031″ pistons were exactly equal in diameter, that is, 3.778″, then each cylinder would be bored .003″ larger than the actual diameter of pistons, or 3.778+.003″=3.781″, the additional .003″ being allowed for clearance. All .031″ pistons however do not always measure as marked.

A .031″ would actually measure from 3.777″ to 3.779″. Therefore do not make a mistake and bore the cylinders .003″ larger than the oversize marked on the pistons.

As previously stated, the pistons should be carefully measured and if the variations exceed .001″, the cylinders should be bored to fit their respective pistons.

Marking pistons: Suppose the measurement of piston marked No. 1 actually showed a measurement of 3.779″. It would be chalk marked 3.779″. Suppose piston No. 2 actually measured 3.777″. It would be chalk marked 3.777″ and likewise, measure and mark No. 3 and No. 4 pistons.

A **clearance** of .003″ (or .004″) must be allowed between piston and cylinder. Take the piston No. 1 which was chalk marked 3.779″. By adding the specified amount for clearance, we obtain 3.779″+.003″=3.782″. Therefore the cutter (C, Fig. 27) must be set to bore the No. 1 cylinder 3.782″. Take No. 2 piston, chalk marked 3.777″. Allowing .003″ for clearance, we obtain 3.777″+.003″=3.780″. Therefore the cutter when boring this cylinder, must be set to bore the No. 2 cylinder to 3.780″ for this piston, and follow the same procedure for No. 3 and 4 cylinders.

The single fly cutter in the boring bar is adjusted and set so that it will bore the correct size as follows: In the example of No. 1 piston we found that the diameter of the .031″ oversize piston was 3.779″, to this we added .003″ for clearance which gave us 3.782″, or .032″ oversize. The special micrometer

[1] These instructions (condensed) are from *Ford Service Bulletin* describing how re-boring of cylinders is performed with a combination machine. Applies to Model "T" Ford. (See page 790 for babbitting and boring and align reaming Ford main bearings.) [2] .03125″ is actual size, as explained on page 813A but will be referred to as .031″.

furnished with the equipment is then adjusted to show a reading of only **half** of this amount or .016″ and the boring cutter set to correspond with this reading. The reason for adjusting the cutter to cut only half of the amount that the cylinder is to be bored oversize, is due to the fact that as **only one cutter** is used, it is measured from an imaginary center of the shaft to its point, but as it cuts all the way around the circle it actually doubles this measurement, so that by setting the cutter to .016″ it actually cuts .032″. Cutter for No. 2 piston, which measures 3.777″, or .030″ oversize, would be set to .015″.

The cutter (C, Fig. 27) **can be adjusted** by slightly loosening the two set screws on the cutter head with a special set screw wrench and turning the adjusting screw with a screw driver until the setting of the cutter corresponds with the reading on the special micrometer. The set screws are then tightened and the cutter again checked to make sure the adjustment was not altered when the set screws were tightened.

Boring Operation

After correctly adjusting cutter the boring bar is placed in the cylinder, and is located by means of two (two-piece) tapered locating plugs (L), as shown in Fig. 27. One of the plugs at each end of the cylinder on the boring bar insures perfect centers.

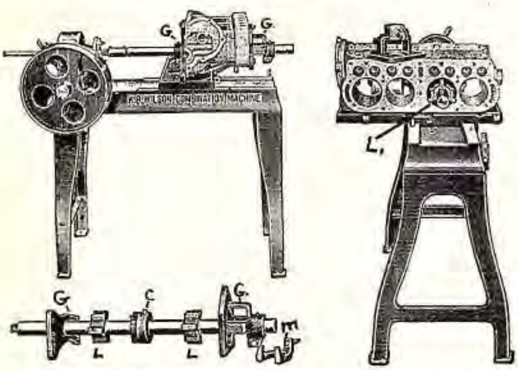


Fig. 27. Combination machine being used to rebore cylinders.

The permanent guides (G) are then positioned and fastened to the block on both cylinder-head and crank-case ends.

The tapered locating plugs (L) are then removed through the openings provided, leaving the boring bar all set up.

We now place an 8″-wrench on the square end of the boring bar, and with another "speed-type" wrench, we tighten the adjusting screws of the split bearings on each of the permanent guides until it requires considerable pull on the 8″-wrench to turn it.

Now place the universal joint in position, and throw in the feed lever. In 9 minutes the cylinder will be rebored, during which time no other attention except setting up is required.

Cutters are interchangeable (at slight cost), and it is not necessary to tie up the cylinder re-boring machine while the cutters are returned to the factory to be re-sharpened and fixed up.

The **cutter is adjustable** to take up any wear, and on account of the narrow cutting edge will not dub over when it hits a hard spot or a scored cylinder. A narrow cutting edge could not be used with any equipment other than a cylinder boring bar, having a fixed guide on each end that will prevent chatter and keep cutter from digging in or following the old hole.

Because the "cylinders are bored to fit the pistons," nearly all hand operations, such as filing, turning, lapping-in, etc., are eliminated. Occasionally a slight amount of hand filing is necessary to remove high spots and niches from pistons. Pistons fitted by this process to .003″ to .004″ clearance are absolutely free in the cylinder and, without rings or oil on them, will "fall through" without friction.

While lapping-in will cut off some of the high spots in the cylinders and pistons, it will not fill up the low spots.

Filing pistons in a lathe will make them smaller, but will throw them out of round more than ever, for the reason that when the file hits the relieved portion of the piston near the piston pin boss, it will jump and "dig-in" again about one inch from the edge of this relieved portion.

Lathe turning is unsatisfactory because the average service station is not equipped with proper tools for this work. Even if it were, it is a difficult proposition to "chuck up" a piston accurately to remove only a few thousandths of an inch. These facts show why it is necessary to bore the cylinder accurately in the first place, if you want a first-class job at a minimum cost.

Stormizing Method

Machinery for another well-known boring method is called the Stormizing equipment (Storm Mfg. Co., Minneapolis, Minn.).

Questions and Answers on Enlarging Cylinders; Continental Engines

The following questions and answers pertain to the Continental engine (see Index), but are applicable to many other engines:

Q. 1: Are cylinders ground, reamed, or bored?

Ans.: All Continental cylinders are bored and reamed with special fixtures and tools which insure perfect alignment. After these operations they are honed accurately to a glassy smooth finish.

Q. 2: Are pistons fitted to each individual cylinder, and what is the standard clearance?

Ans.: Not only the piston, but the piston rings as well, are individually hand-fitted to each cylinder bore. (See also ans. to question 11, page 817.) The clearances allowed in each case depend upon the size of the engine and the service for which it was designed. (See pages 810, 811.)

Q. 3: How are engines marked to show the original diameter of the cylinder bores?

Ans.: The diameter of each cylinder is stamped on the lower machined face of the cylinder block where the valve-chamber cover is attached. These marks are in decimals.

Q. 4: What factor determines the amount of clearance to be allowed when fitting pistons in the cylinders?

Ans.: The amount of expansion. This depends upon the materials used in the pistons and cylinders, the general design, and the operating temperature of the engine. The temperature of an engine in operation is affected by the amount of fuel consumed, the resistance offered the power impulses, and the timing of the ignition.

Q. 5: What is meant by .003″ loose-fit and .004″ tight-fit of piston clearance?

Ans.: The piston would be free in the cylinder with a .003″ thickness gauge (also called "feeler") between it and the cylinder walls, and the same piston would be tight in the cylinder with a .004″ feeler.

MISCELLANEOUS CYLINDER RECONDITIONING TOOLS AND DEVICES[1]

Portable cylinder reborer and regrinding machines driven by an electric motor, **and portable grinders of the stone type, also reamers and hones,** which are capable of doing accurate cylinder work are shown in examples following.

On engines where cylinder-heads are removable, and where the cylinder does not come underneath the dash board they can be reconditioned **in the chassis,** thus saving the expense of tearing down the engine. Great care however must be taken to **protect the bearings** from chips and emery dust.

Fig. 28

Fig. 29

Fig. 28 (left). **The Simplicity[2] portable cylinder reborer and grinder.** We quote from booklet issued by this concern: "When a large amount of metal needs to be taken out, due to a score, or for any other reason, such as to straighten out hole and remove the hard scale on cylinder walls, it is a distinct advantage to re-bore first and then true up and finish the hole by grinding.

"The Simplicity vacuum cleaner and blower is a separate unit operated with a ball bearing motor. The dust nozzle is placed at the bottom of cylinder and **collects boring chips and emery dust** which prevents these materials from getting into the bearings, especially when the job is done in the chassis."

Fig. 29 (right). **The Jiffy Jordan[2] portable cylinder regrinding machine.** We quote from booklet issued by this concern: "This machine bores and grinds at the same setting, both going down and coming up. It is portable and clamps to the face of the engine block. Will regrind ninety per cent of all engines without removing from chassis. Adjustable to all cars, trucks, tractor sizes. Cuts as little as .0025" or as much as necessary."

A portable cylinder grinder of the vertical stone type is shown in Fig. 30. This grinder is used by a number of automobile manufacturers on production.

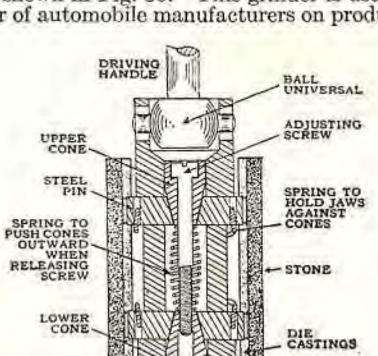


Fig. 30. **The Hutto[2] portable cylinder grinder** (vertical stone type). This device is known as the positive set, meaning that when the grinder is set it is locked so that it cannot deviate from the diameter it is set for. **If there is a hard spot of metal in** the cylinder wall it must be ground off; there is no means, the manufacturers state, by which the grinding stones will spring back and depend upon the grinder to finally wear off the high spots by longer grinding.

A cylinder reamer, hand-operated type for reconditioning worn or scored cylinders for service shop use is shown in Fig. 31. Reamers—power driven are used quite extensively in factory production.

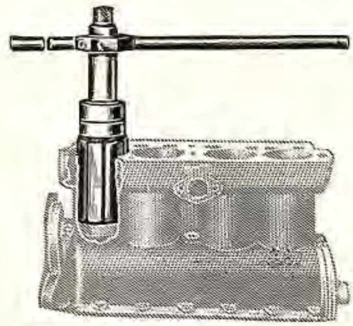


Fig. 31. **Foster-Johnson[2] cylinder reamer** is hand operated for reconditioning worn or scored cylinders. With this tool when used with the F-J ratchet wrench the great majority of blocks having detachable head can be reconditioned without removal from the chassis.

The above-mentioned firm states: "The blades of this tool expand parallel and are expanded after being inserted into the cylinder to a depth of three or four inches thus making the tool self centering, self piloting and self aligning, and reamed hole will be true to the natural path of the piston travel. The finish and accuracy that can be obtained will equal that of any factory reamed cylinder. Honing is not necessary for final sizing. Roughing blades can be obtained, making it possible to remove .010" of metal in less than two and one-half minutes."

As an example of a typical type of hone, the Hall hone will be used. This hone is shown in Fig. 33.

It is made of a nickel base alloy die-casting. The stones are cemented into steel channels which the makers claim eliminates trouble with stone breakage. See also page 816 relative to honing cylinders.

The internal construction consists of precision ground cones (**H**) (Fig. 33), a part of the mainshaft, actuating the stone carrier arms equally.

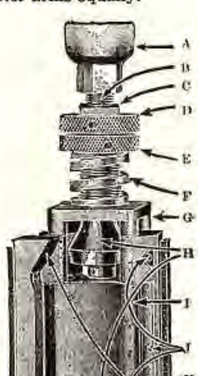


Fig. 33. The Hall hone[2] used as an example. **Names of parts: A,** ball joint driving socket; **B,** main-shaft; **C,** tension adjusting plate; **D,** upper flange nut and extending sleeve with left-hand thread for solid pressure; **E,** lower flange nut with right-hand thread for spring pressure; **F,** main spring; **G,** pressure flange; **H,** upper and lower cones, part of main-shaft, supporting stone carriers; **I,** body; **J,** stone retaining screws; **K,** honing stones in stone carriers; **L,** taper bearing pads on stone carrier arms that swing in and bear on taper cones **H;** **M,** lock nut and protection flange.

It embodies the two necessary features; **spring pressure** for fast cutting, and **solid setting or pressure for sizing.** Pressure may be changed from spring to solid or solid to spring pressure without removing the hone from the cylinder or the drill from the hone.

[1] **Ricardo cylinder head** subject, formerly on this page, is now on page 806. [2] Circulars can be had by writing the manufacturers (please mention *Dyke's Auto Encyclopedia*). See page **824B** for address.

Lubricant: One-half cylinder oil and one-half kerosene mixed is proper for lubricating. Do not run hone dry.

Rubbing stones are necessary to sharpen honing stones and remove the iron which fills the pores of the stones, causing them to stop cutting. Fast cutting requires frequent use of the rubbing stone. Rubbing stones are made of a harder texture than cutting stones and therefore will remove this metal thereby renewing the cutting surface of the honing stones.

Instructions for Operating Hone

1. **To prepare block for honing,** remove head, oil pan (or inspection plate), pull pistons, and clean block with kerosene.
2. **Measure cylinder carefully with dial indicator gauge** to determine how much **taper** or out-of-roundness exists and to what **oversize** to hone.
3. **Protect the bearings and crankshaft** and other parts from grindings, if work is done in chassis, by placing a wet rag around them, or covering them with heavy grease.
4. **Insert short coarse stones** in lower part of stone carrier and tighten screws (Fig. 33).
5. **Wash and lubricate stones and cylinder wall** with one-half kerosene and one-half cylinder oil. After this, insert hone in cylinder and drive with electric drill which usually is suspended overhead on a flexible spring (or a Ford inner tube). Work hone up and down the cylinder.
6. **A thirty or sixty-second run** is sufficient. Remove hone and measure, especially when using spring pressure. To apply spring pressure, screw upper flange nut (D) down in a left-handed direction until hone is expanded within 1/16" of cylinder diameter; then hold upper flange nut (D) and screw lower flange nut (E) down in a right-handed direction until stone carriers are expanded against the cylinder wall with sufficient pressure to slow down drill sufficiently to speed up cutting. Fast cutting demands plenty of pressure, and at the same time speed is essential when using spring pressure.
7. **After having roughened out cylinder with spring pressure, removing most of the taper,** then free the spring pressure and with a hone set in upper part of cylinder apply solid pressure sufficient so that drill will just drive hone at an average speed. Apply power and work hone up and down until you feel it freeing up. If a tight spot in any given part of cylinder is felt, this shows a slightly smaller diameter and hone should be run at that point, increasing pressure if necessary, until you do not notice any change in drill speed at any point. When drill speed is even all the way down, cylinder should be parallel. Use a dial indicator gauge to determine variations. Be careful to not allow stones to pass out of top or bottom of cylinder more than an inch at any time.
8. **A finer stone is installed to finish and polish cylinder** and size .001" to .0015" should be all that finishing stones are required to remove.
9. **On closed cylinder heads where it is desired to remove a ring ridge and not cut any of the other part of cylinder wall,** wooden blocks can be made or purchased to fit upper part of stone carriers, thereby allowing operator to use a stone about 1" long, that has anywhere from ⅜" to ¾" of surface coming in contact with the cylinder wall or ring ridge.
10. **Clean cylinders and parts with kerosene.**

ENGINE RECONDITIONING PROCEDURE

A general engine rebuild usually consists of first checking the various parts and then properly doing the work of reconditioning the part if worn as follows:

1. **Check cylinder** for wear, taper and out-of-round condition. (See page 814-B).

   Recondition by grinding or other process; this should insure proper alignment of cylinder bores with cylinder base. When enlarging cylinder new **oversize pistons and rings** are necessary and should be properly fitted as explained on pages 814B and 833B.

2. **Check crankshaft** for wear, out-of-round journals, for cracks or flaws and straightness. (See pages 791, 784A.)

   Recondition by grinding; this insures it being round and straight and having journals in line.

3. **Check main bearings** as explained on pages 784, 784A.

   Recondition by align reaming or boring with adjustable pilots or fixtures that will insure perfect parallel alignment from the original crankcase bore.*

4. **Check connecting-rod bearings** as explained on page 803.

   Recondition by align reaming, or boring with reamers or align boring fixtures that will give uniform distances between piston-pin center and bearing center and also align the rod and piston assembly as per page 803.*

5. **Check valves** as explained on pages 767–770.

   Recondition as explained on page 776D.

   After reconditioning an engine it should be thoroughly cleaned inside and outside, then run-in as explained below and on pages 833A, 833B.

Care of a New or Reconditioned Engine; Glazing the Cylinder Walls

When an engine is new or has been reconditioned by enlarging cylinders and fitting new pistons and rings the cylinder walls and rings are soft and care should be exercised, particularly at first, to use lots of oil and a light blue smoke should come from the exhaust for the first few hundred miles and by no means should the engine be overheated by running car at a high speed.

Many manufacturers, who hone cylinders and crankshaft journals, state that this process is equivalent to running-in. While this may be true, it is advisable to use plenty of oil and to run at slow speeds for the first few hundreds of miles.

As previously stated on page 812 and as discussed on page 814, **the wear on cylinder walls is usually where the rings travel** and this wear in most instances is found to be near the **top** and the reason is traced principally to insufficient lubrication and also to a thrust action.

Cylinders usually are made of soft cast iron, likewise the piston rings are made of soft material and it would seem that friction of the rings on the cylinder walls would result in excessive wear. While there is some wear, it should not be excessive providing the cylinder walls are properly lubricated and means for proper lubrication of the cylinder walls are now taken care of with oil control rings (see page 826), that is, lubrication is provided but not to excess.

Cast iron will become glazed or case hardened when rubbed with other metal while properly **lubricated** and it is this **glaze** that is desired.

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[1] Some of the concerns specializing on cylinder reconditioning tools and machines and who issue instructive literature on the subject are: Automotive Maintenance Mchy. Co., Chicago, Ill.; Simplicity Mfg. Co., Port Washington, Wis.; Storm Mfg. Co., Minneapolis, Minn.; The Hall Mfg. Co., Toledo, Ohio; The Heald Machine Co., Worcester, Mass.; The Hutto Engineering Co., Detroit Mich.

* Many engines now use interchangeable type bearings, as explained on p. 786 for both crankshaft and connecting rods.

INSTRUCTION No. 71

PISTON RINGS: Types, Construction, and Fitting; Piston-Ring Gap Clearance; Piston-Ring Groove Clearance; Measurements of Piston Rings; Standard and Oversize Piston Rings; Testing and Fitting Piston Rings

PISTON RINGS [1] [2]

A piston must be fitted with piston rings. The piston is slightly smaller than the bore of the cylinder, in order that it will not stick to the cylinder wall (termed "seizing"), when it becomes hot and expands. See page 807 explaining purpose of piston.

The purpose of the piston ring is to fill up or seal the gap clearance between the piston and cylinder walls, preventing the high-pressure burned gases escaping into the crank case during the power stroke* and an excess of oil working into the combustion chamber.

As these gases are under pressure, it is necessary that the rings not only fit snugly around the **cylinder wall,** but in the **grooves** of the pistons as well; otherwise the gas and oil work through behind the rings.

Since the rings present small wearing surfaces, they become undersize in time. See pages **824B**, **833A** about care of a new engine until cylinders and piston rings get their **glaze.**

Piston rings also lose their pressure after long use and cease to press against the cylinder wall all around, and the compressed gases escape between cylinder wall and ring. If worn in groove, or if there is a loose fit in groove, a leak will occur around the ring.

Some piston rings are heat-treated after they are roughened out of the castings and before they are finished. (This also applies to pistons; see Questions 3, 4 pages 809, 810 and Question 16, page 817.)

To insure maximum power, together with minimum oil and gas consumption and the best all-round satisfaction, the rings should be renewed wherever oil or gasoline consumption becomes excessive or tests show leaky piston rings (excessive "blow-by") or loss of compression (see pages 829 and 766–769). Definite mileage figures for satisfactory piston-ring life cannot be given. (See also p. 814B.)

Ring grooves are cut in the wall of the pistons for the rings. The grooves are slightly wider than the ring. See Fig. 17. They should fit freely but without side play.

If the groove is too large, there will be a compression leak between the groove and the ring. **If too narrow,** the ring will stick in the groove and will not exert its pressure against the cylinder wall.

The fit of the piston ring in the ring groove is very important. If the ring has considerable up-and-down motion in the ring groove, it will shift up as the piston goes down, drawing oil under and behind the ring. It shifts down as the piston goes up, and forces the oil collected out over the top of the ring, and in this way acts as a small oil pump. Quite a lot of oil can be pumped into the combustion chamber in time. When the rings are worn the gas has an unobstructed path behind the ring. See I, Fig. 28, page 767.

It is important that a piston ring exert equal pressure against the cylinder wall at all points of its circumference. Right here is one of the most important duties of a piston ring. If it fails to do this, then the part of the ring which does not press against the cylinder wall is bound to permit the compressed gas to pass into the crank case and oil into the combustion chamber, causing a loss of compression, resulting in a loss of power, fouled spark plugs causing misfiring and carbon deposit.

Requirements of a piston ring: (1) permanent pressure; (2) uniform wall pressure; (3) not too much pressure to cause undue wear and friction, but enough to seal the clearance; (4) maximum flexibility; (5) oil control; (6) gas-tight at all times.

The ring gap is provided on all rings for three purposes: (1) to permit assembling rings on the piston; (2) to permit the ring to expand, owing to its elasticity, and to exert pressure against the cylinder walls; (3) to permit expansion of the ring when heated, without causing it to seize cylinder wall. As the ring expands, because of heat, the gap decreases.

Cylinders are bored and honed or ground as the case may be, for the purpose of making the bore round, smooth, and straight, so that an accurately machined piston ring will fit perfectly and conform to the cylinder without setting up any severe forces while in operation and thus sealing the clearance between the cylinder wall and piston and holding a maximum compression.

For many years, various manufacturers have tried to make a piston ring to fit properly an out-of-round and tapered cylinder, and consequently the "flexible type" of piston ring was originated.

Many repairmen are of the opinion that if a cylinder bore is round, smooth, and square with the base, the connecting-rods aligned and perfect ring grooves in pistons, an accurately and properly made "one-piece-ring," often termed a plain ring, will give perfect service with proper lubrication.

This does not mean that only the plain one-piece ring should be used. Flexible rings of proper construction could probably be used with greater efficiency than the one-piece ring under some conditions.

Material: Piston rings are usually made of cast iron, and manufacturers have different formulae and treatment.

There are usually three or four piston rings, sometimes more.

Practically all pistons are equipped with one or more **oil-control rings** placed in the lower ring grooves. Oil drain holes are usually drilled in these grooves. Sometimes one oil-control ring is placed below the piston pin.

[1] This instruction has not been revised for some time.

[2] Follow manufacturer's latest instructions for fitting and clearances. See page 690 for *literature on piston rings.* See also page 814B; also page 828 (*piston ring and skirt expanders*). There may be a slight discrepancy between index and text on pages 825–837.

* **Termed "blow-by"** which increases temperature of engine oil, decreases compression and causes loss of power. There is always some "blow-by." At high speeds "blow-by" increases. Defective rings, pistons and cylinder bores increase the amount of "blow-by" at all speeds. See also pages 168, 833.

Racing engines often use one or two piston rings. This permits better lubrication at high piston speeds because of the minimum amount of ring contact.

Piston rings are known as "compression rings," and "oil-control rings."

To avoid oil pumping[1] and oil-soaked spark plugs, oil-control rings, such as per Fig. 4, are fitted; or oil holes may be drilled in the ring groove, as shown in Figs. **4B, 4C,** and **5A,** and fitted with oil-control rings, as shown in Figs. **4A** and 5.

The ring land between the first and second ring grooves should never be drilled, as this releases the compression and only the top ring will be holding the compression.

The three types of piston-ring joints generally used are shown in Figs. 1, 2, and 3, and are known as a **bevel** or **miter joint,** the **step-cut joint,** and the **butt-joint** (see Fig. 3).

Fig. 1. A plain one-piece piston ring with a beveled joint (**M**) cut slantwise. Termed a **"miter cut"** or **"diagonal" joint** or **"bevel joint."**

Fig. 2. A plain one-piece piston ring with stepped or lapped joint (S). Termed a **"step-cut"** or **"lap-joint" ring.**

Classification of Piston Rings

Piston rings are of two types: compression rings and **oil-control** rings.

Compression rings serve the **purpose** of sealing the clearance between cylinder wall and piston to prevent gas leakage, and where placed in the lower part of skirt they also help to prevent piston slap to a certain extent.

Oil-control rings are employed to control the amount of oil reaching the combustion chamber and as a measure of oil economy.

The piston rings in most general use are of the plain one-piece type which may have either step-cut, miter, or butt-joints.

In order to obtain more satisfactory results from cylinder walls that are "slightly scored, tapered, or out of round, several **patented flexible rings** have been devised.

The primary purpose of these rings is to create equal pressure against the cylinder wall at all points of circumference or to prevent leakage at joints by various methods. Patented rings are of one, two, or three-piece type.

Compression Rings

There are a great many different makes of piston rings. A few as examples will be shown here. The one-piece and two-piece types are shown. There are a number of rings of the three-piece type.


Fig. 3 (left). **A plain butt-joint, one-piece type of ring.**

Fig. **3A** (right). A plain step-cut joint, one-piece type of ring termed a **quick-seating ring—purpose,** to seat within a short time—25 to 50 miles instead of 500. Note the serrations or grooves around the circumference of the ring. The depth of the serrations determines the quickness of seating; if too deep, the wear of ring is rapid and of shorter life.



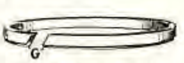
Fig. **3B** (left). **A hammered step-cut joint one-piece type of ring.** Illustration is that of the "American" hammered ring. Note that the inside has been hammered or peened with hammer marks. The makers claim that this operation causes the ring to exert **equal pressure** at all points of its circumference. There are several other makes of hammered rings; for example, the "Richmond," etc.

Fig. **3C** (center). **A double-step interlocking-joint concentric patented one-piece type of ring,** the "Gill."

Fig. **3D** (right). **A two-piece patented ring,** the "Leak-Proof." The manufacturers claim it creates even outward expansion all around the ring, thus maintaining equal pressure against the cylinder walls.

Oil-Control Rings

Examples of oil-control rings to overcome oil pumping or an excess of oil reaching the combustion chamber are shown below.



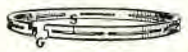


Fig. 4 (left). The "Superoyl" patented piston ring to control oil. For use where there are no oil holes drilled in piston. A small oil groove (G) or reservoir is cut around the lower edge of this concentric ring, providing a scraping edge (end view is shown in center illustration).

The principle of this ring is that its special reservoir (G) collects excess oil from the cylinder wall on each down-stroke and empties itself on each up-stroke. It is a concentric type of ring with bevel-cut joint.

Fig. **4A** (right). The "Ventilated Superoyl" patented piston ring. A combination of the oil scraper principle by means of groove (G), and with ventilating slots (S) through the face of the ring to reduce further the oil pumping; a concentric-type step-cut joint one-piece ring. These rings are **used only where pistons have holes drilled in the grooves** so that the excess oil can drain through the drilled holes in the piston.


Figs. **4B, 4C. Instructions for installing** Ventilated Superoyl rings: On pistons with three or more ring grooves above piston pin install in first groove above pin (Fig. **4B,** left); on pistons with two grooves above pin, install in groove below pin (Fig. 4C).

Always **drill** vent holes through back of groove in which this ring is installed. Drill at least ⅛-inch holes spaced ¾ to 1 inch apart. The holes may be drilled at right angles to wall of piston (straight through), or they may be at an angle sloping down at the inner end.[2]

Always **install** with oil-scraping groove (G) facing downward toward bottom of ring groove. (Manufactured by McQuay-Norris Mfg. Co.).

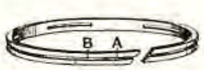
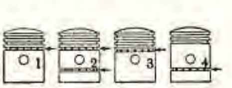



Fig. **5** (left). The "Teetor Perfect Circle" oil-regulating patented piston ring. Groove (**A**) is turned on the face midway between the edges which is a trap for the surplus oil that tends to pass the face of the ring. At equal intervals in this annular groove, slots (**B**) are milled through the body of the ring connecting the groove with the cavity behind the ring. The oil

[1] **Oil pumping is sometimes due to misaligned connecting rods, late valve timing, or loose bearings in pressure lubricated** engines permitting more oil to be sprayed into cylinders than piston rings can return to crankcase. See also "How piston rings pump oil" and "piston ring pounding" at bottom of page 832.

[2] **Follow manufacturer's latest instructions.** See also footnote, **page** 825.

which fills groove (A) is distributed over the cylinder walls as required and the surplus drains through the slots (B) and then back to the crankcase through oil-draining holes which are drilled in the lower ring groove or grooves of the pistons.

Fig. 5A (right). **Instructions for installing** Teetor rings are as follows: (1) Oil-draining holes must be drilled in the ring groove of piston which carries the oil-regulating ring. The location of drain holes on four different designs of pistons is indicated by the arrows on the piston diagrams above. Drill these holes ¾" apart at lower edge of groove, being careful not to damage the groove. The holes should be drilled at right angles to side of piston. For ⅛" groove use 3/32" drill No. 32; for 3/16" groove use 5/32" drill No. 22; for ¼" groove use 3/16" drill No. 12. (2) **Joint or ring-gap clearance:** .003" for every inch of cylinder diameter (3" bore, .009" clearance; 4" bore, .012" clearance). (Manufactured by The Perfect Circle Co.)

Fig. 5B. The "No-Leak-O" oil-control patented ring: The square edge of piston ring groove at (B), (C) scrapes oil from cylinder wall on the down-stroke, and the sloping face of groove distributes oil again on the up-stroke. This groove of oil conforms to any low spots in the cylinder, sealing them against escape of compression or surplus oil.

Top ring (A) is inverted. This is done to prevent refuse or unburned gas from getting down into the crankcase. The ring reversed in this manner functions just the same as the bottom rings do in controlling the oil; that is, this top ring traps the refuse and constantly pushes it back into the combustion chambers where it is eventually burned or blown out through the exhaust, but prevents this refuse from getting down into the crankcase, thinning out the oil. (Manufactured by The Piston Ring Co.)

There are a number of other good oil-control rings on the market. Space prevents giving more examples. **See list of some of the piston-ring manufacturers, page 833B, and write for circulars.**[3]

An inner ring is another device intended to stop oil pumping and also piston slap. It is shown in Fig. 5C.

Fig. 5C. The Ramco cushion inner ring. Made of heat-proof tempered Swedish steel. The inner ring (I) fits behind the regular piston ring (R), and is intended to maintain uniform ring pressure on cylinder walls. (Made by Ramsey Accessories Mfg. Co.) **Another make of inner ring** is the "Apex," made by Thompson Mfg. Co. The "Simplex" and "Panyard" (not shown) are **expanding type of piston rings** designed to fill the ring groove as well as to conform to cylinder walls.

Fig. 6. **Ford**[2] piston rings. These are two compression rings above the piston pin and one oil ring below the piston pin, and they **are tapered,** that is, they are machined .003" taper on the face of the ring. This insures the ring wearing so as to conform to the cylinder walls in the shortest possible time, and, when assembled with the word "Ford" up (stamped on upper side), the ring presents a sharp edge to the cylinder wall on the down-stroke and an incline on the up-stroke. The incline rides over the oil, while the sharp edge pushes the oil before it, thus preventing the oil from working into the combustion chamber. Ford rings are mitre-cut.

While all rings control oil due to taper, the taper in time wears off. **To control oil, the bottom ring groove is chamfered at its lower edge;** on up-stroke ring moves to bottom of groove and oil passes above and behind ring; on down-stroke ring moves to the top of groove and oil passes out at bottom over and around chamfered edge lubricating cylinder walls.

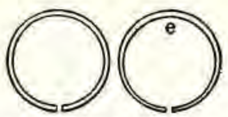
Ford ring-gap clearance: Before new rings are installed, the gap between the ends of the ring should be checked. To do this place the ring in cylinder as shown in Fig. 16 and check with a thickness gauge. The top rings are checked at the top of the cylinders. In a car which has been in service for some time, the bottom ring should be checked at the bottom of the cylinder (cylinders sometimes wear slightly taper).

The ring-gap clearance for the **top ring** should be .012" to .015"; the **center ring** .010" to .012", and the **bottom ring** .008" to .010". If the gap is too small, the ends of rings can be filed, as explained farther on.

Concentric and Eccentric Piston Rings

The concentric ring (Fig. 7, left) is one of equal thickness throughout its entire circumference.

The eccentric ring (Fig. 8, right) is made eccentric (thicker) at one point, as shown at (e).



Some manufacturers claim that the concentric ring will maintain equal pressure under heat, if made of the right material, and others claim that the eccentric ring is the best. See Question 6 and answer, page 833B.

Measurements of Piston Rings

Manufacturers differ as to the measurements of a piston ring. A gauge is generally used for this purpose.

One type is a cylindrical gauge[1] in which the piston ring is fitted. For instance, this gauge would represent, say, a 3⅞" cylinder bore, and when the ring fits into this gauge with a certain opening of the ring gap it would be a 3⅞" ring. Thus it will be observed that a ring is not measured by closing it tightly and measuring its outside diameter, but, in other words, the **gap opening** of the ring must be considered.

For example, suppose the manufacturer recommended a .002" **diametrical clearance** of piston ring so as to allow for expansion when heated.

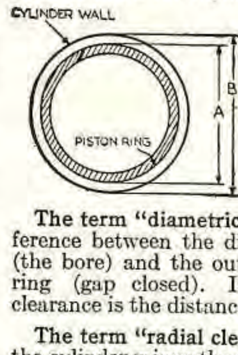
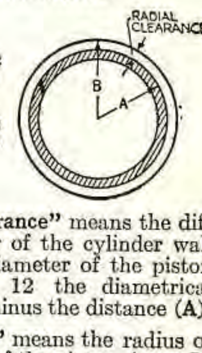


Fig. 12 (left.)

Fig. 13 (right)



The term "diametrical clearance" means the difference between the diameter of the cylinder wall (the bore) and the outside diameter of the piston ring (gap closed). In Fig. 12 the diametrical clearance is the distance (B) minus the distance (A).

The term "radial clearance" means the radius of the cylinder minus the radius of the piston ring. In Fig. 13 it is represented by (B–A). It would be .001" in this example.

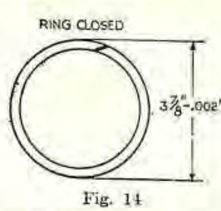


Fig. 14

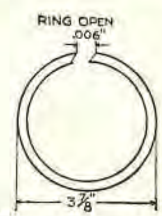


Fig. 15

Therefore a ring that was rated as of a 3⅞" diameter would, when **closed** (Fig. 14) measure 3⅞" less about **.002"** in diameter, or, in other words, if the ring were allowed to **open** about .006" in its gap, it would measure 3⅞" (Fig. 15), because a **difference** of .002" in **diameter** equals a **difference** of .006" in **circumference** (.002" x 3.1416" = .0062832").

Piston-Ring-Gap Clearance

If the **ring is out of the cylinder,** it would approximately measure on its outside diameter, if compressed to about a .006" open gap, 3⅞", as shown in Fig. 15. **If in a cylinder** of 3⅞" bore, the gap would be approximately .006" (when stationary and not running).

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[1] Other makes of piston-ring gauges: Universal Circular Gauge Co., San Francisco, Cal.; D. F. Dunham, Los Angeles, Cal.; Wilkening Mfg. Co., Philadelphia, Pa. [2] Refers to Ford Model "T". [3] See also, p. 690 for *literature on piston rings.*

When **engine is in operation,** the piston-ring gap would almost close, due to expansion of metal when heated. This expansion is really an elongation.

This **gap must not close entirely** otherwise ring ends will butt together and cause ring to buckle resulting in scoring of piston ring and cylinder wall.

Hence the importance of the exact gap clearance which should be ascertained from the piston-ring manufacturer when ordering or fitting piston-rings.

Method of finding the ring-gap clearance in the opening of the ring is shown in Fig. 16

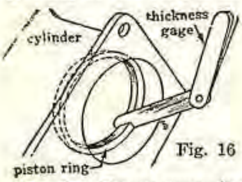


Fig. 16

Fig. 17

Fig. 16. **To measure ring-gap clearance,** place the piston without rings into the cylinder. Then slip the ring into the cylinder be ind the piston. It may be necessary to slightly file the edges of t e ring to do this, as some rings are oversize when new. Pull the piston up against the ring in order to square the ring up in the cylinder. If the cylinder is worn, it is usually where the rings travel; therefore fit it to the smallest part. A thickness gauge is then applied, as shown.

Fig. 17. **Measuring ring-groove clearance.** The measurement is made above or below the ring when in the groove. See page 829, "The width of the ring groove."

It is recommended that the ring manufacturer's specifications be followed. Clearance depends upon the type of ring, character of material and conditions under which it operates For example, a **quick-seating** ring may be given less gap clearance than a **ground ring** and engines operating at a **high temperature** for long periods of time, such as engines on fire apparatus would probably be given more clearance.

In the absence of explicit instructions from the piston-ring manufacturer, a minimum gap clearance of .003' for each inch of cylinder diameter should be allowed: .004' per inch for top rings. (The top ring is usually given slightly greater clearance at gap to allow for increased expansion, owing to its being exposed to greater heat.)

If the space between the ends of the ring is less than the clearance desired, the edge can be **dressed** with a fine file, as explained farther on.

The usual method of ordering piston rings is to measure the diameter of the piston and the width of the groove, and to state the make of engine. The manufacturer has a list to which he refers, and can then give the proper ring. The best plan is to measure the cylinder bore with an inside micrometer at the **smallest diameter.**

Standard and Oversize Piston Rings

New cylinders are perfectly round, and of the standard bore; therefore the **standard-size** piston rings should be used.

When cylinders have been reconditioned by one of the methods of **enlargement, oversize rings** corresponding to the enlargement should be used. Piston rings are available in oversizes corresponding to the **standard oversizes for cylinders and pistons:** 0.005", 0.010", 0.015", 0.020", 0.030" and 0.040" oversize. If the cylinder has been enlarged 0.010", the piston rings should be 0.010" oversize, etc.

When cylinders have not been reconditioned, it is frequently possible to improve engine performance by installing new piston rings of the **same size** as that to which the cylinder was last enlarged. If the cylinder has never been enlarged, **standard** rings should be used. If the cylinder has been enlarged to 0.015" oversize, use 0.015" **oversize rings,** etc. To determine the **size of the cylinder,** the micrometer should be placed at that part of the cylinder in which the **rings do not travel.** Replacement of piston rings alone is only justified when rings have been worn considerably but the cylinder is not badly worn. Experience and judgment are necessary to determine when this method is advisable.

Oversized rings in worn cylinders: It is not good practice to instal oversize rings in cylinders that have not been enlarged to a corresponding oversize. In other words, cylinder wear cannot be rectified by installing piston rings which were made to a larger oversize. Oversized piston rings in a worn cylinder may lock and cause damage.

Installing piston rings in worn cylinders: Many patented piston rings are available which will render reasonably satisfactory service in worn cylinders without the necessity of enlargement, providing the cylinder taper or out-of-round is not excessive. (See also, p. 814B). **The best results** from badly worn cylinders are obtained by **proper cylinder enlargement and fitting of new oversize pistons and rings.**

Piston Ring and Skirt Expanders

Patented spring-expander type piston rings are available which, according to the claims of their manufacturers, will render satisfactory service in worn cylinders (up to certain limits, as specified in their literature) when properly fitted to old pistons, **without the necessity of cylinder enlargement and replacement of pistons.** Their use is **justified when** the expense of a complete enlargement job cannot be considered.

Piston skirt expanders are frequently used in split-skirt aluminum-alloy pistons to offset piston wear or **collapse** (closing up o the split in the skirt). They are frequently used together with spring-expander piston rings. (See also page 833B for another method of resizing aluminum-alloy pistons.)

The ridge at the top of the ring travel in the cylinder should always be removed when installing new piston rings. (See p. 833.)

Partial honing of the cylinders to decrease taper will improve the performance of jobs in which piston-skirt expanders are used. This is not a substitute for complete cylinder enlargement.

Installation of spring-expander piston rings and piston-skirt expanders, together with grinding valves, fitting new piston pins, check up of connecting-rod bearings, and the usual engine tune-up of checking the ignition an carburetion, constitutes *this type of engine overhaul job.* For literature on this subject, see page 690 under *Piston Skirt and Piston Ring Expanders.*

Piston Ring Groove Clearance

The ring should be rolled around the ring groove in the piston, as shown in Fig. 26 page 832. The proper fit of a **piston ring in a groove** is that which permits the ring to **fit snugly without binding** or sticking at any point. The fit should be just full, so that the ring can be turned around the piston with the fingers. When it is loose or sloppy in its ring groove, there is danger of lubricating oil getting behind the ring and traveling to the combustion chamber, resulting in the formation of carbon and in gumming the ring.

Extreme care should be taken to see that the groove is clean, and that the wall thickness of the ring is not greater than the depth of the ring groove. Therefore the outer edge of the ring should not extend above the edge of the piston at any point when placed in the groove. See also p. 833.

To measure ring-groove clearance (see Fig. 17). Remove all grit and see if the groove walls are straight and not worn.

If a ring groove is not straight and becomes worn V-shaped, the piston can be put in the lathe and trued up and then groove widened to take a wider ring. See page 833.

The reason ring grooves wear V-shaped is that when the piston travels up the ring has a tendency to move down, and when the piston travels down the ring moves up; and if not properly lubricated this rapid up-and-down motion wears both the groove and ring. See bottom of page 832 on this subject.

If the ring is slightly tight or wide for the groove for which it is intended, this difficulty can be overcome by the use of a piece of fine emery cloth tacked to a flat surface (Fig. 30, page 833). See that outer edge of ring groove is not "burred," if so, round off edge of groove slightly with a fine file.

Piston ring width: Recommended standard widths of *compression rings* are 1/8" for cylinder diameters of 2" to 4 7/16" and 5/32" for cylinder diameters of 4 1/2" to 5 7/16". The actual width is slightly smaller than the size by which it is known; the 1/8" ring is not actually 0.1250" wide but is 0.1235" to 0.1240" wide and the actual width of the 5/32" ring is 0.1545" to 0.1550". Some manufacturers use 3/32" rings having an actual width of 0.0925" to 0.0935" (see page 1054B). The recommended widths for *oil rings* for cylinder diameters of 2" to 4 7/16" is 1/8", 5/32" or 3/16" (0.1855" to 0.1865"); for cylinder diameters of 4 1/2" to 5 7/16" is 5/32", 3/16" or 1/4" (0.2480" to 0.2490").

The width of the ring groove in the piston should be a minimum of 0.001" to 0.0015" more than the width of the ring except for the top compression ring which should have a minimum clearance of 0.0015" to 0.002".

The thickness of piston rings increases as the cylinder diameter increases. Some typical standards are: for 2 1/2" bore, the piston ring thickness is 0.115"; for 3" is 0.135"; for 3 1/4" is 0.145"; for 3 1/2" is 0.150"; for 3 3/4" is 0.160"; for 4" is 0.165"; for 4 1/2" is 0.180"; for 5" is 0.195".

The depth of the piston-ring groove is determined by specifying the maximum diameter measured at the bottom of the ring groove. The diameter for oil ring groove is 0.040" less than for compression ring grooves (the groove is therefore 0.020" deeper). The groove diameter for aluminum pistons is less than for cast iron pistons, that is, aluminum pistons have deeper grooves. The groove diameter for 2 1/2" aluminum pistons is 0.005" less than for cast iron and for 5" pistons is 0.010" less. Some typical diameters for compression ring grooves in cast iron pistons are 2.240" for 2 1/2" cylinders; 2.698" for 3" cylinders; 3.166" for 3 1/2" cylinders; 3.634" for 4" cylinders; 4.102" for 4 1/2" cylinders; and 4.570" for 5" cylinders.

PISTON-RING TROUBLES, TESTS AND REPAIRS

If the rings do not fit the cylinder wall with equal pressure at all points, there will be a loss of compression and a smoky exhaust.

If the rings are exerting equal pressure, they will be smooth and shiny, as will also the cylinder walls.

If the rings are dull, and there are spots or streaks on them, it will indicate that the flame from the combustion passes between the piston rings and the cylinder wall, leaving a sooty deposit and perhaps burning them. The compression will pass the ring thereby reducing power of engine.

Causes of Leaky Piston Rings

1. **Rings sticking in their grooves** because of gummy deposit from lubricating oil; rings that are stuck in their grooves will usually not press against the cylinder walls.
2. **Rings may have become broken.**
3. **The joints of the rings may** allow the compression to escape.
4. **Ring gap too wide:** see pages 768, 769, 828.
5. **Rings may be worn or cut** from lack of oil.
6. **Rings may not be wide enough** for the grooves, **or grooves may be worn** (see bottom of page 832).
7. **Too light a grade of oil.** Too great an oil pressure may cause oil pumping.
8. **The rings may have lost their pressure,** due to heat.
9. **Rings may be warped** and do not seat all around on lands.

Testing Rings and Cylinder for Leaks

First test compression, as explained on page 767, and if compression is weak be sure it is not due to some other cause, such as leaky valves (see pages 769 and 779 for testing piston rings and valves).

In order to find out if the rings leak, try the piston and see if the gas is escaping through the rings into the crank case. This can best be accomplished by removing the lower part of the crank case, after which turn the crank so that the piston makes its compression stroke, and listen for a bubbling sort of hiss in the crank case.[1] Test each cylinder separately. First determine which cylinder is leaking. There is no mistaking this sound, since the crank chamber acts as a resonator, and even the slightest leakage is distinctly audible. (See also pages 768, 769, 779.)

If the sound of gas escaping past the piston rings continues for an appreciable time (upward of a minute or so),[1] the chances are that the oil is diluted, or not the proper grade for engine.

However, if the escape is of short duration, the matter is more serious, involving as it may a cracked piston, scored cylinder walls, or broken, warped, or gummed rings.

If any of these troubles are suspected crank the engine, stopping when piston starts upward on compression stroke, flush then the cylinder combustion chamber with an oil-gun full of gasoline, then crank the engine on the compression stroke, and with the aid of an electric lamp and a small mirror, observe the bubbles caused by the escape of the gas about the lower edge of the piston. There will naturally be no bubbles at this point if the piston head is fractured, but it may be possible to see the crack through which the leakage occurs. At any rate, if enough gasoline has been left in the cylinder, one will be able to see it trickling down the connecting rod or inner piston walls, should such a crack exist.

If the cylinder walls are scored, one will see the liquid at but few points about the lower edge of the piston, and, as the gasoline washes the oil away, possibly the score marks will also be seen.

In case the trouble is with the rings, the bubbles will be more evenly distributed about the periphery of the piston, and will be all of about the same size. Should this latter be the condition, use the kerosene treatment for gummed rings; this may eliminate the leak if the rings are only gummed. If this latter is not effective, the job is one of replacing rings.

If the gas is escaping through the rings, it will be necessary to take out the pistons and to look at the rings. If there are **black spots on the rings,** it is evident the gas has been escaping at this point.

To test a piston for a leak in casting: Set the piston bottom side up in a pan and pour gasoline into the interior of the piston. If there is a hole in the piston, the gasoline will seep through it.

Remedying Piston-Ring Troubles

Gummed rings: After long periods of running, a deposit of charred, or partially charred, lubricating oil is liable to form behind the ring and to interfere with its free movement; it is a good plan, therefore,

[1] There is a small amount of leak that is audible after oil has drained from the piston rings. Do not confuse this with serious leaks, as rings depend on an oil seal to be perfectly gas tight.

when overhauling the engine, to slip the rings from the piston and thoroughly to clean out the grooves.[1]

A kerosene oil treatment to loosen rings: Engines have been known to lack power merely from the rings becoming gummed up. This trouble can be remedied by first running the engine until it is warm; then stop it, take out the spark plugs, and pour some kerosene into each cylinder, by pouring the kerosene through the spark-plug holes. Plug up the holes with old spark plugs, and then crank the engine several times by hand, so that the oil will work its way down around the rings; leave this oil in over night, and next morning crank the engine a number of times until you think the oil has passed into the crank case. Drain the crank case. After thoroughly draining, and putting in fresh lubricating oil, start the engine. The engine will smoke considerably to begin with, but this will soon pass away. This will not only loosen up the rings, but will also clean any soft carbon that may have become deposited in the combustion chamber. This treatment often saves the trouble of fitting new rings, and in some cases will make a marked difference in the running of the engine. Be sure, however, to clean out all kerosene, otherwise the lubricating oil will be thinned.

If the ring is broken or if it is dull and dirty in spots and streaks, a new ring or rings must be fitted.

If a ring is cut or scratched, a new ring is necessary.

If the walls of the cylinder are cut or scratched, then rebore, grind, ream, hone, or lap, as directed on pages 814–815, and fit oversize rings.

If the ring has lost its pressure and does not spring freely against the walls of the cylinder, it can be peened, as shown in Fig. 18, or a new one installed.

Remedying Excessive Smoke

As previously stated, if the rings are leaking, an excess of smoke will pass out of the exhaust, as a result of the oil passing the rings and entering the combustion chamber.

Peening Piston Rings

This operation is for a ring which has lost its pressure. A peening hammer should be used instead of the various flat-headed types that are used at times for peening a piston ring. The metal may be more readily distributed by the blows from a peening hammer, which can be directed better, since the head is so designed that a large part of the surface is not covered at one time nor struck by any single blow.

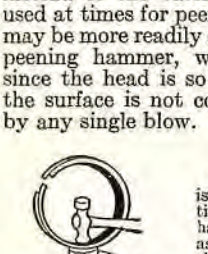


Fig. 18. Peening a piston ring. It is very important in any peening operation that the surface upon which the hammering is done be as flat and hard as possible, for any irregularities in the shape of the surface plate will be just as effective in causing distortions as a blow from a badly shaped hammer. One method of providing such a surface plate is shown.

Note: This work should be avoided if possible, by **installing a new ring.**

[1] Tools for cleaning ring grooves and applying rings to piston can be obtained of auto supply houses.

Removal of Rings

When working on pistons or rings, it is best to clamp the piston in a piston vise which has babbitt-lined jaws, so as not to distort or mar the piston.

Be careful of handling pistons with light walls, as they may be easily sprung, causing piston to be out of round. (Fig. 18A.)

If no piston vise is available the piston and connecting-rod may be held in a vise as in Fig. 18B. It is best to provide copper jaws or wood blocks in vise.

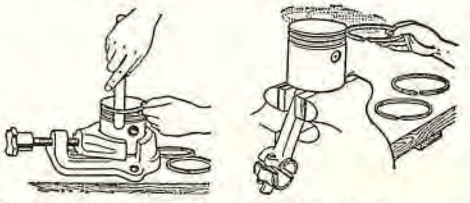


Fig. 18A (left). **Piston vise** with babbitt-lined jaws can be obtained of auto supply houses.

Fig. 18B (right). If an ordinary vise is used, be sure to use **copper jaws** or wood blocks.

The removal of rings from piston grooves is not difficult if a little forethought is taken. To open them, it is best to use a pair of very thin-jawed pliers, the jaws opening outward (see Fig. 20). A substitute for pliers can be made from iron wire.

When the ring is slightly expanded by the use of pliers, similar to those shown in Figs. 19, 20, a narrow strip of very thin metal (tin or brass will do) should be pushed through the opening and worked to the opposite side of the slot; then if the ring is opened a trifle more, an additional strip of metal can be placed near the ends of the ring, when it can be worked off quite easily and without any risk of breaking it, such as would result from an attempt to expand it too much.

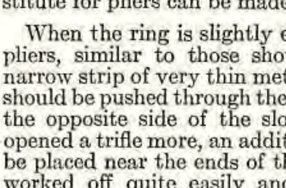


Fig. 19. **One method of removing piston rings from piston grooves.** The ring is expanded slightly by special pliers. Strips of metal are then inserted under the rings at equidistant points, when the ring can be safely slid off. In replacing the rings, the lower one is first fitted on over the strips, and then the other two.

Fig. 20. Piston-ring pliers.

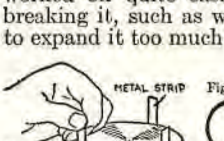


Fig. 20A. **Another method of removing a ring:** Insert the handle end of a file, table knife, hack saw blade or some similar object under the ring near the gap, and raise the end of the ring out of the groove. While pressing the ring out of the groove, run end of file around piston until the ring has been completely lifted out. It may then be slipped off the top end of the piston. Before replacing a ring the groove should be cleaned of the carbon. Care should be taken in sliding a ring over the skirt, especially an aluminum piston, to not score the surface.

Marking Piston Rings When Removing

The amateur or junior repairman who removes the piston rings from a piston for the first time, either for examining the piston-ring grooves for sandholes or wear, or for cleaning the rings and grooves generally neglects to see that the rings are marked so that they may be replaced in their proper grooves. The result is that considerable difficulty often is experienced in getting the rings back into the piston in good order. To avoid this, mark the piston rings as indicated.

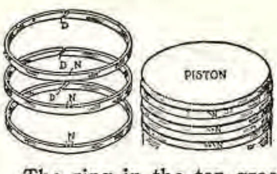


Fig. 21. Mark piston and rings when removing the rings.

The ring in the top groove of a piston has one notch (N) in the upper, inner edge, opposite the diagonal opening or ring gap (D). This notch is made with a file and is very small, so as to be just visible, but at the same time not deep enough to weaken the ring. In a similar manner, the next ring below it is marked with two notches, and the third ring, with three notches. If more rings are used, a corresponding number of notches are employed to mark them. With rings thus marked there should be no difficulty in getting them replaced in their proper grooves. Care should be taken, however, when the rings from more than one piston are removed at the same time. In fact, it is advisable to remove, clean, and replace the rings of one piston before removing them from others.

Fitting and Testing a Ring to Cylinder

After having selected a set of rings, the first operation is to fit them into the cylinder to see if they have the proper ring-gap clearance. Taking one of the rings, try very carefully to shove it straight in, concentric with the cylinder walls; if the ring is of the diagonal slot or miter-cut type (Fig. 1, page 826) and its diameter is a little large, the ends will run upon each other, throwing the edges out of line; while if a ring with step-cut overlapping ends (Fig. 2, page 826) is used, it will not go in at all. In such case, the **ring ends must be filed** (see also page 828, for testing piston-ring gap clearance).

When trying a ring into cylinder, a simple test can also be made at this time to see if cylinder is out of round or tapered, by inserting ring into the cylinder bore and sliding it up and down the full length of the bore of cylinder and **watch the opening of the ring gap** and see how much it opens and closes at different points in the cylinder.

If the gap varies considerably, it is advisable to test cylinder with a gauge as shown in Fig. 11, page 812, and if out of round or tapered up to about .005″, cylinders may be reconditioned by honing as shown on page 816. If over .005″ out of round or tapered, cylinders should be bored or reamed and honed.

If new piston rings are fitted to an out-of-round or tapered cylinder, the new rings will touch only the high spots in the cylinder, leaving a space between the rings and the cylinder walls.

Fig. 21A. **To test the fit of new piston rings, proceed as follows:** Slide the piston (P) into the cylinder bore (top up). Insert the ring (R) into the bore and press it down until it rests snugly against the piston at all points. It may be necessary to **file the ends of the ring to do this,** as all rings when new are oversize; however, use care not to remove more metal than necessary to make ring rest squarely on piston head.

Slip a thickness gauge (G) between the two edges of the split in the ring. If the space between the split is too close, remove the ring and with a very fine file dress the end until the proper clearance is obtained.

Note: This gap on Star car (4 cyl.) is .003″ on beveled-edge cut ring; on Chevrolet (K, V) the gap between the ends of the step cut ring should be approximately .006″; on the Ford, see page 827, Fig. 6.

Filing Ring Gap for More Clearance

A very simple and effective means of **holding a ring for filing** is shown in Fig. 22. The ring is placed on a block of wood and a few small nails are driven into the block both inside and outside of the ring in such a manner that the ring is held securely in place for filing.

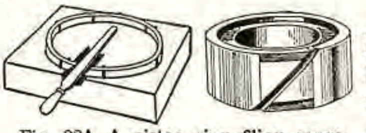


Fig. 22. **Filing a ring joint:** The groove on the block is used when reducing the diameter of diagonally slotted rings.

Fig. 22A. **A piston ring filing gauge.** By inserting the recessed groove the bevel edges can be filed without danger of rounding the edges.

The heads of the nails are then cut off, the ring is removed, and the nails are filed down so that they will extend just below the top surface of the ring when it is replaced on the block. With the nails well placed, there will be no danger whatever of breaking the ring when filing. A thin, smooth, flat file is best for this. The ring can also be placed in a vise, between vise clamps, and filed.

The ends must be trimmed off so that when the ring is well up into the cylinder there will be the proper clearance space between ends (Fig. 16, page 828), to allow for expansion caused by heat of the explosions.

Try each ring in the cylinder to which it is to be fitted, being sure to have it placed fully up into the cylinder where the ring travels. Then measure the opening in the ring as described on page 828 (Fig. 16). If too great an opening is allowed to exist, compression can easily escape. See page 828 for "Gap clearances."

The ring should be repeatedly tried in the cylinder in order that the space may not be filed to exceed the dimensions stated. The inside portions of the rings near the ends should rest against the nails (Fig. 22), in order that they may not be broken off when filing the slot.

Having attained the proper space between the ends of the ring, now place a light in the cylinder behind it and see how its face conforms to the wall of the cylinder, and also see if the ring makes full **contact with walls of cylinder**—if not get another one.

Fit each ring separately and do not forget to **clean all filings from ring.**

If the ends of the rings are hard butted against one another when in place in the cylinder, they may be buckled by expansion when hot, and make starting the engine a two-man job.

If there is a contact all around, when testing rings in the cylinder, the ring is then ready to be fitted to the piston; but if the contact is poor, either the ring or the cylinder is out of round, leaving space between cylinder wall and the ring, as at (C) and (P) in Figs. 23 and 24.

If the fault lies in the ring, it can be lapped to a fit, or another can be selected; but if the cylinder is badly out of round, it will have to be rebored, reground, reamed or honed.

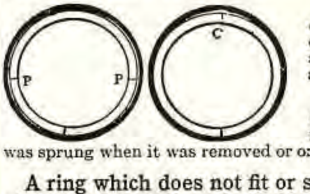


Fig. 23. Cylinder out of round or ring is not exerting equal pressure at all points. Note open space at (P).

Fig. 24. Note space at (C). The same conditions may have existed, or ring was sprung when it was removed or originally placed on piston.

A ring which does not fit or seat the cylinder wall all around permits oil to pass to the combustion chamber and gasoline to pass to the crank case, thus thinning the lubricating oil.

Lapping a Ring to the Cylinder

To work or lap a ring to fit the cylinder: Make a plug of yellow pine (Fig. 25) to fit easily into the cylinder and square one end. Lay the ring on this end with a small batten across, secured by a screw through the center, but not holding the ring tightly.

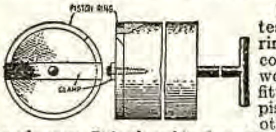


Fig. 25. **A handy device for testing and fitting the piston rings in a cylinder.** This device consists of a round block of wood with a handle on one end fitting cylinder snugly. The piston ring is placed on the other end and is held by a block and screw. It is placed in the cylinder and worked back and forth.

Smear the bore as evenly as possible with a little vermilion and lubricating oil mixed to a paste, and move the ring to and fro in the cylinder while it is held square by the plug. Generally, it will be found to bear hardest at each side of the slot. File such places carefully with a smooth file. See also page 815, for directions for lapping rings, pistons, etc. An old piston can be used for this purpose, but it is best not to use the regular piston. Rotten stone mixed with oil to form a paste can be used, and is preferable to emery (see page 815 for manufacturers of lapping compounds).

Testing Rings to Fit Piston Grooves

When the rings have been fitted to the cylinder, the next operation is to test them for a fit in their respective grooves on the piston. The fit of the rings in the grooves should be free, neither tight enough to jam, nor slack enough to rock.

Fitting Rings to Piston

Piston rings should be laid on a surface plate and aligned to see if **sprung.** Edges should be flat. If not, the ring should be discarded.

If the piston ring is loose due to a sloppy groove, do one of two things: (1) turn the grooves out 1/32" larger on the lathe and get rings to fit, or (2) buy and install new pistons. Remember, no piston ring will function properly if loose or sloppy in the ring groove.

If the pistons have too much play in the cylinders, replace them with new pistons. Don't expect the impossible of any piston rings.

If the bore of the cylinder is found to be worn extremely out of round, see if ring is sprung. Throw away if so. The cylinder block should be sent to some reliable concern for regrinding or reboring. Such a degree of efficiency in that art has been reached that a worn cylinder can often be made as good as, if not better than, new, and particularly when the repairman or mechanic specifies and insists on the installation of good piston rings. Have the same concern fit oversize pistons or rings individually to each cylinder at the time the cylinders are ground, as this is necessary if the cylinders are enlarged. Where this is not possible, secure oversize piston rings and lap to fit the cylinder, as explained on pages 815, 816.

Try each ring in its groove by slipping into the groove, and by rolling it all the way around groove in the piston, as shown in Fig. 26, and **make certain the ring fits properly in its groove. This is of vital importance in controlling oil pumping and leakage.**

If the ring is too loose, try another ring. If too tight dress down as shown in Fig. 30.

The repairman should also use caution to fit piston ring in the groove so that it will lie flat on the ring land, making full contact all around. If it does not, try another ring, or lap ring to the ring land with very fine lapping compound by placing ring in groove and working it around. Clean thoroughly afterwards.

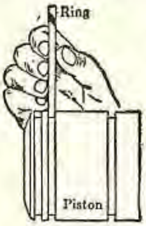


Fig. 26. **Testing a piston ring in the piston groove.** The ring should fit in groove with about .001" to .002" play, and should move freely all around. If the ring is the proper thickness, you should feel it drag slightly in the groove. If it is too loose, try another ring.

Some repairmen lap the ring in the groove by placing grinding compound on the ring and rolling the ring in its groove round and round until it will roll in the groove by its own weight, but without any side shake or looseness.

It is very important that the groove be thoroughly cleaned of carbon and gum, which can be done with a small screwdriver, some kerosene, or gasoline, and a cloth.

Also be sure that the piston is perfectly round. If the piston is slightly oval, squeeze it in a vise, the jaws of which are covered with copper or lead, or tap the piston gently with a rawhide or wooden mallet, at it's greatest diameter.

The piston ring should fit snugly, as at (A) (Fig. 27), but should still be free to slide in and out easily; if it binds in any place, dress the sides down as in Fig. 30.

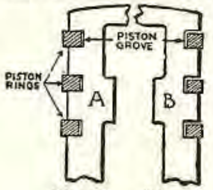


Fig. 27 (left) Fig. 28 (right)

An example of an ill-fitting piston ring is shown at (B) (Fig. 28) and also in Fig. 24, page 831, where (C) (Fig. 24) shows the space left open between the ring and cylinder wall by the ring being sprung when it was put on the piston.

Occasionally small ridges or shoulders are found at the back or bottom of the ring groove, which may prevent the ring fitting into the groove. These can be removed with a lathe, but where no lathe is available, this trouble can be overcome by making a slight change in the piston ring as follows: Take a file and rub it slowly around the inner edges of the ring—the edges which come in contact with the ridges at the back of the groove—and remove enough material in this manner to permit the ring to fit into the groove without binding on these ridges.

It sometimes happens that a ring does not seat all the way round. Such a ring allows the oil and gas to pass, and should be replaced.

Most manufacturers now cut the grooves in the piston, and grind the face and edges of the rings to a gauge, making very little hand-fitting necessary. But there are cases (and these are the ones that generally come into the repair shop), where the cut was just a trifle larger, or the ring a little smaller, than the gauge, making it **essential that each ring be individually fitted to the groove** in which it shall subsequently rest.

How the piston ring pumps oil when loose or a sloppy fit in the ring groove: When the piston moves down, the ring moves to the top of the groove. The oil on the cylinder wall then collects in the space under and back of ring. **When piston starts up,** the ring moves to the bottom of groove and oil below and in back of the ring is forced around to the upper side. As piston reaches top of stroke and starts down, the ring again moves to top of groove and oil is deposited on cylinder wall at a point above the top ring, and therefore, cannot be carried back with the piston on its down stroke. Thus it will be seen that quite a large amount of oil can be pumped into the combustion chamber in this manner.

Piston ring pounding: When wear has progressed to such an extent that the piston rings possess perceptible up-and-down movement, the pounding action of the rings on the sides of their grooves tends to increase the enlargement at a very rapid rate. **This is the point at which trouble from oil pumping usually commences.**

Lapping Sides of Ring to Fit Groove of Piston

Tight rings in grooves may be eased by grinding or lapping the sides on a sheet of fine emery or crocus cloth (E) placed on a surface plate (S) or on a piece of board planed quite flat and true. The ring (R) mounted on a flat board (B) is gently rubbed back and forth, or with a circular motion, with an even downward pressure, as shown in Fig. 30.

Remove the ring from the board and try the fit, repeating the grinding operation if necessary. Use care to not remove more metal than is necessary.

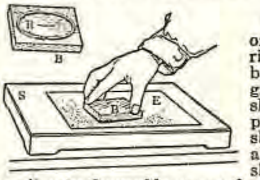


Fig. 30. **Method of dressing or lapping the sides of a piston ring** on a surface plate (or a board planed true) to fit the groove in the piston. Lapping should not continue for a long period on one side. The ring should be turned over occasionally. After lapping, the ring should be immersed in clean gasoline to *thoroughly remove the abrasive* and then fitted to the groove—not to any groove, but to the groove which it nearly fitted before. If every part of the circumference of the ring fits every part of the groove, the lapping is complete and the ring may be tagged or marked to designate its location.

To dress down a ring properly requires some skill, and a good mechanic will select a ring which will demand the least amount of trimming, for it is a delicate operation. Burrs at edge of ring grooves caused by machining must be removed with file before fitting a ring to new piston.

Installing Rings in Grooves of Pistons

First be sure that the piston-ring grooves are perfectly clean and free of carbon. This is important. Most of the manufacturers listed at the bottom of this page make **ring-groove cleaning tools.** An old piston ring, same width of groove, broken in half and one end filed or ground to an edge, will serve the purpose. **Be careful to not scratch** the sides of the grooves. A narrow strip of fine sandpaper can be used to polish the bottom of groove. The rings are supposed to **seat on the ring lands,** and this seat is important in order to prevent "blow-by." On some pistons the **piston-ring grooves are burnished** top and bottom to secure a good seat for the ring.

Also **be sure that ring groove walls are straight**—not worn V-shaped.

If groove walls are worn, they could be trued up in a lathe and overwidth rings fitted; 1/32" would be sufficient.

When fitting rings in the grooves, begin with the ring selected for the bottom groove, so that that ring will be the first to be slipped on to the piston.

Select the best fitting ring for the top, so that oil below it cannot be consumed by the high temperature of the burned gases. If hot, high pressure gases from the combustion chamber blow past the rings (termed *"blow-by"*), oil will be burned off the piston and the cylinder wall, causing it to become scored, even though the oiling system might be working perfectly with the best grade of oil.

A ring should never be sprung over a piston to the second or third groove. Use strips (S) (Fig. 31), which will permit easy replacement without distorting the ring.

Fig. 31. One method of slipping a ring on a piston and into the groove. Take three strips of sheet metal, brass or tin (S), for instance, about 1/32" thick, 1/2 wide, and 5" long; bend these at right angles and hang them on the edge of the piston at equal distances apart. The ring (R) may then be slipped over these skids till it is opposite its groove, when the strips may be removed and the ring allowed to slide into place. Instal the ring in the lower groove first and work to the top groove last. The same strips may also be successfully used in removing the rings.

Replace the same piston rings in the same cylinders if removed and replaced again. The use of boards with numbered pegs is recommended, to avoid mixing the rings.

When placing the rings on the piston ready to replace in the cylinders, they should be set with the joints (if it is a piston with three rings) about one-third way from each other, so that the openings will not come in a straight line or be close together.

Pinning Piston Rings

When the ring is in the cylinder, the gap clearance is very slight. If it were too little, it would close up entirely when heated and buckle (see p. 828); if too great, there would likely be a leakage of compression through the gap, or if all of the gaps were in line when in the cylinder, it is likely that there would be a leakage of compression from the combustion chamber to the crank case through the gaps.

Inasmuch as the rings are free to work in their grooves, it is possible that the rings may work around in the grooves, until they are all in line at one time. For if the rings thus work around, they are likely to continue working, and if originally placed on the piston an equal distance apart, there is not much chance for all of them to get in line at the same time.

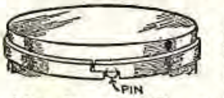


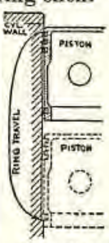
Fig. 31A. **A pinned piston ring.** Before the advent of the patented ring, the rings were usually pinned, that is, the gaps were first placed 120° apart on the piston, and then the ends of the rings were notched with a fine round file, so that the semicircular notches just closed over the pins. The pins were a source of trouble in high-speed engines; and unless great care was exercised in screwing or fitting the pins tight into the piston, they would loosen and project and cut the cylinder wall.

This practice was abandoned to a certain extent. Pins are still used on many large, slow-speed engines and on two-cycle engines. There is no doubt that the pins had the advantage of insuring against their getting in line. But they also had disadvantages. The growth of the popularity of all kinds of patented rings with gas-type joints has thrived on this claim as well as on the claim that the patented ring exerts equal pressure at all points of its circumference.

Piston-Ring Travel Wear in Cylinder

Cylinder wear occurs in that part in which the rings travel (Fig. 32). Greatest wear is at the top of the ring travel, gradually tapering down to the smallest wear at the bottom. A pronounced **shoulder or ridge** is often formed at the **top,** and a lesser shoulder is sometimes formed at the **bottom.** (See also p. 814.)

When installing new piston rings without enlarging the cylinders, always remove the top ridge with a hone or a ridge removing tool to prevent the square edge of the new ring from striking the shoulder, thereby ruining the ring and many times causing a ring click.



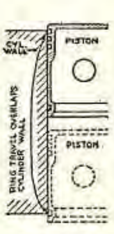


Fig. 32 (left). Showing the ring travel on cylinder walls of most engines. The top ring will wear most, and it will also wear the cylinder most; thus, the greatest wear is near the top of the ring travel.

Fig. 33 (right). Showing how the ring slightly overlaps the cylinder wall on some types of engines.

Sometimes it is advisable to remove the bottom ridge to avoid piston knock or the collapsing of aluminum-alloy pistons.

If the top ring groove of the piston is widened, it is important to remove the shoulder to avoid damage to the ring or piston.

Some of the concerns who supply cylinder ridge-removing tools (also mechanics hand tools) are: Cornwell Quality Tools Co., Mogadore, Ohio; Hall Mfg. Co., Toledo, Ohio; Hastings Mfg. Co., Hastings, Mich.; Herbrand Corp., Fremont, Ohio; Geo. L. Hunt Mfg. Co., Inc., Boscobel, Wis.; Lisle Corp., Clarinda, Iowa; National Machine & Tool Co., Jackson, Mich.; Snap-On Tools, Inc., Kenosha, Wis.; Truth Tool Co., Mankato, Minn.; Wilkening Mfg. Co., Philadelphia, Pa. See also footnote 1, page 698.

Replacing a Piston in the Cylinder

Before putting pistons into cylinders, place cylinder oil on sides of pistons and wipe out cylinder bores with a cloth free of lint, as oil will not have a chance to reach the upper portion when first starting.

Also see that the piston pin is properly set, and that the **piston-pin set screw or locking ring** is tight, and that the piston and connecting rod are in **alignment.** See page 803.

On pistons, such as aluminum alloy split-skirt type, the split side of piston must be installed on the side of lesser thrust. See also pages 809, 811, 812, on installing.

When replacing the piston in cylinder, some device must be provided for holding each ring in its groove, so that it will easily enter the cylinder. **By no means force or drive the piston and rings into the cylinder.** A string may be used as shown in Fig. 35. A better method is shown in Fig. 36.

Fig. 35. Method of **replacing a piston in the cylinder** with a string holding the ring in its groove.

Fig. 36. A serviceable **device for compressing rings when fitting piston to the cylinder.** To use this device draw compressor over end of piston, then place skirt of piston in cylinder and, with slight pressure on top of piston, the spring at the bottom of the compressor automatically closes rings as they enter cylinder. Instantly adjusts itself to all rings from 2¾" to 4½".

Replacing cylinders over pistons (non-detachable cylinder heads): It is not difficult to put a single cylinder back on its piston after it has been necessary to take it out, but it is not so easy when the cylinders are cast in pairs, as it is difficult to guide the rings into the cylinder barrels simultaneously.

The job is greatly simplified by taking the precaution to place the cranks up and down, so that one piston is at its highest point and the other is at its lowest. This means that the pair of cylinders can be dropped straight over the pistons, the rings of the upper piston being guided into the cylinder before those of the lower piston are replaced.

When it comes to dropping one of the mono-block castings of four cylinders on to four pistons, it is still best to work this way, so that only one other pair of hands is required, and that the two upper pistons may be guided into their cylinders first.

When reinstalling a piston, be careful not to push it up into the cylinder as far as it will go. The upper ring may **jump over** the counter-bore in firing chamber, holding the piston until the ring is released, which is a difficult situation to remedy.

On some engines the piston and rings are placed in cylinder from the under side, and the lower ends of the cylinder bores are beveled to facilitate the insertion of the piston with the rings attached.

When fitting new rings to only one piston, be sure that all the other cylinders have good compression, otherwise the cylinders with good compression will have a rich mixture and those with poor compression a lean mixture; result, engine will not idle properly.

Piston Rings—Oversize[1]

Oversize piston rings must be fitted to pistons when oversize pistons are fitted to cylinders.

S.A.E. standard oversizes for piston rings are: .005", .010", .015", .020", .030", .040". Larger oversizes, when necessary, shall be held to multiples of .010" (same as pistons page 813).[3]

RUNNING-IN ENGINE AFTER RECONDITIONING

After having reconditioned cylinders and fitted pistons and piston rings, or after having fitted piston rings or bearings, the engine should be "run-in" carefully with plenty of oil in the crankcase. See page 787 explaining the precaution to take after fitting bearings, also, see page 824B explaining the importance of carefully running-in engine until the cylinder walls are glazed.

A running-in machine is usually provided in most shops on which the engine is placed to be run-in, tested and adjusted. (See page 789 showing a machine of this type. Home made running-in machines are shown on page 790-B.)

Where a running-in machine is not available, after fitting the above mentioned parts, the engine should be run under its own power slowly and at intervals at first, allowing it to cool between times, then allow to idle for about an hour or so or **until the heating is reduced** and until fairly free. Additional friction and heat will be produced at first and until parts are worked in, therefore, use plenty of oil, in fact, sufficient oil should be used to cause smoke to come from the exhaust which indicates that cylinder walls and pistons are getting oil. About one gallon more than normal should be provided. Run with spark advanced as far as possible and **do not race engine.**

Connect the radiator with the water hose so that water will run through the circulation system to keep it cool as the friction of new parts will cause more heating than usual. Closely observe that undue heating is not taking place, that is, if any part gets so hot it will not bear the touch of the hand. then it may seize and score.

For example. a bearing set too snug will heat readily at first, therefore the danger of scoring or burning is very great until the bearings have time to work in. This also applies to other parts—and don't forget to use plenty of oil during this process.

Care must also be exercised in driving car after running-in for the first two hundred miles, that is, to use plenty of oil and not run car over 15 miles per hour. A speed of 20 m.p.h. should not be exceeded during the first five hundred miles. Thus the parts will burnish and glaze to a nice fit.

Use plenty of good oil when working-in a reconditioned or new engine. Repairmen often place about one pint, or even slightly more of light, high grade **engine oil mixed with about 5 gallons of gasoline** in the tank to assist in lubricating upper parts,[2] such as the cylinder walls, rings, valve stems, guides and upper parts and prevent sticking of pistons and valves. In fact, after fitting new pistons and rings it is advisable to also inject oil in the air intake of carburetor after starting.

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[1] See page 833-B for list of piston ring manufacturers and assorted sizes of pistons, rings and bearings and where to obtain.

[2] **On new cars** it is common practice to use oil in this way to work in the engine.

One brand of special oil prepared for this purpose, is known as Upper-Cylinder-Oil. About three ounces to ten gallons of gasoline is used; it passes into engine with the fuel. The claim is that it lubricates upper moving parts and also tends to soften carbon deposit.

[3] **Other sizes,** although not recommended by S.A.E. can be obtained, as .0025", .003", .031", .033", .045", .0625".

See also page 166, "*Breaking-in a new or reconditioned engine.*"

PROCEDURE OF INSTALLING PISTONS AND RINGS AND PRECAUTION TO TAKE AFTERWARDS[1]

1. **Clean all parts** thoroughly by removing emery dust and dirt; wash in gasoline. The mechanic's hands should be free from grit or dirt.
2. **Clean piston-ring grooves thoroughly and fit rings** to them. (See pp. 832–833.)
3. **Align** connecting rod and piston.
4. **Thoroughly oil piston pin.**
5. **Install piston** in cylinder bore, having first applied oil to it.
6. **Connect connecting-rod bearing,** being careful not to twist or bend connecting rod.
7. **Inject oil on piston head** before starting engine.
8. **Fill crankcase** up to high level with S.A.E. 10 oil or add "break-in oil" to S.A.E. 20.
9. **See that radiator** and circulation system is filled with water.
10. **See that fan belt** is properly adjusted.
11. **Check ignition, valves, ignition timing, valve timing.**
12. **Check carburetion** for rich mixture, as excess gasoline washes oil off of the cylinder walls and is a major cause of rapid piston-ring wear.
13. **Add one pint of light break-in oil** to every 5 gal. of gasoline for first 500 miles, or as *recommended* by oil concerns.
14. **It is sometimes advisable to also inject "upper cylinder oil" in intake manifold** or in air intake on carburetor and proceed at intervals for ½ hr. after starting.

    This oil will mix with the gasoline and lubricate cylinder walls, rings, and upper parts until the oil is properly circulated from crankcase.

    The engine should be run idle with full advanced spark for about two or three hours. If at any time one or more cylinders miss, the trouble should be traced immediately and rectified, as a missing cylinder will allow gas to escape to the crankcase, causing dilution of oil, which will result in poor lubrication.
15. **Do not exceed** 25 m.p.h. for first 500 miles.
16. **Change oil** to regular grade at about half the normal period.

QUESTIONS AND ANSWERS ON PISTONS AND RINGS

Q. 1: How many piston rings are generally used on each piston?

Ans.: 3 or 4.

Q. 2: How are piston rings generally placed on pistons?

Ans.: Usually all above piston pin. Sometimes one oil-control ring below pin.

Q. 3: What clearance should cast-iron pistons have on an average?

Ans.: .001″ per inch of piston diameter. See pages 811, 809.

Q. 4: What clearance should aluminum-alloy pistons have on an average?

Ans.: See pages 811, 809.

Q. 5: What is the difference between concentric and eccentric piston rings?

Ans.: A concentric ring is one of equal thickness throughout its entire circumference. An eccentric ring is not. At a point (e) (Fig. 8, page 827) opposite the split in the ring, it is made thicker.

Q. 6: What is the advantage of each?

Ans.: Unless a piston ring bears with equal pressure on the cylinder wall at all points of its circumference, the compressed gas would pass at the point where it did not bear, and thus leak compression. A ring is subjected to considerable heat, at which time it may lose its pressure at some point of its circumference. Some claim that by making a ring eccentric, it will retain its pressure under heat more than a concentric ring. Others claim that if a concentric ring is made properly it will retain its pressure. Most of the patented rings are concentric; in fact the majority of plain rings (page 826) are concentric. One advantage claimed for concentric rings over eccentric rings; for instance, the carbon that accumulates back of the ring will tend to lock an eccentric ring sooner than a concentric ring, thereby preventing the natural shifting of the ring around the piston groove. Many large rings used on air compressors, locomotives, etc. are eccentric.

Q. 7: What causes piston rings to pump oil?

Ans.: See bottom of pages 832, 826 (see also page 168).

Q. 8: How should rings be fitted to the ring grooves and is this fit important, and should ring groove be cleaned when fitting?

Ans.: Yes. See pages 832, 833.

Q. 9: What are spring-expander type piston rings and piston skirt expanders used for?

Ans.: See pages 828 and 814B.

Q. 10: What is the Koetherizing process of resizing of aluminum-alloy pistons?

Ans.: A patented process consisting of the application of a blast of steel shot against the two inner thrust sides of a piston skirt wall. Write American Hammered Piston Ring Co., Baltimore, Md.

See page 813A on Questions and Answers on fitting standard and oversize pistons; page 809 on pistons; pages 824 and 817 on enlarging cylinders.

PISTONS, PISTON PINS, PISTON RINGS, AND BEARINGS OF ASSORTED SIZES[2, 3, 4]

Regrinding and reboring shops, also service and repair shops, have found that there is greater demand for their services when they carry a full stock of pistons, piston pins, piston rings, and bearings.

Most auto-supply jobbers or distributors furnish information as to the stock that should be carried.

An assortment that the repairman should carry will of course depend upon what cars are most popular in his vicinity. Repairmen who specialize in overhauling particular makes of cars, trucks, or tractors can make up a stock assortment accordingly. The **amount of work** done will of course determine the **quantity** to carry.

For the kind of pistons (iron or aluminum) used on different cars, and also for the **size of piston rings,** see pages 1060 and 1054**B**.

[1] **See page** 690 for *piston, piston ring, bearing,* and other *service literature.* **See also page 828.**

[2] **Some of the piston-ring manufacturers are:** Aluminum Industries, Inc., 2416 Beekman St., Cincinnati, Ohio (Permite); American Hammered Piston Ring Co., Bush & Hamburg Sts., Baltimore, Md.; Aviation Piston Ring Co., Paterson, N.J.; A. B. Chance Co., Centralia, Mo.; Cords Piston Ring Mfg. Co., San Diego, Calif.; Hastings Mfg. Co., Hastings, Mich.; Jambor Tool & Stamping Co., 3057 N. 30th St., Milwaukee, Wis. (Bull Dog); King Quality Products Co., 2320 Cooper St., St. Louis, Mo.; McQuay-Norris Mfg. Co., Cooper & Southwest Aves., St. Louis, Mo. (Super-C, Hi-Unit Superoyl, Super-X); Muskegon Piston Ring Co., Muskegon, Mich.; Panyard Piston Ring Co., Muskegon, Mich.; Perfect Circle Co., Hagerstown, Ind. (X-90, 85, 70); Ramsey Accessories Mfg. Corp., 3693 Forest Park Blvd., St. Louis, Mo. (Ramco); Sealed Power Corp., Muskegon, Mich. (formerly the Piston Ring Co.) (Sta-Tite, Super-Drain-oil); Simplex Products Corp., 1966 E. 66th St., Cleveland, Ohio, U.S. Hammered Piston Ring Co., Paterson, N.J.; Valv-Tite Piston Ring Co., Toledo, Ohio; Wilkening Mfg. Co., 2000 S. 71st St., Philadelphia, Pa. (Pedrick).

[3] See page 813**B** for a list of some of the piston manufacturers.

[4] See page 783 for a list of some of the bearing manufacturers.

INSTRUCTION No. 71-A[1]

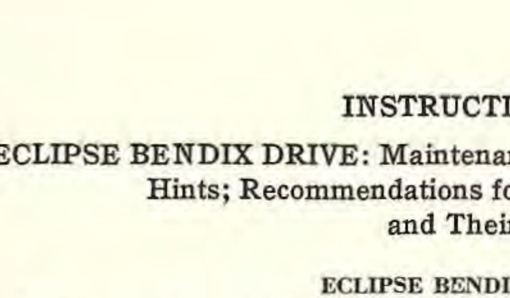
ECLIPSE BENDIX DRIVE: Maintenance; How to Order Parts; Types; Service Hints; Recommendations for Flywheel Steel Ring Gears and Their Mounting

ECLIPSE BENDIX MAINTENANCE

Refer to pages 319 and 320 and study the construction, names of the parts and the principle of operation.

How to Order Parts

In ordering parts, give the name of the part desired as shown in Fig. 5B, page 320; state whether right-hand or left-hand drive (see below); give without fail the make, year and model of the car—and the number of teeth on the pinion gear you are replacing.



Figs. 1 and 2: **How to distinguish between a left-hand and right-hand spring.** Hold the spring in front of you with the eyelets toward you.

Crook your index finger, as shown in the accompanying illustrations, to conform with the **upper** eyelet. If it takes the index finger of your **left** hand to conform with the eyelet, as shown in (1), it is a left-hand spring.

If it takes the index finger of your **right** hand, as shown in (2), it is a **right-hand spring.**

Figs. 3 and 4: **How to distinguish between left-hand and right-hand S.A. assembly.** Grasp the S.A. assembly where the spring attaches, and revolve pinion gear forward. If it revolves over to the left as shown in 3, it is a **left-hand drive.** If it revolves over to the right, as shown in 4, it is a **right-hand drive.**

Note on the left-hand S.A. assembly shown in 3, that the threads wind forward to the left, and that the pinion gear teeth are chamfered off on the **left-hand** corner. On the **right-hand** S.A. assembly, shown in 4, just the opposite is true.

These same tests can be applied to distinguish between right-hand and left-hand complete Bendix drives.

Designation of Eclipse Bendix Drive Types

In designating, or numbering, the standard models of the Eclipse Bendix drive, either the letter "R" or "L" is used as a prefix before the figure or number. The prefix "R" is used when the screw threads and spring coils are right hand, likewise, the prefix "L" is used when the screw threads and spring coils are left hand.

The standard types of the Eclipse Bendix drive are furnished in various sizes as follows:

The R-13 or L-13 is mounted on an armature shaft .802″ in diameter and **is used where a large starting motor** is required.

The R-11 or L-11 is mounted on a shaft ⅝″ in diameter and is the size of drive **for general purpose work,** most commonly used.

The R-10 or L-10 is mounted on a shaft ½″ in diameter and **is used where special conditions warrant this size drive.**

The numbers 13, 11, and 10 also signify the standard number of teeth in the pinion gear on these types; but if a special pinion is used, it is denoted by an addition; for instance, L-11–12 which means an L-11 drive with a 12T-$\frac{8}{10}$ pitch pinion.

An "X" added to the designation of a drive, such as "R-11X," means that a spring and bolts heavier than standard are used on account of special heavy service on particular installations.

In connection with the use of an "X" spring on Eclipse Bendix drives of the 10X or 11X types as mounted on either ½″ or ⅝″ diameter shafts, two additional parts are used under the spring, these being called **spring support clips.**

The purpose of these clips is to form a support for the first one-quarter coil on each end of the driving spring and thereby prevent application of a bending load to the spring screws. Two of these are necessary for each drive, one being snapped over the head and one over the screw shaft.

When in place, the hole of the clip should line up with the screw hole in the head or shaft, and the bent-under portion should set down over the shoulder caused by the reduction of diameter of the head and shaft, this bent under portion preventing sideways cocking of the clip. When assembled in this position the first one-quarter coil of the spring will set firmly on the reinforced lamination—**this is absolutely essential.**

These support clips are furnished in both right and left-hand design for the corresponding types of springs, and are designated by the stamped letters "L" and "R" respectively.

[1] See page 1055 for piston ring sizes for different cars which were formerly on these pages. See 833B for "Questions and Answers" formerly on this page.

THE S.A. ASSEMBLY—WHAT IT IS[1]

The S.A. assembly of the Eclipse Bendix drive consists of screw shaft and all parts which are assembled integrally with it—pinion gear and counterweight, anti-drift pin and spring, stop nut and compression sleeve.

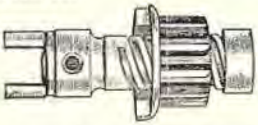


Fig. 5. The S.A. assembly.

It is strongly recommended that it be sold, serviced or replaced as a unit, with the single exception of the compression sleeve.

A few reasons why this recommendation is made are given by the manufacturer as follows:

1. Special care is necessary in the correct parts for a given type of S.A. assembly. An incorrect grouping or assembly of parts in the field means drive difficulties.

2. The pinion gear may be assembled on any one of the three threads on the screw shaft, **only one of which is correct.** This means a three-to-one chance of mistake in field assembly.

3. With the correct positioning of the screw shaft and pinion gear, each individual set of parts is at the factory **lapped together by a special process** and are thereafter never separated.

4. After assembly of the stop nut, accomplished with proper holding tools, it is locked or staked tightly in place. Most field service work on the S.A. assembly necessitates removal of this stop nut, **a difficult operation without proper tools** and very often disastrous to the threads of both screw shaft and stop nut, if done in the ordinary manner. This brings about added difficulties in reassembly, or possibly inadequate assembly. The subsequent relocking of the stop nut requires other tools and for that reason is often improperly done, resulting in other difficulties with the drive after assembly.

5. On the Ford type of drive, the outside diameter of the stop nut must be ground after a complete assembly of the gear and shaft parts, due to the bearing taken by the stop nut. Such an operation is absolutely impossible in the field and if attempted by the assembly of a ground stop nut, usually results in bearing difficulty due to eccentricity.

6. Of special importance is the **proper assembly of the small anti-drift pin and spring** and particularly its adjustment which is described in further detail later.

Always send the S.A. assembly to the factory for any such rebuilding work which will give the assurance of receiving satisfactory performance of the drive. A special department is maintained at the factory for completely rebuilding and carefully inspecting and adjusting all S.A. assemblies returned and the charge for such rebuilding work is exceptionally reasonable.

Eclipse Bendix Service Sleeves

The one exception to the foregoing is the compression sleeve. This can be replaced by the **service sleeve,** which is made for this purpose and can be installed without special tools of any kind.

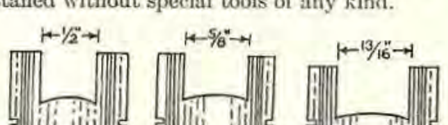


Fig. 6 (left). R-10-112; used with all drives on ½" armature shaft.

Fig. 6 (center). R-11-112; used with all drives on ⅝" armature shaft.

Fig. 6 (right). R-13K-112; used with KX, SX, and XXX types of 13/16" shaft size drums.

The function of the slotted sleeve in conjunction with the lugs of the driving head is to act as a circular filler under the spring, tending to equalize the winding of the coils of the spring, and prevent one spring coil winding down so as to restrict the movement of the tongue and groove portions of sleeve and head, and thereby the longitudinal compression of spring.

It is obvious that none but genuine sleeves stamped "Bendix," which are of the proper structure and length, should be used for replacements.

The sleeves of the ½" and ⅝" armature shaft sizes and certain ones of the 13/16" shaft size, namely KX, XXX, MX types are attached to the screw shaft by a crimping process.

The sizes are determined by the width of the slot, approximately ½", ⅝" and 13/16". These fit the corresponding Bendix screw shafts, the diameter of the hole in the shaft being the same as the width of the slot of the sleeves. It is necessary that the correct size sleeve be used.

This service sleeve can easily be attached by simply placing it over the shaft until it strikes the shoulder, and using a blunt chisel and hammer, lightly hit the divided portions, above and below the corresponding groove of the screw shaft, until they nicely fit into this groove.

For example, note the illustrations, Figs. 7 to 11:

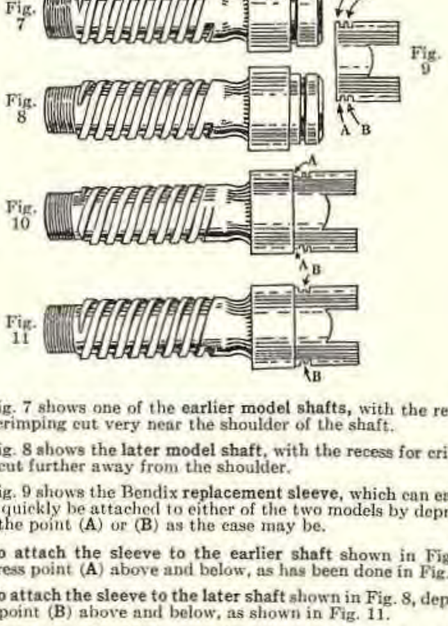


Fig. 7 shows one of the **earlier model shafts,** with the recess for crimping cut very near the shoulder of the shaft.

Fig. 8 shows **the later model shaft,** with the recess for crimping cut further away from the shoulder.

Fig. 9 shows the Bendix **replacement sleeve,** which can easily and quickly be attached to either of the two models by depressing the point (A) or (B) as the case may be.

To attach the sleeve to the earlier shaft shown in Fig. 7, depress point (A) above and below, as has been done in Fig. 10.

To attach the sleeve to the later shaft shown in Fig. 8, depress the point (B) above and below, as shown in Fig. 11.

Great care should be exercised in assembling the repair sleeve on one of the later model shafts (Fig. 8) not to depress the point (A) into the crimping recess on the shaft. This would have a serious effect on the operating of the drive, due to the increase of length of the assembly.

Care should be taken to see that the sleeve is securely fastened, yet is free to turn easily on the screw shaft. This is accomplished by simply placing a screw driver or other similar tool in the slot of the sleeve, and holding the screw shaft secure, rotate the sleeve until it turns easily. **This is very important.**

Beware of replacing a sleeve with any form of structure having an outside diameter greater than the sleeve that was originally on the drive, as its use will interfere with the proper winding of the spring.

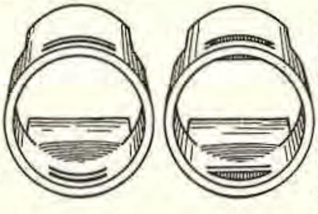


Fig. 12 (left) shows how the service sleeve looks from the end, before point (A) or (B) has been depressed.

Fig. 13 (right) shows how the service sleeve would look from the end, after point (B) has been depressed to fit into the groove of the late model shaft shown in Fig. 8.

[1] See page 1055 for piston ring sizes formerly on this page.

A FEW SERVICE HINTS FOR THE CARE OF THE ECLIPSE BENDIX DRIVE

Lock Washers

Whenever a spring or fastening screw is replaced in the Eclipse Bendix drive, particular care should be taken to see that the two lock washers are properly bent to keep the fastening screws in place.

The lock washers are put in place with the bent lip in the corresponding gap in the spring eye. After the fastening screws are tightened, the second lip of the lock washer must be bent upward until it presses tightly against a flat side of the screw head. **It is absolutely necessary that this operation be completed,** as a partially turned up washer will not keep the screws in place.

Lubrication of the Screw Shaft

Lubrication of the screw shaft is not essential. However, if oiling is done, a very light grade must be used. Gummy oil and grit cause failure to mesh. **To remedy** this, clean screw threads with kerosene.

Care in Re-Starting

It does no harm to step on the starting button with the engine running, but it is recommended that special care be taken in making a restart of the engine after the first one has failed. Wait and make certain that the engine and starting motor have both come to rest, thus preventing the meshing of the pinion gear when the engine is back-rocking or back-firing just prior to its stopping.

Most distorted springs can be traced to this stepping on the starter button for a restart without allowing a moment for the engine to come to rest after the first attempt.

Anti-Drift Spring Tension

The most common difficulties encountered with the anti-drift device are when the tension of the small spring is too light and therefore the anti-drift effect is not enough, or else the spring tension is excessive and the pinion gear therefore fails to mesh under starting conditions, this latter being more often the case in reduction gear starting motors, or where the threaded shaft is covered with heavy oil which congeals in cold weather.

It is obvious then that the tension of this anti-drift must be accurately controlled, and this is one of the reasons why it is recommended not to purchase any of the various parts of the sub-assembly separately.

One other possible difficulty with the anti-drift comes with improper longitudinal location; for instance, if the longitudinal demeshed clearance is only 1/8", the pinion gear contacts the flywheel at the same time as the anti-drift comes into action and therefore the purpose of the anti-drift is lost.

Sticking or Jamming of Gears

Should an end-to-end abutment of pinion and flywheel teeth be such as to cause a sticking or jam of the gears, it can be released by placing the engine in high gear, with the clutch engaged and rocking the car forward with a "to" and "fro" motion.

To remedy, investigate as follows: Make sure that the starter is bolted firmly in place and that the armature shaft is not bent; that there is at least 1/64" backlash between pinion gear and flywheel when meshed; that the forward end of the drive is free to compress longitudinally and that the flywheel teeth are not battered or burred.

Loosened Counterweight on Pinion Gear

Do not attempt to repair a loosened counterweight—it necessitates a new pinion and counterweight which must be correctly assembled. Let the factory rebuild the S.A. assembly at nominal cost and much less trouble to you. This difficulty is caused by improper longitudinal installation and a replacement without correction only means another counterweight.

Failure of Pinion Gear to Mesh

If the pressing of the starter button merely results in a spinning of the starting motor, this can usually be traced to a failure of the pinion gear to mesh, caused by a gummy or oily condition of the Bendix shaft threads—clean with kerosene and do not reoil.

A broken spring or bolt will cause a somewhat similar failure to crank the engine.

In reassembling an Eclipse Bendix drive on armature shaft of starting motor, it is always advisable to clean armature shaft and then place a little oil or graphite grease on it before assembling the drive.

In assembling the starting motor make certain the holding screws are down tight. If possible it is a good plan to mesh the pinion gear of the drive by hand and holding it tight against the stop nut, move the drive and armature shaft as a unit and make certain there is a 1/64" backlash, between the gears. If not, the alignment of the starting motor should be corrected or it should be **shimmed** out from the crank case a slight amount.

In replacing either the shaft spring screw or head spring bolt, it is very important to use the proper length of bolt or screw. It is also equally important in replacing these parts on the "X" type of drive, to use only those screws and bolts stamped with the letter "A" on the head. This signifies that special material and heat-treating has been used in the parts comprising the "X" type drive, due to the heavy duty imposed upon these installations.

The use of either a screw or bolt that is too long or else too short will certainly cause a faulty installation. Consult Eclipse Bendix parts list.

Free Longitudinal Movement Necessary

The free longitudinal movement of the Eclipse Bendix Drive and how it affects proper meshing of the pinion gear is explained below.

The teeth of the Bendix pinion are chamfered on only one side and specially rounded and polished to make the automatic meshing with the flywheel gear teeth natural and easy. However, should the ends of the pinion teeth meet end to end with the flywheel teeth, the threaded screw shaft being freely mounted on the armature shaft is pushed backwards againstthe compression of the driving spring—the longitudinal movement of the screw shaft permitting the pinion gear to turn slightly further and enter flywheel gear.

This action is known as free longitudinal movement and inasmuch as it is natural that the teeth often meet end to end in this manner, it is of supreme importance that the drive be free to compress in this way, also that it be free to easily resume its original position or length.

Any restriction of this longitudinal freedom will of course prevent the slight turning of the pinion gear under such abutment and will cause the pinion teeth to "jam" in the ends of the flywheel teeth and ultimately bring about destruction of the flywheel and many other starting difficulties.

The following conditions will cause such restriction of longitudinal movement:

1. **Drive rusted to armature shaft—to remedy** clean armature shaft and place graphite grease or oil on it before reassembling of the drive.
2. **Rough or burred armature shaft under Bendix shaft—to remedy** file burrs off shaft and smooth it with emery cloth—lubricate as above before reassembling.
3. **Bent armature shaft.**
4. **Use of too long a spring bolt at the shaft end,** causing bolt to protrude through Bendix shaft and bind on armature shaft.
5. **Cocked condition of coils of the spring causing Bendix shaft to drag on the armature shaft—** this more often prevents the ready springing back of the Bendix shaft into its original position after once compressed.
6. **Spread sleeve, misplaced spring support clip, or misplaced Woodruff key,** preventing compression of the spring.
7. **Use of non-genuine spring** which has no possible compression feature due to faulty winding of spring.
8. **Unhooked or improper assembly of the tongue-and-groove portions of the Bendix head and Bendix shaft sleeve**—these parts should always fit into each other as shown in Fig. 16. It is sometimes the case that the space **(AB)** in Fig. 14 is enough over 1/16″ to permit the drive to lengthen enough for the sleeve and head ends to abut. Correct by adding washers ahead of the stop nut and thus reduce space **(AB)**.

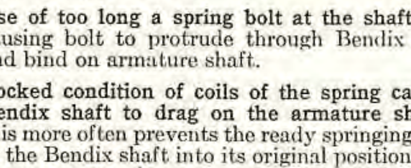


Fig. 14 shows the Eclipse Bendix drive with the spring in its **normal position.** Note that the distance **(AB)** between the stop nut face and the face of the restraining surface is very small, generally 1/16″ or under.

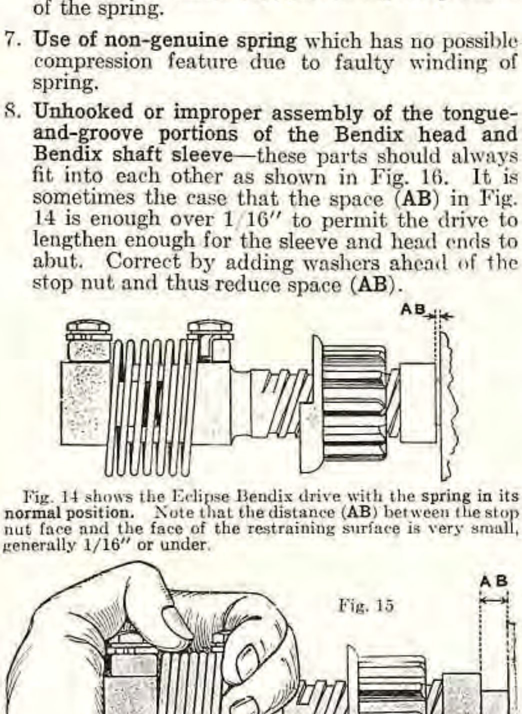


Fig. 15

Fig. 16

Fig. 15 shows the Eclipse Bendix Drive with the **spring compressed by hand,** that is with the longitudinal freedom all taken up. In this position the distance **(AB)** between the stop nut face and the face of the restraining surface is materially increased to about ⅜″, as shown.

In making any repairs to an Eclipse Bendix drive—first lubricate the armature shaft before reassembling the drive on it, and after assembly test for the free longitudinal movement of the drive as shown above, making certain that the drive of itself is likewise free to return to its original length or position.

Fig. 16. Proper assembly of tongue-and-groove portions.

Recommendations for Flywheel Steel Ring Gears and Their Mounting

In the replacement of the original cast-iron flywheel teeth on an engine flywheel with a steel ring gear to be shrunk in place; or in the replacement of one steel ring gear with a new one, special attention should be given; explained as follows:

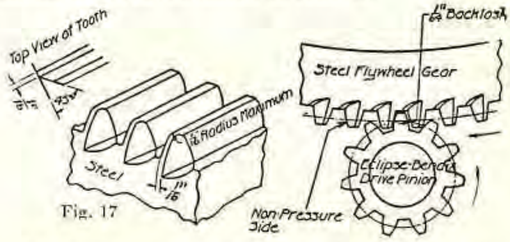


Fig. 17

The ring gear as purchased should be as follows:

1. **Exact number teeth** as originally in flywheel gear.
2. **Machined so as to have the same pitch diameter as the original gear, after it has been shrunk in place**—check this by inspecting the back lash between Bendix pinion and flywheel gear when in full meshed position and with the Bendix pinion gear held against the stop nut—this back lash should be a minimum of 1/64″.

   The S.A.E. standards are as follows: the mounting must be such that there is .015″ pitch line clearance of the pinion on the Bendix drive and the flywheel gear, where center distance is definitely controlled. Where this center distance may vary, due to assembly, the .015″ is minimum and mounting should be designed between this minimum and a maximum of .025″.
3. **Chamfered on the non-pressure side** at an angle of 45° so as to leave a section 1/16″ wide on the ends of the teeth.
4. **The radius on the meshing edge of the ring gear** should not be over 1/16″ as shown in Fig. 17.
5. **Heat-treated or hardened** to have a hardness of at least 55 scleroscope after mounting—**be sure to specify this recommendation in ordering** the ring gear from your source of supply.

In the mounting of the ring gear the following precautions should be taken:

1. **The flywheel should be machined down to the diameter dimension specified by the ring gear manufacturer and at a depth into the face of the flywheel equal to the width of the ring gear.** This places the meshing face of the new ring gear teeth in the same position as the meshing face of the original cast iron teeth—this is a most important point in order to have the Bendix pinion mesh to the proper depth in the flywheel teeth and also in order that the Bendix pinion may be the proper distance from the meshing edge of the flywheel gear, when not in use.
2. **Do not overheat the ring gear in shrinking it in place**—400° F. is plenty and does not materially affect the hardness of the ring gear teeth.
3. **Be sure the chamfered face of the ring gear is on the side where the Bendix pinion meshes and that the chamfer comes on the non-pressure side of the teeth,** that is on the side opposite that against which the pinion gear presses in cranking over the engine. If the chamfer is located on the wrong side, it results in continual jamming of the pinion gear and destruction of the ring gear teeth.

Service bulletins with reference to the Eclipse Bendix drive can be obtained by writing Eclipse Machine Co., Elmira, N.Y., and mentioning *Dyke's Automobile and Gasoline Engine Encyclopedia.*

INSTRUCTION No. 72

ADJUSTING AND REPAIRING CLUTCHES, TRANSMISSIONS AND UNIVERSAL JOINTS

The fundamental principle and purpose of each of these parts, as well as their construction, are explained in the first section of this book. For instance, clutches[1] are explained on page 20, and transmissions on page 25.

We will now deal with adjustment and repairs, using as examples the parts of different makes of cars. Some of the older types of cars will be used, rather than taking all of our examples from the very latest types, owing to the fact that repairs and adjustments are more commonly required on the older types.

Types of Clutches

There are three types of clutches in general use: the cone, the plate, and the multiple-disk types.

The cone types of clutch are those using a **straight cone** or an **inverted cone.** The angle of the cone is usually 17°.

The **facing** of a cone clutch can be **leather** or **fabric.** The latter is being used now, more than formerly.

The plate clutch seems to be gaining steadily in favor.

Of the many different designs in present-day cars, the following are typical: (1) steel against asbestos fabric; (2) steel against molded asbestos; (3) steel against bronze; (4) steel against cork.

There is a strong tendency toward the dry-plate type of clutch, and this tendency seems to be largely due to the fact that the parts, frictional area, etc., of a dry-plate clutch can be made very much smaller than the parts and frictional area of a clutch running in oil. The oil film serves as a lubricant, which reduces the amount of friction and necessitates a very much stronger spring, or an elaborate system of multiple levers.

The introduction of the molded asbestos ring, which has now come into commercial prominence, has resulted in a great refinement in clutch design. These molded rings or disks can be made to closer limits and do not require any stapling at the joint. In some cases the ring is made flat, and in such cases no replacements need be made until these disks have worn practically all the way through. There are no rivet heads to consider.

The multiple-disk clutch, which has a greater number of disks than the plate clutch, each disk requiring multiplying levers to keep an engagement, is found operating both **dry** and in **oil.** Its greatly increased frictional surfaces over the plate clutch necessitate a strong spring, but the disk clutch running in oil is larger and has to have more frictional area than the dry disk type, for the same reasons as have been given in what is said of plate clutches above.

How to Use the Clutch Properly

The clutch on an automobile should be either in or out absolutely.

Many good drivers make it a plan to **keep their foot off the clutch pedal** while they are driving. The weight of the foot on the pedal and a little nervous tension in the driver's leg is sometimes just sufficient to hold the clutch out just far enough to "slip it" on a hard or sudden pull.

Another good way to spoil a clutch is to throw it out in traffic until the car comes almost to a standstill, and then to speed up the engine and to slip the clutch in with the gear-shift lever still in high speed.

When the car slows down with the clutch out, the gear lever should be slipped to second speed, and if the car comes to a full stop, it should be shifted to low speed.

Another important point in driving is to learn to **engage the clutch gradually,** and not to "bang" it in with the engine racing.

It is always better to **run on the engine as much as possible,** throttling it down instead of constantly throwing "out" the clutch, and **when running slowly** with throttle closed, the speed of car can be still further reduced for brief periods by gradually applying the brake.

A well-adjusted clutch **takes hold gradually,** does not slip after it has come to a seat, and releases instantly when the pedal is depressed.

Testing for a Slipping Clutch

A slipping clutch is a constant waste of power and fuel and a strain on the engine. Sometimes this trouble is so noticeable that the driver has no difficulty in diagnosing it. But in many cases it is necessary to test the clutch in order to be sure that it is not slipping.

A simple test is as follows: With the engine running, pull on the emergency brake, put the gears in low, and then let in the clutch. The engine should stall immediately. If, however, the engine continues to turn over in spite of the fact that the car is braked and stationary, then this is evidence that the clutch is slipping. If at any time when using the car the engine appears to overheat for some unaccountable reason, or if the engine lacks power and the gasoline mileage is lower than usual, it is well to make this test.

CONE CLUTCHES; TROUBLES, ADJUSTMENT, AND REPAIRS

The parts of a cone clutch can be enumerated as follows:

1. **Leather or fabric facing** over the cone.
2. **Main clutch spring,** which holds the tension of the cone to the fly wheel.
3. **Pressure or plunger studs,** also called "clutch leather expanders," which are mounted under the clutch leather at various points and allow gradual engagement of the frictional surfaces. The "grabbing" feature is eliminated by the use of these plungers, of which there are usually six, inserted under the leather, as shown in Fig. 1.
4. **Clutch rollers** on the shifter yoke.
5. **Ball-thrust bearings** on the clutch shaft.
6. **Clutch brake,** which prevents spinning of the clutch when released.

[1] See Index under "Specifications of passenger cars" for types and make of clutch used on different makes of cars.

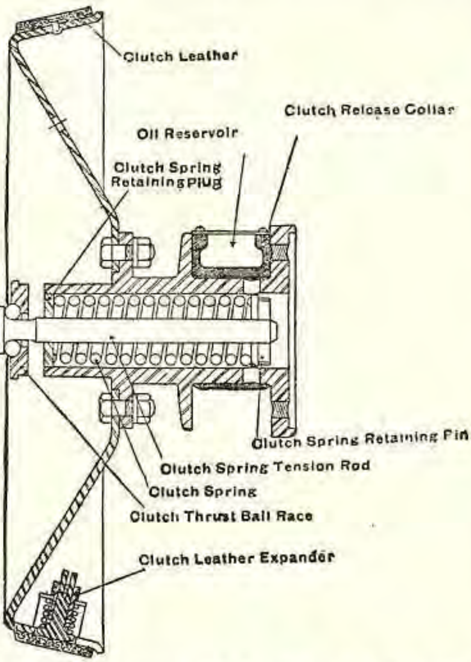


Fig. 1. **Typical example of a cone clutch,** the Chevrolet "490." Note that expanders are placed under the clutch leather so as to present slightly raised points of contact to eliminate "grabbing."

If the clutch takes hold too quickly and causes the car to start with a jerk, it is an indication that the clutch leather expanders need adjusting. To do this, turn each of the expander nuts to the right, until they lightly touch the clips, and then give them a half-turn to the left. This unscrewing allows the expander to act properly under the clutch leather.

The clutch leather will in time "dry" out, resulting in "grabbing," or slipping. Once a month rub a little neatsfoot or castor oil on the leather to soften it. Should the clutch leather become greasy, apply a little fuller's earth to it. Do not use sand or other gritty substances to make a slipping clutch hold.

Cone-Clutch Troubles

Cone-clutch troubles are either fierce engagement or grabbing, slipping, or spinning. The latter makes it difficult to shift the gears of the transmission.

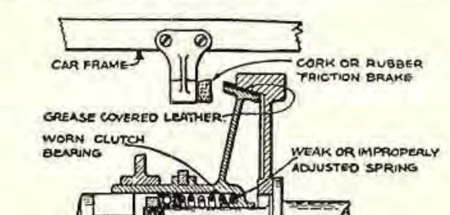


Fig. 2. Various cone-clutch troubles illustrated. (*Motor.*)

Cause of Clutch Grabbing

Clutch leather dry or hard: This can be remedied by applying neatsfoot or castor oil after first cleaning the leather with kerosene, using an oil gun to remove any mineral oil.

A prominent clutch manufacturer states: "We recommend keeping all oil off the clutch leather, and we do not use the common remedy, neatsfoot oil. Better results are accomplished by keeping the clutch face clean, and when an occasion arises where the clutch grabs, **clean it with kerosene, but not gasoline.** The kerosene leaves just enough oil to keep the leather in good condition.

Clutch rivets projecting, as a result of wear of the leather: Remedy by placing a center punch against the rivets and hammering until they are below the surface of the leather. A grating or grinding sound will indicate this trouble.

Clutch lever linkages out of adjustment: The amount of movement between the surfaces of the clutch is small, and it is important that no looseness exists in the pedal connections.

Excessive tension on clutch spring: If this is found to exist, weaken the spring tension. Excessive tension also causes undue strain on the ball-thrust bearings.

Plunger studs improperly adjusted: The six plunger studs, also termed the clutch leather expander studs (Fig. 1), should be properly adjusted.

Clutch release ring bearings may be worn, as a result of lack of lubrication. If run while dry, they are liable to seize and to prevent clutch releasing entirely, in which case new bearings must be fitted (see Fig. 9, page 841).

Cause of Clutch Slipping

Burned or worn clutch lining: Usually results from allowing the clutch to slip when starting, or speed changing, and from using the clutch too much, instead of the throttle, while running. Even though it be worn to a certain extent neatsfoot or castor oil will sometimes improve its operation. Otherwise a new clutch leather must be fitted.

Clutch leather oily and greasy: The cure for this is either to wash the oil off by spraying a pint or so of kerosene, with an oil gun, over the clutch leather, while holding the clutch out, or by wiping off with a cloth moistened with kerosene, and to dress the leather afterwards with neatsfoot oil, if necessary. The oil can also be absorbed by sprinkling powdered fuller's earth or talc over the surface and leaving it standing for a while. Don't use dirt or sand—it will cut the leather.

Leather worn down: If it cannot be raised enough by adjustment of the plungers (clutch leather expanders), a new leather must be fitted.

When the surface of the clutch and seat are new, the latter touch all over, but when worn, they touch on only the high places. If the surfaces touch in only a few places, they naturally cannot transmit the power that is possible with a good contact; they can be forced to transmit it by pressing them more firmly together, but it is better to reface the surfaces.

Clutch-spring tension weak: Tighten the adjustment (see page 841). If no adjustment nut is on spring, place a washer between the spring and its seat. **Also examine the pressure or plunger studs.**

Clutch shaft out of line: Sometimes caused by too great a spring tension, causing the balls to break in the thrust bearing and cutting the ball race, lowering the clutch shaft out of line. It may also be due to a bent clutch shaft or the clutch shaft being out of alignment. Sometimes **shims are placed under transmission support,** and if not carefully replaced, will throw clutch out of line with transmission.

Ridge or shoulder worn on the clutch leather (see page 843 for remedy).

Clutch Spinning

When a clutch spins, when thrown out of engagement, it is difficult to shift gears.

The shift of gears by the gear-shifting lever ought to be made without a particle of noise if the clutch is thrown out when shifting. If there is a noise, then it is usually due to the clutch not being fully thrown out, or to dragging or spinning, or to the transmission shaft being out of line, owing to worn bearings.

Clutch spinning is often due to excessive friction in the spring-thrust bearing (see Fig. 2), though sometimes faulty alignment of the flywheel and clutch cone prevents the engaging surfaces from entirely clearing each other. A bent clutch shaft might be the cause of this.

Sometimes the fault lies in the clutch. A heavy rim or cone will store up energy and continue to revolve when disengaged.

When a clutch spins from lack of alignment or adjustment, the remedy is obvious, but if the fault is in the design, a clutch brake (see Fig. 2) should either be fitted, or the clutch rim lightened by drilling or machining away metal at or near the outer circumference.

Clutch Brake

Unless the clutch-shaft speed is reduced approximately to the speed at which the main shaft of the gear shafting is revolving at the time, there will be a clash of gears at the time of engagement, with consequent damage to the face of the gears and annoyance to the driver. The clutch brake will overcome this to a considerable extent if it is properly fastened and proportioned.

The **purpose of the clutch brake** is therefore to keep the clutch from spinning when thrown out. See Figs. 2, 10 and 11. It consists of a small spring-mounted fiber pad attached to the left of the frame, against which the clutch cone strikes when disengaged. It should be so adjusted that when the pedal is pressed half-way down, the cone should just begin to come in contact with it, so that by the time the pedal is all the way down, the spring on the clutch brake will be fully compressed. For an example of a clutch-brake adjustment, see page 842

If the car is not equipped with a clutch brake and it is desired to attach a clutch brake or dampener, to check the revolving of the cone when released, either cork or rubber can be fitted into a metal bracket which can be attached to the car frame.

The position of the brake should be just to the rear of the clutch rim, against which the clutch will draw when the disengaging pedal withdraws the cone.

Cone-Clutch Lubrication

Lubrication of a cone clutch is usually at the **rollers or clutch yoke** and **ball-thrust bearings;** otherwise oil should be kept from the clutch leather as much as possible, as a leather-faced cone is supposed to run dry, but yet be kept flexible. This can be done by the use of neatsfoot or castor oil, as explained.

If the Clutch Fails to Release

When a cone clutch fails to release, it is usually termed a **"frozen clutch."** This may be due to rusty or tight pedal connections or to loose pedal linkage connections; clutch yoke rollers run dry sometimes, from too tight a spring adjustment.

The amount of movement between the surfaces of a clutch is small, and it is important that no looseness in the pedal connections or bending of the levers should exist to prevent gradual engagement.

When cleaning or treating a clutch with neatsfoot oil, it can be held out of engagement by using a prop placed against the clutch pedal, as shown in Fig. 3.

The cone part of the clutch with the leather facing on it can then be turned by hand and neatsfoot oil applied, or the oil gun filled with gasoline can be used for cleaning, as shown in Fig. 4.

Fig. 3

Fig. 4

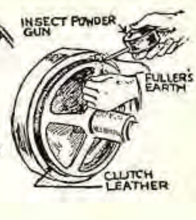


Fig. 5

An insect-powder gun, filled with talc or powdered fuller's earth can be used as a temporary remedy for oily slipping clutch or brake, if necessary (Fig. 5).

Cone-Clutch Adjustments

The adjustments on a cone clutch are:

1. Clutch pedal adjustment.
2. Main clutch-spring adjustment
3. Clutch-leather expanding spring adjustment.
4. Throw-out adjustment.
5. Clutch-brake adjustment.

Clutch-Pedal Adjustment

There are various methods used to adjust the foot-clutch pedal. The illustration (Fig. 6) is that of the Oakland model 34**B** (cone type clutch).

There are two possible causes or reasons for the necessity of adjusting the clutch pedal:

1. The pedal, when in driving position, with the clutch **in,** may vibrate back and forth, owing to there being too much clearance between the pedal and toe board.
2. The clutch may be slipping, because of the pedal pressing against the toe board before the clutch is fully engaged. (See importance of **free play of clutch pedal,** next page.)

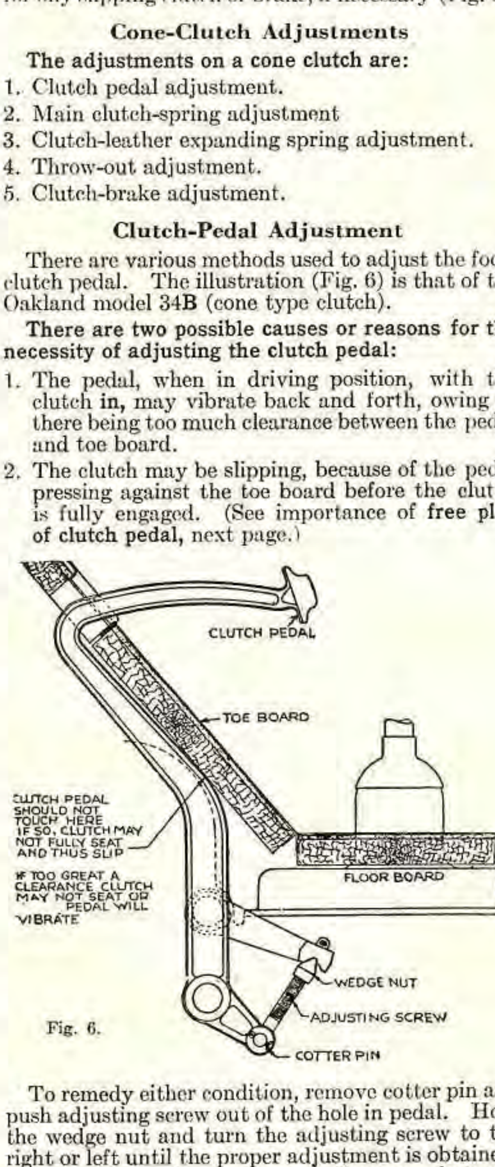


Fig. 6.

To remedy either condition, remove cotter pin and push adjusting screw out of the hole in pedal. Hold the wedge nut and turn the adjusting screw to the right or left until the proper adjustment is obtained; replace and put in cotter pin. Clearance between pedal and toe board should be approximately 1–16".

One of the first places to look whether the clutch is slipping is the clutch pedal (either the cone or disk type). As the **clutch facing wears, the clutch pedal**

travels toward the toe-board, and when wear is sufficient (or pedal is out of adjustment) to permit clutch pedal to rest tight against the toe-board (see **E**, Fig. 7), without any free play, then the full action of the clutch spring is not obtained, thus causing slipping and rapid wear to frictional surfaces.

The main point to observe is that when the clutch is in the fully engaged position, **the clutch pedal should have free play, or should depress from ¾" to 1¼"** (see **G**, Fig. 7), **under light spring pressure before the resistance of the heavier clutch spring is encountered.**

On some clutches (see paragraph under Fig. 25, page 847), the **adjustment of the clutch** will restore the proper clearance between toe-board and clutch pedal.

On other types of clutches, where there is no clutch adjustment provided, it is necessary to **adjust the clutch pedal** to restore the free play, as shown at **G**, Fig. 7.

Note: It is also important to see that the pedal pad (A. Fig. 7) is clear of upper side of toe-board (D) when fully depressed, otherwise the clutch will not fully release. Sometimes the toe-board gets out of place.

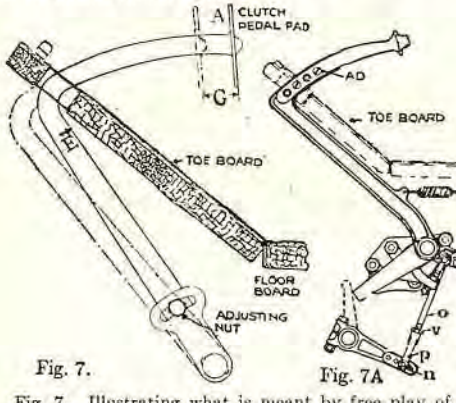


Fig. 7. Fig. 7A

Fig. 7. Illustrating what is meant by free play of clutch pedal. For a distance of ¾" to 1¼" travel of clutch pedal pad (see G), there should be free play. If clutch pedal is tight against the toe-board and there is no free play, then the clutch plates are worn, or the pedal is out of adjustment.

Fig. 7A. Clutch pedal arrangement of the Cadillac type "57."

Adjustment of clutch pedal clearance of the Cadillac (type "57," multiple disk dry type of clutch, see page 22): After the car has been run for some time it may be found that the facings on the clutch disks have become compressed or worn to some extent, and that consequently the clutch pedal strikes the stop screw before the clutch is fully engaged. When this condition exists, a readjustment of clutch pedal may be made as follows:

Remove the pin (**n**) (Fig. **7A**), and unscrew the yoke (**p**) which is threaded on the rod (**o**), so that when the pin (**n**) is replaced, **the clutch pedal has a movement back and forth of 1 ¼" without starting to release the clutch.** Secure the pin (**n**) with a cotter pin, and tighten the lock nut (**v**).

Do not slip the clutch when starting off from a slow speed in high gear instead of shifting to a lower gear.

Do not ride the clutch pedal: that is, do not hold the foot against it while driving, as there is a possibility of keeping it partially disengaged. This causes excessive wear in the plates.

Main Clutch-Spring Adjustment

There are two or three methods of arranging the main clutch springs so that they will hold the clutch cone firmly to the inner surface of the flywheel.

One method is as shown in Fig. 8. Note that the main clutch spring (**S**) is placed over the clutch shaft between the clutch spider and a collar provided **with an adjusting nut.**

To adjust: With a screwdriver remove the cover plate, loosen the clamp screw on the clutch-adjusting nut, and turn up the clutch-spring adjusting nut (just below the clutch "throw-out" fork (**F**), until there is sufficient compression. Then tighten the screw. Also note the clutch leather engaging the spring, for the purpose of expanding the clutch leather (explained farther on).

Care: Keep the clutch-yoke grease tube filled, and be sure it does not clog. Keep the drain hole in the bottom of the clutch housing free, so that oil cannot accumulate on the clutch leather. Turn the grease cup down often, on the "clutch throw-out." The first 50,000 Dodge cars used the clutch as shown above. Later cars use disk clutches of the dry type, described farther on.

The first 50,000 Dodge cars used the "cone "clutch as described above. Later cars use the disk clutch, dry type, consisting of 4 driving and 3 driven members.

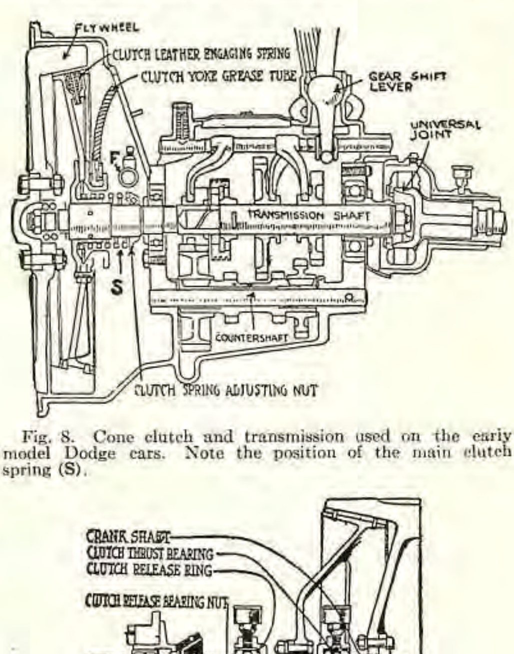


Fig. 8. Cone clutch and transmission used on the early model Dodge cars. Note the position of the main clutch spring (**S**).

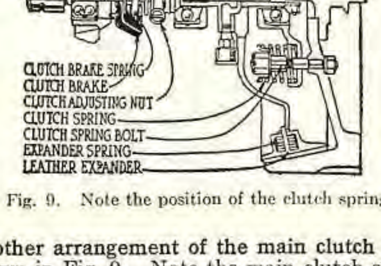


Fig. 9. Note the position of the clutch spring.

Another arrangement of the main clutch springs is shown in Fig. 9. Note the main clutch spring is within the clutch spider.

Here again, the regular remedies for a slipping clutch caused by a worn, oily, or burned leather, apply.

Adjustment: A worn leather may be made to hold by increasing the tension on the four large clutch springs within the clutch spider. In doing this, be careful to turn each nut to exactly the same extent.

Clutch brake: When the lining of the clutch brake becomes worn, thus allowing the clutch to **spin** after disengagement and make the shifting of gears difficult, adjust by loosening the clamp bolt and turning the adjusting nut to the left, or counter-clockwise. This will compress the brake spring sooner, and consequently stop the clutch more quickly.

To grease the clutch, loosen the wing nuts and remove the cover of the clutch housing. Give the grease cup on the clutch release ring a turn or two. Press the clutch pedal, and turn the clutch cone around until that grease cup appears, and give it a turn or two. Turn the engine over until the grease cup on the clutch spider appears and turn that down the same amount. Apply a few drops of flowing oil to the clutch release-yoke trunnion bearings.

Note that the **leather expander and spring** for expanding the clutch leather are in this clutch also.

Clutch-Leather Expanding Adjustment

The clutch-leather expanding adjustment, called the "clutch-leather engaging spring" in Fig. 8, and the "expander spring" in Fig. 9, is for the purpose of preventing "grabbing." The expanders are so placed as to present a slightly raised point of contact of the clutch leather to the fly-wheel inner surface.

If the clutch takes hold too quickly and causes the car to start with a jerk, it is an indication that the clutch-leather expanders need adjustment.

The clutch-leather expanders usually consist of six small spring-mounted clutch plungers placed under the clutch leather, which raise it at various points and allow gradual engagement of the friction surfaces. Should these plungers become fast in their guides, or should anything prevent the leather over these plungers from first coming into contact with the seat in the flywheel before the entire surface engages, "grabbing" will result.

They should be **adjusted** so that with the clutch in complete engagement, approximately 1/16" remains between the adjustment nut of the plunger stud and the guide to the cone, when the clutch is fully engaged.

The clutch leather will in time "dry" out, resulting in either **"grabbing," or slipping.** It is a good idea occasionally to rub a little neatsfoot or castor oil on the leather to soften it. Should the clutch leather become greasy, apply a little fuller's earth to it. Do not use sand or other gritty substances to make a slipping clutch hold. If you do, you are simply inviting a large repair bill.

Cone clutch with cork inserts: On the early models (1914, 1915, 1916) Moline-Knight cars, a cone clutch was used where the leather on the face of the cone had cork inserts regularly placed around the leather. They are backed up by an adjusting screw.

Clutch Throw-Out Adjustment

The throw-out adjustment, or the amount of leverage for the distance to which the clutch is thrown out, is adjusted on the clutch pedal, or, on some clutches, at the shifter yoke collar, also termed the releasing ring. See Figs. 9 and 11.

Clutch release ring bearings (Fig. 9), which, by pressure upon the clutch release ring, disengage the clutch from the flywheel, should be kept well greased or oiled, as the case may be.

Ball thrust bearings should be supplied with oil (see Fig. 2, page 839).

Clutch-Brake Adjustment

The clutch brake, as used on the Studebaker series "20" cars, is shown in Fig. 10. There are two arms, one on each side of the clutch, so arranged as to make the adjusting screws accessible after removing the floor board. The double construction equalizes the pressure on the clutch cone, and prevents any tendency for it to bind on the shaft.

The object of a clutch brake is to facilitate gear shifting and eliminate clashing of gears. Its action is to slow down the transmission counter-shaft gears so that the gears while being shifted, will have the same speed.

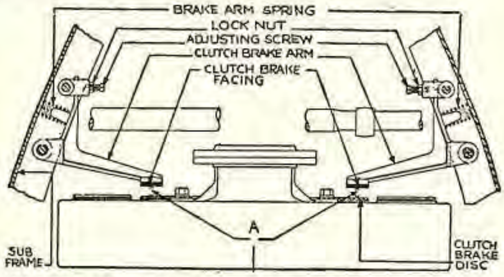


Fig. 10. Clutch brake as used on the Studebaker series "20" cars.

Cars when shipped are so adjusted as to give the best results. When a car has been driven 500 miles, the clutch-cone facing will become slightly compressed, allowing the cone to enter the flywheel farther, which, together with a slight wear of the clutch-brake facing, will increase the gap at (A) (Fig. 10). It will then be necessary to screw out on the adjusting screw, decreasing the gap (A) to 5/16", taking care to adjust both sides alike.

Removing and Replacing a Cone Clutch

As an example, the Willys "six" is used, as shown in Fig. 11.

To remove the clutch, first remove the two cap screws which hold the spacer shaft (Fig. 11) to the clutch cone. Remove the three nuts on the motor side of the first member of the universal joint, and drive the studs back so that the spacer shaft, with the first member of the universal joint, can be removed.

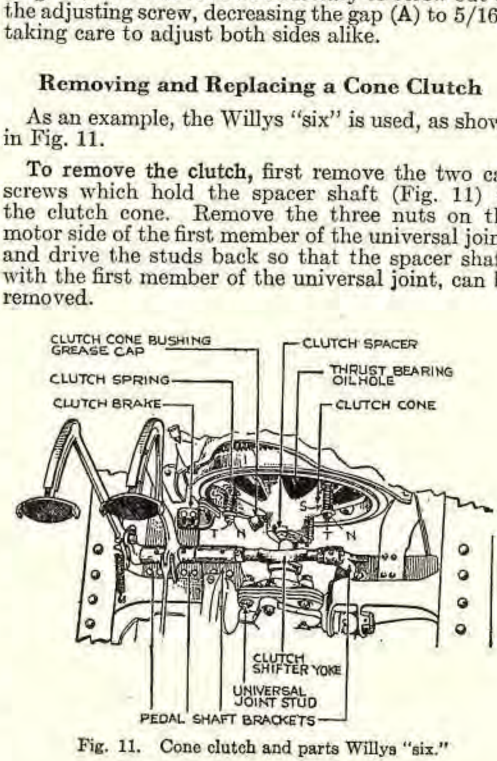


Fig. 11. Cone clutch and parts Willys "six."

Remove the clutch brake and the bolts holding the foot pedals and clutch shifter yoke, so that the shifter yoke and its shaft can be raised slightly. Next remove the nuts holding the three main clutch springs in place and take off the springs (Fig. 11), after which the clutch cone itself can be withdrawn.

In replacing the clutch, the springs (S) can be compressed sufficiently to start the retaining nuts (N), if a pry bar (P) is held back of the clutch spider (R) pressing the studs out (Fig. 12). Be careful to get an even tension on the main clutch springs, which will be reasonably assured if the retaining nuts are screwed on to their respective studs (T) approximately the same distance. Do not fail to fasten the cap screws holding the spacer and universal joint nuts with cotter pins.

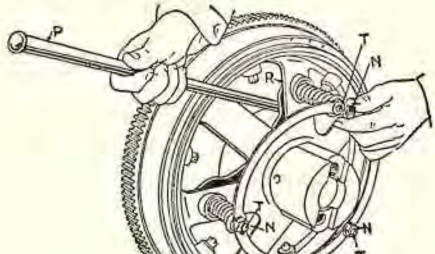


Fig. 12. Replacing clutch springs.

In replacing the clutch brake, it should be set so that when the clutch is thrown out to its limit the edge of the cone bears firmly on the clutch brake, but does not compress the spring solidly.

Fitting New Leather to Clutch Cone

First, be sure that replacement is necessary. See pages 839, 840, and note the causes of trouble.

If the leather is worn or the rivets project, then it will be necessary to remove the clutch in order either to replace the leather or to drive the rivets down below the surface of the leather.

If a shoulder of about 1/16″ or 1/32″ has worn on the leather, a careful trimming of it off with a file or rasp will permit the cone to go farther into the flywheel and may be all that is necessary—together with cleaning the whole surface of the leather and removing oil or glaze, and then applying neatsfoot or castor-oil dressing.

If however a new leather is necessary, then procure it of the dealer of the car if possible. It comes cemented ready to apply, and can be slipped over the cone and can be driven into position with a mallet or a piece of wood.

When the clutch must be relined in an emergency, and the old lining is not available to serve as a pattern, secure a piece of first-class, unstretchable belting, 3/16″ thick, 10″ wide, and 44″ long (Fig. 13).

If you must make the leather facing, then first remove the old leather by cutting the rivets with a chisel and hammer. Then procure first-class, unstretchable leather belting (or chrome-tanned leather) 3/16″ thick for the new leather. The leather should first be cut as shown in Fig. 13.

Then place the leather over the clutch cone in the correct position, and draw it as tight as possible. The leather, if cut as shown, will lap from 3″ to 4″.

Mark on the inner side of the lapped leather the end of the first turn which lies against the cone. Next remove the leather and measure back or toward the long end of the leather 5/8″. Measure back from the unmarked end of the clutch leather 3″, and bevel the leather off, as shown in the illustration. Add 3″ to the corrected length of the leather, and bevel this end as shown.

The leather may now be cemented, and after it is thoroughly dried it may be installed. Always put the rough or flesh side on the outside. For the kind of cement to use, ask a harness maker.

Before a new clutch leather is installed, it should be thoroughly soaked in neatsfoot oil and stretched tightly over the clutch face. Before the leather is fastened to the clutch drum, the "clutch plungers" (or pressure studs) should be forced in below the surface of the clutch cone and held in this position by the clutch-plunger adjusting nuts, which may be screwed up on the stem of the plunger.

In riveting the leather on to the cone, extreme care should be exercised to see that the rivets are properly clinched or turned over on the inside of the clutch cone, and that the heads are driven into the leather of the clutch face until they are well below the surface. Unless this is carefully done, the clutch will "grab" or engage suddenly.

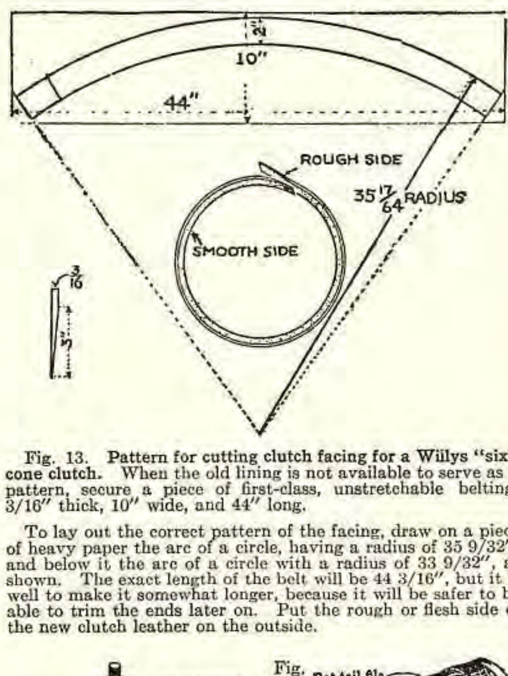


Fig. 13. Pattern for cutting clutch facing for a Willys "six" cone clutch. When the old lining is not available to serve as a pattern, secure a piece of first-class, unstretchable belting, 3/16″ thick, 10″ wide, and 44″ long.

To lay out the correct pattern of the facing, draw on a piece of heavy paper the arc of a circle, having a radius of 35 9/32″, and below it the arc of a circle with a radius of 33 9/32″, as shown. The exact length of the belt will be 44 3/16″, but it is well to make it somewhat longer, because it will be safer to be able to trim the ends later on. Put the rough or flesh side of the new clutch leather on the outside.

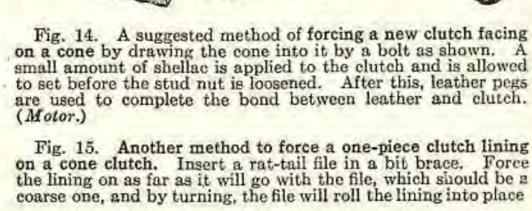


Fig. 14. A suggested method of forcing a new clutch facing on a cone by drawing the cone into it by a bolt as shown. A small amount of shellac is applied to the clutch and is allowed to set before the stud nut is loosened. After this, leather pegs are used to complete the bond between leather and clutch. (*Motor.*)

Fig. 15. Another method to force a one-piece clutch lining on a cone clutch. Insert a rat-tail file in a bit brace. Force the lining on as far as it will go with the file, which should be a coarse one, and by turning, the file will roll the lining into place

An alternative sometimes used on older makes of cars is strips of asbestos brake lining. It is made in parallel lengths and riveted to the cone in six or eight sections, the edges being cut at a slight angle, according to the diameter of the cone.

Note. A very important point to observe in fitting a new clutch leather or fabric is to have the surfaces absolutely clean, otherwise the clutch facing will be raised if there is any substance under it, and will thus cause the clutch to grab.

If, after relining a cone clutch, the clutch grabs, or if it grabs even though not relined, this is usually due to high places on the facing, or the leather is dry.

If, after treating it with neatsfoot oil, it still grabs and the high spots cannot be determined by the general appearance of the leather, then try this method: Depress the clutch pedal and then insert a piece of white paper between the flywheel and the leather-faced portion of the clutch. Engage the clutch, and then depress the pedal again. When the paper is removed, the high spots will be plainly indicated on it. The leather should then be trimmed to the surface uniform in height.

THE MARMON CONE CLUTCH[1]

The Marmon "34" cone clutch is simply an aluminum wheel having a conical rim engageable with the corresponding surface within the flywheel. Depressing the clutch pedal moves this cone back and disconnects the engine, while a spring action holds the clutch in contact when the clutch is let in.

Smooth application of power is assured by the **five steel disks set within the flywheel,** which give a slipping contact with gradually increasing force until the whole surface of the cone comes into full contact as the clutch is entirely engaged.

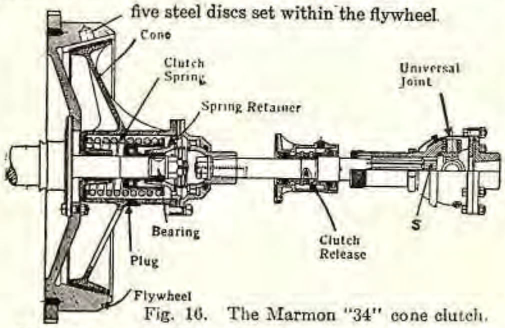


Fig. 16. The Marmon "34" cone clutch.

No adjustment for easy engagement is necessary. The metal and **asbestos fabric** with which the cone is lined usually require replacement after 10,000 to 20,000 miles of running, the life being largely dependent upon the class of service.

To disassemble the clutch, remove the circles of bolts at the universal joint and at the clutch flanges, and take out the drive shaft, thus released. Then remove the cotter and back off the main clutch nut. The spring retainer can then be pulled off its key after inserting 3/8" cap screws in its threaded holes. Then the cone will slide off the pilot shaft. In replacing, care must be taken in fitting the spring retainer on its key.

Relining clutch: The standard facing for these clutches is superior to leather, and to get best service, renewals should be made with same material.

To install, clean off all remains of the old facing, lubricate the cone with graphite, and slip the new facing in place. It may be necessary to force it gently, but do not hammer the edge. Soaking the facing in water will aid the facing to slide on easily. Then put rivets firmly in place, making sure the heads are below the surface. This is best done by placing the rivet head against a punch or small steel bar held vertically in a vise, and riveting with the round head of a machinist's hammer.

Replacing: See that the felt washer and hub bushing at the front of the cone are in good condition; then fill the hub with oil and replace, making sure to get all parts back just as they came out.

Clutch release: The shaft back of the clutch has two flanges about which is fitted a split collar, giving a marine type of bearing, which should be filled with oil. The backward thrust to release the clutch is applied to this collar by a yoke linked to the clutch-pedal shaft. The bushings of these shafts and links are self-lubricating. The clutch pedal stop is against the floor-board. Inspection should be made, from time to time, of the shifting collar, to be sure that, from lack of lubrication, this part does not revolve with shaft when clutch is released.

Note play allowed in splined shaft (S) for the movement of clutch shaft when clutch is thrown out.

CONE-CLUTCH REPAIR—THE CHEVROLET "490" AS AN EXAMPLE[1]

Evidence of Trouble

1. **A heavy grinding noise when the clutch is released.** This is usually caused by worn or broken balls in the clutch-thrust bearing.
2. **Actual failure of the pedal to release or move the clutch or to come back into position when pushed out.** This indicates that the clutch-spring retaining plug has become unsoldered and has unscrewed from the clutch hub.
3. **Excessive slipping of the clutch,** that cannot be cured either by application of neatsfoot oil, if dry, or fuller's earth, if slippery.

The first necessitates a complete removal of the clutch, together with the flywheel and clutch-spring tension rod; **the second,** a removal of the clutch hub, and **the third,** the removal of the hub and clutch.

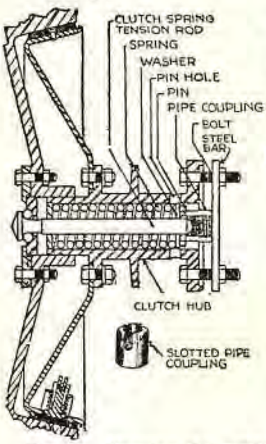
Disassembling the Clutch

1. Remove the floorboards.
2. Remove wiring running from battery to starter.
3. Remove the three bolts holding the V-brace to the engine base and the gearbox support, and remove the V-brace.
4. Disconnect the brake rods from the pedals.
5. Remove the bolts holding the clutch-release shaft to the gearbox support, and remove the clutch release cross-shaft, together with pedals.
6. Remove the bolts on the rear clutch-hub drive ring.
7. Remove the four bolts holding the gearbox to the gearbox side-arms. (Care should be taken in removing the shims under the gearbox, so that they may be replaced in the same position.)
8. Remove one bolt holding the left gearbox side-arm (on the pedal side) to the engine. (This permits the gearbox side-arm to spring to one side when removing the gearbox).
9. Lift the gearbox up and slide it forward. It may then be removed from the chassis. (A jack

[1] Single disc dry-plate type now used on models 68, 78 Marmon. A single-plate clutch is also used on the Chevrolet International AC.

should be placed beneath the propeller shaft to hold it in place when the gearbox has been removed. In some cars it is necessary to spring the gearbox arms apart or to force the gearbox out with a jack.)

10. Turn the flywheel until the pinhole (Fig. 17) passing through the clutch hub is at the top, and clutch-spring retaining pin is in line with hole.
11. Using either the compressor shown in Figs. 17, 18, compress the clutch spring. The clutch-spring retaining pin will usually drop out when over the hole in the housing; but, if not, it may be driven out with a drift and hammer.
12. Draw out the clutch spring.
13. Remove the bolts holding the clutch hub to the clutch spider, and remove the clutch hub. (This is necessary, as the hub would otherwise interfere when removing the clutch.)
14. Pull out the clutch. (This will take some little effort, as the gearbox arms squeeze on to the clutch and must be sprung.)
15. Remove the nuts holding the flywheel to the crankshaft flange and with a bar loosen the flywheel and remove it. (It is advisable to mark the position of the flywheel on the flange so that it may be replaced in the same position.)
16. Remove the flywheel together with the clutch-spring tension rod, and place it on two boards nailed to the bench.
17. Separate all parts and clean with gasoline and waste.



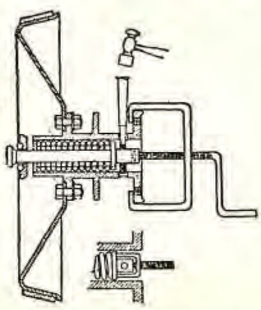


Fig. 18. Showing the method of compressing the clutch spring, **permitting the lock pin to be removed.**

Fig. 17. Showing the **method of compressing the clutch** spring. The steel bar is 5/16" x 1" x 4". The bolt holes are 3/8" and 3" between centers. The pipe coupling is 5/8" inside diameter; the slots are about 3/4" deep.

Clutch Troubles

Clutches of this type give but little trouble if properly used, and the necessity for relining is only occasional. **If slipping** has been experienced and the leather is damp, it is usually because it has been soaked with mineral oil. This may be removed by cleaning the leather with gasoline, after which neatsfoot oil should be applied to keep the leather flexible.

Grabbing: On model "490" there are six clutch leather expanders. These expanders are placed under the clutch leather and present a slightly raised point of contact. Their function is to prevent the clutch from grabbing. If the clutch grabs, the expander should be adjusted. To adjust the expanders, turn each of the expanding nuts in the same direction as the hands of a clock, or from right to left, until they lightly touch the clip, then give them a half-turn in the opposite direction. If this method fails, the chances are that the clutch is dry.

Though a dry clutch will occasionally cause slipping, it more often causes "grabbing." Unless the leather is burned, or worn out, it may be restored by roughing the surface slightly with emery paper, and then dressing it with neatsfoot oil.

Another cause of a sticking clutch is protruding rivets, and these should again be set beneath the surface of the leather. A small shoulder will also cause trouble, and this should be scraped or filed.

A new leather should never be fitted unless it is certain that the old leather cannot be reclaimed.

If relining the clutch is imperative, it is best to obtain the new lining from the makers. If this is not expedient, the old lining should be carefully removed and used as a pattern for cutting the new lining. The new leather should be much thicker than the old lining, and of uniform thickness. The most essential point in fitting the new leather is to have it fit tight and true to the cone.

If the clutch has been relined it will not work perfectly until it has been worked in. This usually takes some time and during that period should receive frequent applications of neatsfoot oil.

To Fit a New Leather

1. Soak the leather in water.
2. Secure one end of the leather to the cone by one copper rivet (rough side out). (Never use anything but copper rivets; other metals will score the metal clutch facing.)
3. With only about three-quarters of the leather on the cone, pin the other end to the cone by a rivet. (See Fig. 21.)
4. Force the leather up into the cone. It should fit evenly and with uniform tension.
5. Drill and countersink the rivet holes.
6. Rivet the leather in place. Be certain that the rivet heads are 3/32" below the leather and well headed on the inner side.
7. Allow the leather to dry slowly. It will otherwise shrink too much and expose the rivets. A coarse file may be used to remove the high spots.

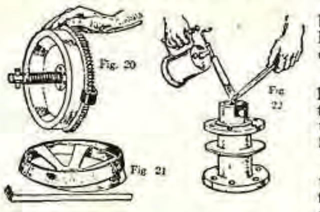


Fig. 20. **The thrust-bearing assembly** is held together by three old valve springs.

Fig. 21. **The new leather should be fastened at the ends,** and then forced over the face of the clutch.

Fig. 22. When loose, **the plug in the end of the clutch hub** should be sweated back in place

Clutch-Hub Repair

If the solder holding clutch-spring retaining plug has become loosened, permitting plug to unscrew—

1. Clean and scrape both plug and hub end.
2. Screw the plug into the hub until the upper surface is slightly below the hub.
3. Heat the end with a torch, as shown in Fig. 22, and run solder into the joint.

Thrust-Bearing Repair; Assembling

1. Examine the balls and races of this bearing, and if they are pitted or show the slightest indication of wear, the entire assembly must be replaced.

2. Place flywheel on bench, with gear side up.
3. Force a ball race into the flywheel casting. This must go in evenly and come to a seat evenly, otherwise the bearing will quickly destroy itself.
4. Assemble the balls and clutch-spring tension rod, packing the balls in grease.
5. Slip the clamp shown in Fig. 20 over the end of the stud. This holds it firmly in place and permits one man to put on the retaining springs.
6. Slip three old valve springs over the end of the stud and pin in place, as shown. The clamp may now be removed, and the stud, with the thrust bearing, cannot fall apart in reassembling the clutch.

   An alternative method, and one commonly used in assembling the tension rod and bearings is to place the ball race, balls and tension rod together before placing them in the flywheel. They may be held together by the three valve springs.
7. Lift the flywheel back into place on the engine. Bolt it back in the same position as before it was removed. Do not tighten any one bolt until all are drawn snug. This removes the possibility of having the flywheel out of true, which would ruin the thrust bearings.
8. Remove the pin and three old valve springs from the clutch-spring anchor stud.
9. Force the clutch back into position.
10. Bolt the clutch hub to the clutch spider. Draw all bolts up snug, before any one is tightened.
11. Put the clutch spring back in place and pack with grease.
12. Using the compressor shown in Figs. 18, 17, or 19, replace the clutch-spring retaining pin.
13. Lift the gearbox back into the frame. It will have to be sprung past the gearbox side-arm.
14. Replace the bolt holding the gearbox side-arm to the engine.
15. Replace the bolts on the rear clutch-hub drive ring. Bring all up snug together.
16. Replace the bolts holding the gearbox to the side-arms. (Make certain that the shims are replaced exactly in the same position from which they were removed.)
17. Replace the clutch release shaft with the clutch yoke and pedals.
18. Connect the brake rods.
19. Replace the V-brake, connecting gearbox support with engine.
20. Refill the oil reservoir on the clutch yoke and the grease cups on the clutch cross-shaft. Oil all working parts.
21. Replace the wiring. Start the engine and note whether everything seems to be working properly. If there is a rattle in the clutch drive ring it will indicate that the gearbox is out of line. The shims will have to be shifted, or possibly removed. When perfect alignment is reached, the rattle will cease. (*Motor World.*)

PARTS OF BORG & BECK SINGLE-PLATE CLUTCH; ASSEMBLY AND ADJUSTMENT

General Description

This clutch is termed a "single-plate clutch" because a single dry disk or plate (2) (Fig. 23) is locked to rotate with the flywheel by gradual pressure between two asbestos facings, or rings (1) and (3), thus driving the clutch shaft (S) (Fig. 26) that carries power to the transmission.

In two-bearing clutches[1] (Figs. 26, 27), all of the clutch except the driven plate (2), facings (1, 3), sleeve (8), and shaft (S), rotate at all times with the flywheel.[2] The sleeve (8) is keyed to shaft (S).

In single-bearing clutches[1] (Figs. 28, 29, 30) the sleeve (8) is not keyed to the shaft (S), and rotates with the flywheel.

The holding action is obtained by gripping the driven plate (2) between the friction rings (1 and 3) and the flywheel (F) and thrust ring (4) of the clutch. A spring (7), operating against three bell-crank levers (L), applies pressure to the thrust ring.

The friction or driven plate (2) is mounted on the clutch shaft (S) by a splined fitting. It rotates between two wire-corded asbestos facings (1, 3) which are free to float in the flywheel. The facings absorb the

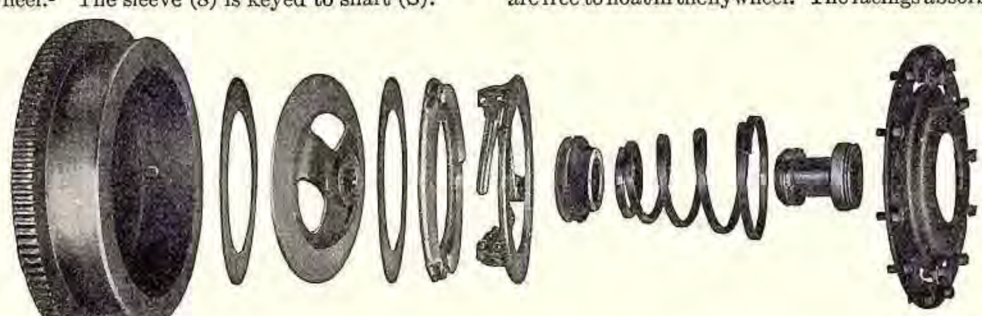


Fig. 23. **Parts of the Borg & Beck dry-plate clutch.** (F) represents the flywheel ready for the clutch parts, which are shown disassembled in the order in which they are to be assembled. Note that inside of the flywheel the dowel pins that carry the thrust ring (4) are shown projecting (see also (P) Fig. 26.) The Borg & Beck Co., Chicago, are the manufacturers.

(1) **Friction ring,** a duplicate of No. 3. These rings take all the clutch wear.

(2) **Friction disk,** or dry plate, keyed to the shaft by 10 splines.

(3) **Friction ring;** copper reinforced woven asbestos.

(4) **Thrust ring;** note the inclined face toward the center, and adjustment inclines.

(5) **Mounting ring;** fastens to the cover with adjustment bolts; it carries the bell-crank levers.

(6) **Retractor collar;** the ends of the bell cranks engage in slots.

(7) **Spring** is compressed between cover (9) and the retractor collar; it operates the bell-crank levers.

(8) **Sleeve** carries retractor collar; note the thrust bearings.

(9) **Clutch cover** bolts to the flywheel; note the adjustment bolts in the slots which are shown as (A) in Fig. 25.

[1] See footnote page 847. [2] Parts 1, 2, 3, and 8 come to rest when the clutch is disengaged.

wear caused by slippage during engagement. When engaged, all parts are friction-locked into a solid unit and revolve with the flywheel. The driven plate (2) and shaft (S) come to rest when the clutch is released.

Fig. 23A (left). Assembled clutch in flywheel. Fig. 24 (right). Thrust ring (4) and mounting ring (5) with the three bell-crank levers.

The friction surface of the thrust ring (4) is a flat polished surface. The opposite face is a tripple cam surface against which pressure is applied (see Fig. 24). It is inclined radially to take the wedge action of the thrust shoes, and the three cam surfaces on the rear face provide adjustment. Three equally spaced dowel pins (P) (Fig. 26) drive the thrust ring (4) with the flywheel. It is mounted freely, however, to permit a slight forward and back movement as the pressure is applied or released.

The adjustment or mounting ring (5) carries three bell-crank levers (L) (Fig. 26) which transmit the spring pressure. Two slots are provided in the clutch cover (Fig. 25) that allow adjustment of this ring. It is bolted to inside of cover by the two adjusting screws (A). It should be readily understood that the pressure shoes come in contact with a thicker section of the thrust ring (4), or higher on the cams, when they are moved to the right, or clockwise, into a new position. This compensates for wear on the asbestos facings (1 and 3).

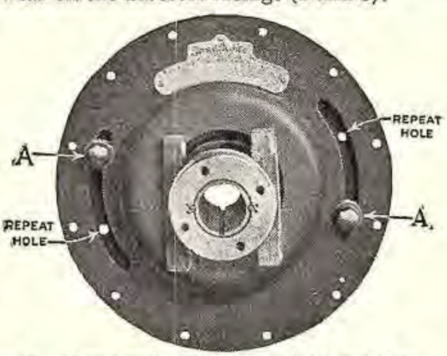


Fig. 25. View showing adjusting bolts (A) and slots.

Clutch troubles are not frequent. Ninety per cent of those which do occur are caused by failure to adjust when necessary. The pedal moves toward the floor-board as the clutch wears. Clearance must always be maintained between pedal and floor-board. Adjusting the clutch restores this clearance. Do not change pedal adjustment instead of adjusting clutch (see footnote, page 848).

Adjust the clutch (not the clutch pedal) at once, should it start slipping. The better plan is to inspect at intervals and adjust before slipping starts.

General Remarks on Adjusting

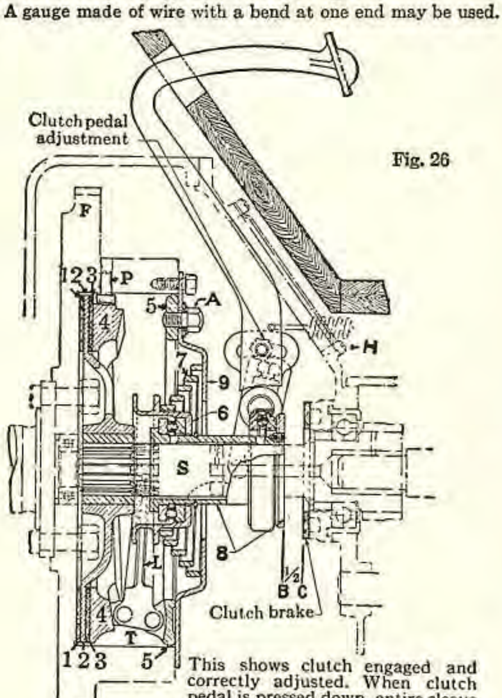
Refer to all illustrations (Figs. 26 to 30); **(A)**, adjustment bolts; **(B)**, correct engaged position; **(C) correct released position.**

As the clutch facings (1 and 3) wear, the engaged position of the sleeve assembly (8) changes, allowing increased travel toward the flywheel. The clutch adjustment is provided to compensate for this wear, and by moving adjustment bolts (A) to the right, the sleeve (8) travel is decreased as much as desired to return sleeve assembly to normal.

The distance from the correct engaged position (B) to the correct released position (C) is ½ inch; in other words, when the clutch pedal is pressed down, the sleeve assembly should be pulled away from the flywheel ½ inch.

The released position of the forward end of the sleeve assembly is not affected by wear or clutch adjustment, and, when correctly set, is always the same distance from face of flywheel. There are several ways of measuring this position, but the easiest way is to remove hand-hole plate (by removing screws **H**, Fig. 27) and observe position of retractor collar (6), as shown in Fig. 27.

A gauge made of wire with a bend at one end may be used.



This shows clutch engaged and correctly adjusted. When clutch pedal is pressed down, entire sleeve assembly moves back ½ inch. Note clutch brake.

To Adjust Two-Bearing Types

To adjust two-bearing types DX, DAX, DAX-1, GX, GX-1, SGX, SGX-1, RGX, JX, proceed as follows:[1]

1. Loosen both adjustment bolts (see Fig. 25). As both bolts are screwed into the same mounting ring (Fig. 24), moving one also moves the other.

2. Hold clutch pedal down. Move bolts **(A)** to the right, or clockwise, which tightens the clutch.

3. While the pedal is down, note position of retractor collar (6). The rear face of it should be about flush with the face of clutch cover (9) (see Fig. 27). If it is inside the cover, the pedal adjust-

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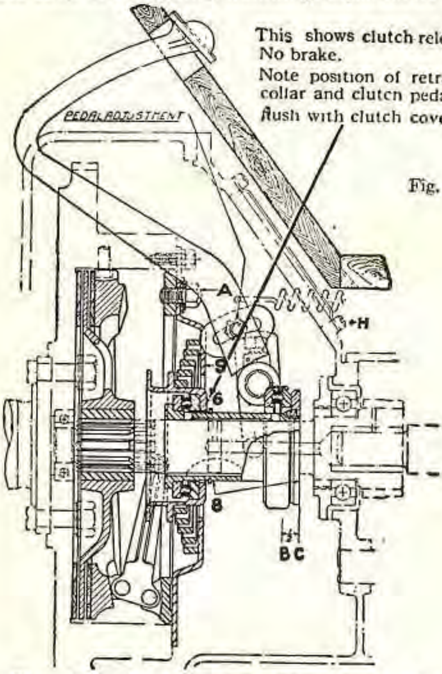
[1] The type of clutch can be found on name plate located at front of clutch (see Fig. 25).

The "two-bearing clutch" refers to the two ball bearings, one at each end of clutch sleeve (Figs. 26, 27). The "single-bearing clutch" refers to the one bearing shown at right end of clutch sleeve only, in Figs. 28, 29, 30.

ment should be changed, raising the pedal enough to bring retractor collar to that position.[2]

4. Let in clutch and note the distance that the sleeve travels. If more than ½ inch, throw out clutch and move bolt (A) to right. If less than ½ inch, move bolt (A) to left. After ½ inch travel has been obtained, tighten both bolts (A). This completes clutch adjustment. When bolts (A) reach the right ends of the cover clots (Fig. 25), due to repeated adjustment, remove them and screw into the repeat holes which have been exposed at opposite ends of slots, thus doubling adjustment range.



This shows clutch released. No brake. Note position of retractor collar and clutch pedal flush with clutch cover.

Fig. 27

The foregoing describes the manner of adjusting the clutch pedal where no clutch brake is used, allowing the pedal to be pressed down until it touches the floor-board (see Fig. 27).

Where a clutch brake is used, it is located at (C) position, and pedal adjustment should be set so that sleeve makes contact with brake before pedal touches the floor-board (see Fig. 28).

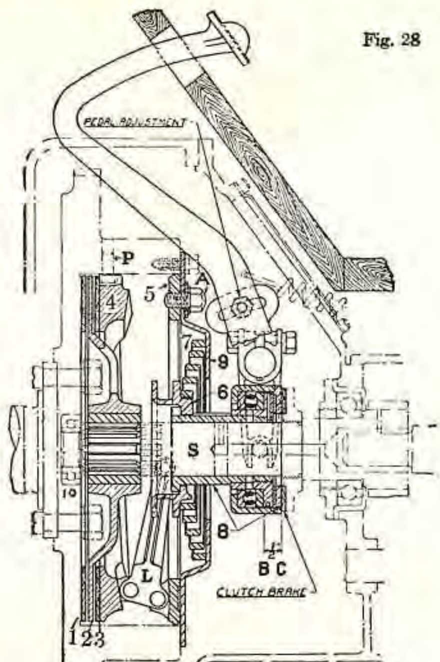
To adjust clutch of the two-bearing type DXY, follow instructions given above, except that when the pedal is down, the rear face of retractor collar (6) should extend about ¼ inch out of clutch cover (9). If it does not extend out that far, the pedal adjustment should be changed, raising pedal enough to bring retractor collar to that position.

To adjust two-bearing type FGX: All have clutch brakes. Adjust pedal as shown in Fig. 28, and adjust clutch to allow ½ inch travel of sleeve from engaged position (B) to brake (C).

To adjust two-bearing heavy duty types 13FX, FJX and single-bearing heavy duty type FJS: These have three adjustment bolts instead of two, and all have clutch brakes. Adjust pedal as shown in Fig. 28, and adjust clutch to allow a little more than ½ inch but not more than ⅝ inch travel of sleeve from engaged position (B) to brake (C).

[2] If the clutch pedal is adjusted alone without adjusting the clutch, the left end of sleeve (8) will come in contact with hub of driven disk (2) and will prevent spring from operating levers and thus cause clutch to slip. To correct, adjust clutch first and raise pedal adjustment afterwards.

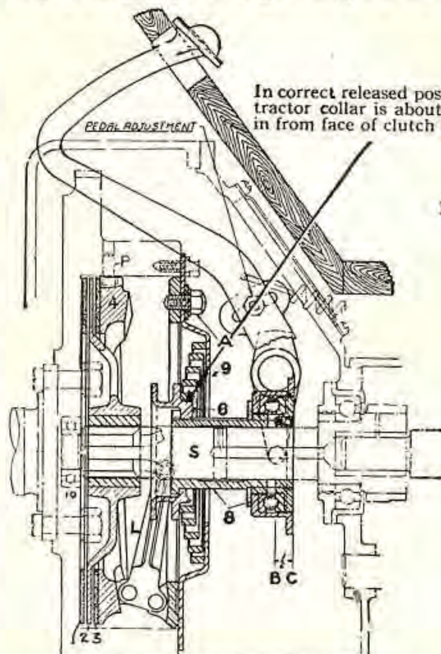
Fig. 28



This shows single-bearing clutch with clutch brake. (Released.) Note pedal does not go down to floor-board.

To Adjust Single-Bearing Types

To adjust single-bearing types, M, D, DN, DA, DU, GA, GA-1 follow instructions given above, except that when pedal is down the rear face of retractor collar (6) should be ½ inch in from face of clutch cover (9), as shown in Fig. 29. If more than ½ inch from face of cover, the pedal adjustment should be changed, raising the pedal enough to bring it to that position.



In correct released position, retractor collar is about ½ inch in from face of clutch cover.

Fig. 29

This shows single-bearing clutch without brake. (Released.) Note position of retractor collar, and that pedal goes down to floor-board.

To adjust single-bearing types DS, G, G-1, GS, SGS, RGS, J, JS: These types all have clutch brakes. Adjust pedal as shown in Fig. 28, and adjust clutch to allow ½ inch travel of sleeve from engaged position (B) to brake (C) (see Fig. 30).

If the foregoing instructions are correctly followed, there will be proper clearance between floor-board and clutch pedal when clutch is engaged, as shown in Fig. 26.

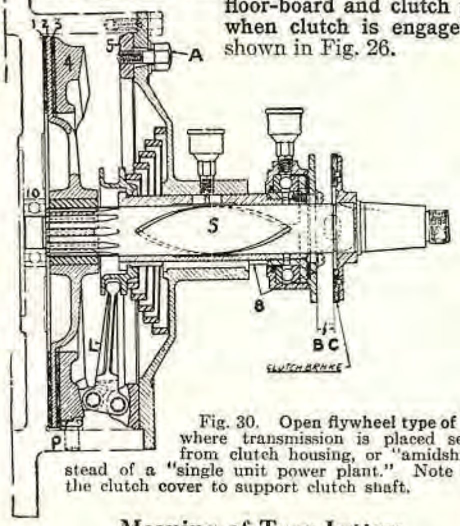


Fig. 30. **Open flywheel type of clutch,** where transmission is placed separate from clutch housing, or "amidship" instead of a "single unit power plant." Note hub in the clutch **cover** to support clutch shaft.

Meaning of Type Letters

The first clutches manufactured were of the single-bearing type, and the letter used referred to its diameter as follows: M—8 inch; G—12 inch; D—10 inch; J—14 inch. Latter types are indicated by adding letters as follows:

S means open flywheel type, as in Fig. 30.

A indicates a bearing cup required in crowded housings, as in Fig. 29.

X signifies a two-bearing clutch with the sleeve keyed to shaft, as in Fig. 26.

U indicates the use of self-contained T.O. bearing without a bearing cup and no retractor collar bearing.

Y indicates new sleeve design. **1** indicates special clutch cover.

When letters are prefixed: **S** indicates wide friction-surface parts; **R** indicates wide friction-surface parts, but slightly narrower than those with prefix S; **F** indicates heavy-duty truck clutches.

On latest clutches the size or diameter is prefixed in figures, and letter code for size is dropped, as in 13FX.

Care and Lubrication

If clutch seems to drag and gear shifting is difficult after adjustment instructions have been carried out, there is probably surplus oil in the clutch.

To correct, wash out or clean clutch by pouring about one-half pint of kerosene through a funnel or chute into the large opening in the clutch cover while engine is running, and engage and disengage the clutch as it runs. The surplus kerosene can be drained from the clutch by letting the car stand overnight with the front wheels higher than the rear. This permits the liquid to work its way between the friction surfaces readily if the clutch is released and gear in mesh. If the first application is not sufficient, repeat the operation.

Care should be taken to see that the oil level in transmission is not too high—approximately up to the center of the lower shaft.

Lubrication: Oil for sleeve (8) and bearings is provided from the transmission through the hollow clutch shaft and holes bored in the sleeve itself. Care should be taken to see that the **oil level in the transmission** is not too high; it should come approximately up to the center of the lower, or secondary, transmission shaft. **An oil of a liquid nature** should be used in the transmission of about the consistency of 600 W.

Over-lubrication will cause clutch plates to slip and also drag. **Under-lubrication** will cause clutch sleeve and bearings to become noisy. The surplus of oil may be removed by washing it out with kerosene, as explained in text above.

After about every thousand miles, remove the adjusting bolt and squirt a little cylinder oil into the clutch—just enough to **moisten the asbestos rings.** Too much oil will cause the clutch to slip until the oil is burned out.

If trouble is encountered after these instructions have been carried out, it is an indication that facings require replacement or that some part of the clutch is out of position or incorrectly assembled.

Pointers on Operating Clutch

Do not slip the clutch excessively instead of shifting gears. Slipping it makes the clutch do all the work that the transmission was designed to do.

Do not drive with the foot on the clutch pedal. It puts a constant pressure on the throw-out bearing and shortens its life, and tends to wear clutch facings. Keep the clutch properly adjusted.

Clutch Troubles: Cause; Remedy (Borg & Beck)

Slipping is a bad condition that may ruin facings, drive disk, bearings, sleeve, in fact the whole clutch, if allowed to continue.

It is usually caused by a continual pedal pressure on the under side of the floor-board which holds the clutch partially "out", thus wearing the facings, or it may result from an excess of oil in the clutch, or driving with foot on the clutch pedal.

Remedy: Adjust the clutch by moving the two adjustment bolts, as described on the preceding pages. If slipping comes from too loose an adjustment of the clutch, the same remedy will correct it. If there is too much oil, drain the clutch housing and wash it out with kerosene. If this does not relieve the trouble, the clutch facings (1 and 3) may be worn, or the spring (7) damaged.

Slipping of the clutch, followed by chattering and grabbing: This indicates that the asbestos facings (1 and 3) are glazed and should be replaced, and this necessitates the removal of the clutch.

Dragging, which makes gear-shifting difficult.

Cause: Failure of the clutch to release properly, and so to allow the driven disk (2) and the clutch shaft (S) to come to rest. It may come from: too tight an adjustment of the clutch; failure of the clutch-brake action; accumulation of oil and dirt in the clutch; bent, worn, or incorrectly assembled parts; worn out pilot bearing (10) in flywheel.

Remedy: Adjust correctly; wash off brake facing with gasoline, or renew brake facing; wash out with kerosene; remove clutch and make any necessary repairs; put in new pilot bearing.

Grabbing or stuttering: This condition causes the car to jump and shake as the clutch is let in, and shows uneven gripping of the friction or drive disk by the asbestos friction rings.

Cause: It has been found that this is nearly always caused by imperfect alignment of the clutch in installing.

Remedy: Take the clutch down and secure proper alignment of the clutch shaft. If the grabbing comes from a warped drive disk, caused by overheating from slipping, it will be necessary to replace the drive disk and friction rings.

At times, grabbing may be caused by the accumulation of dirt or foreign matter on the asbestos facings and drive disk.

Remedy: Wash out the clutch by cleaning it with kerosene, as described on this page. Do not fail to oil the clutch after using kerosene, as explained under "Lubrication."

If clutch facings (1 and 3) are worn, trouble will be experienced when shifting gears into first speed when car is standing.

Remedy: Remove clutch and put in new facings.

Noise may develop at the three points on the thrust ring where it is driven by the dowel pins (P) (Fig. 26) in the flywheel.

Cause: The fact that the pins were not properly fitted at the time of installation, and the fact that the backlash causes wear in the slots of thrust ring.

Remedy: Take down the clutch and replace the dowel pins with pins of proper fit for thrust-ring slots.

Improper lubrication will cause the retractor collar bearing or throw-out bearing to become noisy.

Remedy: Open up the oil holes in the clutch shaft, replacing the bearings, if worn.

These bearings may also become noisy if the bearing seat on the clutch sleeve is allowed to get out of line, or if the clutch shaft is out of line.

Cause: This sometimes results from hasty installation or from bad alignment of the throw-out yoke.

Remedy: Straighten the bearings on the sleeve and set the clutch-pedal yoke to bear evenly on the throw-out bearing.

If clutch will not pull when engaged, or drags when disengaged after having correctly made adjustment.

Cause: Clutch shaft, flywheel, or other bearings may be out of line, or drive disk may be in wrong (the clutch shaft may have been sprung when assembling and replacing transmission).

Actual failure of the clutch to operate, or excessive noise when the clutch pedal is pushed out, indicating that the clutch spring or some of the operating members are worn or broken, and necessitating a removal of the clutch.

Ordinarily a washing and adjustment of the clutch will place all parts in good condition. Unless it is positively indicated that a removal is necessary, cleaning and adjustment should always take place before tearing the clutch down.

To Remove Clutch and Disassemble

This is necessitated by worn clutch rings, by actual failure of the clutch to operate, or by continued presence of oil after repeated cleanings.

In order to remove clutch, it is necessary first to remove transmission and disconnect clutch pedal.

1. Punch the remounting "line-up" marks on the cover and flywheel, so that the cover may be replaced exactly as removed. If the cover should be replaced wrong, or shifted in remounting, the clutch will not operate properly.
2. Throw the clutch "out" and lock out the spring, by placing two blocks of wood (space block), as shown in Fig. 25 (see also Fig. 30B) between the cover and the throw-out yoke.

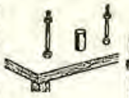
Note: It is best to use two wood blocks as shown in Fig. 25 because one block is liable to slip out when used in (X) type clutches and allow bearing to go through hole in cover.

3. Remove clutch-cover bolts and draw out clutch.

Note: If all working members are in good condition and are not worn excessively, new friction rings should be slipped in place and the clutch should be reassembled.

It may, however, be necessary to completely dismantle clutch, in order to replace the spring or some other worn member. The average tolerance in wear of parts is .016".

4. To remove spring, the assembly can be placed in an arbor press or drill press, and the pressure of the spring removed from the levers, after which the adjustment screws (A) may be removed allowing complete disassembling.



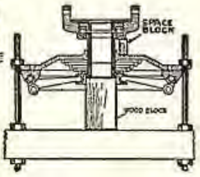


Fig. 30A. Details of a simple clutch compressor which can be easily constructed on the bench and used for disassembling and assembling a clutch.

Fig. 30B. The clutch compressor in use. An arbor or drill press may be used in a similar manner, to hold the clutch in the "out" position.

To Reassemble Clutch

1. Reassemble clutch, using the compressor shown in Figs. 30A, 30B, or use an arbor, or drill press.
2. Place the space block in position, and remove the clutch from the compressor.
3. Place the friction ring (1), then the clutch-driven plate (2) in the flywheel, followed by the other friction ring (3) and as shown in assembly (Fig. 23, page 846). Then insert the three dowel pins in their holes in the flywheel. Next put in the thrust ring (4) (see note).
4. Then put the clutch assembly in place.
5. Replace the clutch cover bolts, making sure that the cover is in the same position as when removed.
6. Replace the transmission, drive shaft, etc.
7. Check up adjustment of pedals and clutch as outlined, and see that clutch brake is working all right.
8. Grease all parts, and replace all fittings.

Note: The thrust ring, or pressure plate (4) must slide freely on the three dowel pins (P) in the flywheel. Do not file slots if ring sticks. See that pins are turned so that flat sides are parallel with slots in ring.

Line up flywheel bearing and driven plate with clutch shaft before tightening clutch cover cap screws.

Tighten cap screws before pulling out shaft.

Place a small amount of hard oil on sleeve before assembling transmission to engine. **Do not let transmission hang in** clutch assembly.

Inspection and Repair of Clutch Brake

The purpose of the clutch brake is to stop the spinning of the clutch and to prevent gears clashing when shifting. To examine see below:

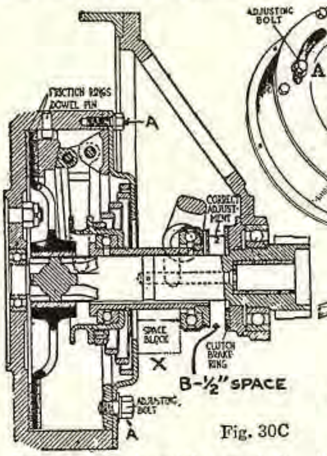


Fig. 30C

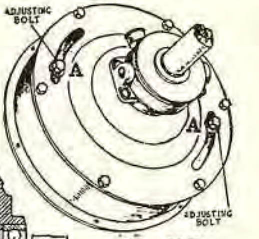


Fig. 30D

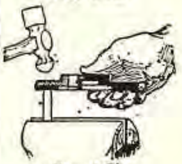


Fig. 30E

1. Press the clutch pedal down fully. The clutch brake with the "X" type clutches is fastened onto the forward side of transmission and if the clutch has been assembled with the correct length sleeve for the housing on which it is used, the end of the sleeve will come in contact with the brake, if the clutch pedal is set so that it does not strike the floor board when fully depressed.
2. Examine the brake (see Fig. 30C showing the clutch-brake ring), and see whether it actually touches the end of sleeve or not. If it does not touch, it is due to incorrect adjustment of clutch pedal. Adjust clutch pedal as directed above.
3. If the clutch-brake facing is worn very thin or is glazed, it should be removed and a new one should be riveted on in its place. Brass tubular rivets should be used, and should be countersunk well beneath the surface of the facing (see Fig. 30E) (on some transmissions the clutch-brake facing is not riveted, but floats in a flanged ring).

The transmission must be removed in order to remove or replace clutch-brake facing.

One common cause of wear of clutch-brake facing is coasting, as the clutch brake then not only stops clutch parts from spinning, but also acts as a brake through the transmission.

Adjusting Borg & Beck Type "9KP" and "10KP" Clutch

This clutch differs from those shown in Figs. 23 to 30E, in that this clutch is termed a **"push type,"** that is to say, the throw-out bearing (8) is **pushed against the tension of spring (7) in order to release clutch, instead of "pulling."** Also note that the two friction rings are riveted to the friction disk.

To adjust types 9KP proceed as follows:

1. Loosen both adjustment bolts (A). As both bolts are screwed into the same ring (5), moving one also moves the other.
2. Throw out clutch by pushing pedal down until pad rests on toe board. (As shown in Fig. 30F, the spring should then be compressed nearly flat against the cover.) Move bolt (A) to the right, or clockwise, which tightens the clutch.
3. Let in clutch and measure distance from rear face of release collar (8) to clutch cover (9). This should be 1", and a gauge made of wire with a 1" bend at one end may be used to advantage.
4. If this space is more than 1", throw out clutch and move bolt (A) a little more to the right. If less than 1", move bolt (A) to the left. After correct setting has been obtained, tighten both bolts (A). This completes clutch adjustment.
5. The clearance (E) between the clutch pedal (when clutch is "in"; now shown "out") and under side of toe-board (E1) should now be 1" or more. If less than 1", the clutch pedal adjustment (G) should be changed, shifting the pedal down until that clearance is obtained. Now let clutch "in" by pressing the pedal down (position shown in illustration) and note distance the release collar (8) travels. It should be pushed toward the flywheel about ¼", which is necessary for a clean release. If it does not travel that distance, shift pedal up a notch so as to allow little more travel.
6. The clutch pedal adjustment has now been set in its correct position and should not be touched again, because adjusting the clutch automatically returns pedal to its correct position and restores clearance under the toe-board.

Fig. 30F

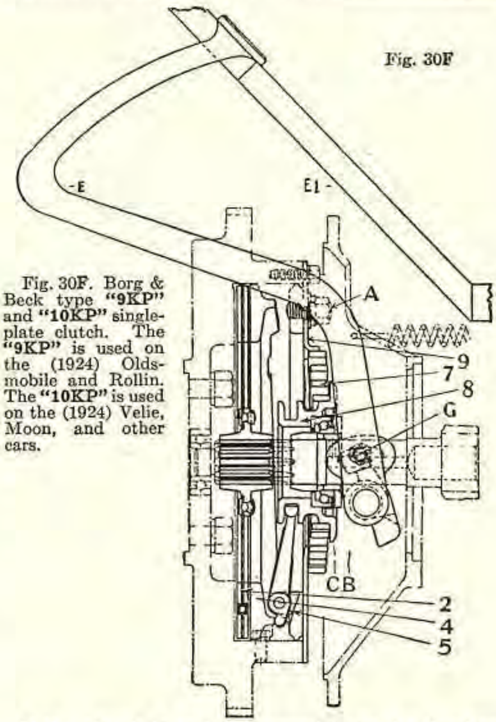


Fig. 30F. Borg & Beck type **"9KP"** and **"10KP"** single-plate clutch. The **"9KP"** is used on the (1924) Oldsmobile and Rollin. The **"10KP"** is used on the (1924) Velie, Moon, and other cars.

If the clutch is to be removed from the flywheel, first punch remounting line-up marks on cover and flywheel, as clutch will not operate if cover is shifted in mounting.

Before the holding screws are removed, be sure that the two adjustment screws (A) are in place and securely tightened. Then, after all the holding screws have been relieved about ½", the levers will strike the cover (9) and retain collar (8) and spring (7) in place. **To remove spring,** the assembly can be placed in an arbor or drill press and the pressure of the spring removed from the levers, after which the adjustment screws (A) may be removed, allowing complete disassembling.

When placing driven plate in flywheel, be sure that the **flange end** of hub is toward the outside.

To adjust type 10KP clutch, follow the foregoing instructions, except that the dimensions differ as follows: Distance in items 3 and 4 should be 1 3/16" instead of 1".

ADJUSTMENT OF A MULTIPLE-DISK CORK-INSERT LUBRICATED TYPE OF CLUTCH

This clutch, as an example, is made with seven driving and seven driven members. They are provided with cork inserts and run in oil.

New corks may be inserted in the disks by the use of a special tool after the corks have been soaked in warm water to make them pliable. They are trimmed off so as to leave a projection of about 1/32" on each side, and then they are ground to an even surface on the disk grinder.

A more convenient method for the average repairman is to use fine sandpaper. The disks should be trued by rubbing them on a flat surface which has a very thick coating of prussian blue or lamp black. The cork inserts should not project too far over the disk or the clutch will drag; 1/32" is the maximum.

The clutch spring (S) (Fig. 31) **is not adjustable;** a new and stronger spring is installed if greater tension is required. The position of pedal will shift toward floorboard after clutch has been in service a short time, because inserts, when brought under pressure of clutch spring, will compress slightly.

If the pedal is not adjusted, it will cause a continuous pressure against the clutch and eventually produce slipping. There should be ¾" clearance between the clutch pedal and the upper side of the floorboard. This is adjusted by loosening the lock **nut at the end of the turnbuckle.**

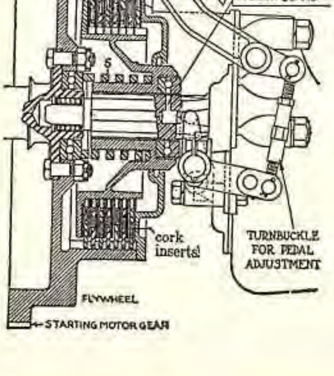


Fig. 31. Sectional view of a multiple-disk cork-insert lubricated type of clutch. Note adjustable foot-pedal.

To remove the clutch it is first necessary to take off the gearbox; then the cap screws which attach the clutch-plate cover to the drum of the flywheel are removed, and the entire clutch assembly may be taken out.

To reassemble the clutch it is necessary to compress the clutch spring, which can be accomplished by using two 5/16″ studs about 3½″ long, threaded full length. They should be inserted in two opposite holes in the clutch drum. Then take the driven clutch member and install the disks on it—a plain disk first and then a cork disk, and so on.

Place the clutch plate over the hub of the driven clutch member and insert the spring over the front end of the hub of this part. The lugs on the outer edge of the driving disk should then be run in line. Next coat the gasket on the clutch plate thoroughly with shellac and allow it to dry until it becomes sticky.

The clutch assembly may be entered into the clutch drum of the flywheel and the two studs, mentioned above, can then be inserted in the drum and used to draw the clutch into position. Finally install the cap screws which hold the clutch-plate cover to the flywheel, and after removing the two studs tighten all of the screws firmly.

It is sometimes necessary to remove the main drive gear from the front end of the transmission and to use it as a guide, in order to be sure that the clutch is in proper alignment with the rear bearing in the rear end of the crankshaft which supports the front end of this main drive gear, otherwise there may be difficulty in getting the transmission into place.

HUDSON LUBRICATED MULTIPLE-DISK CORK-INSERT CLUTCH

The Hudson clutch is of the multiple-disk type with cork inserts. It is fully enclosed in the flywheel and runs in what is suitably termed clutch oil. The cork inserts become saturated with this oil, and maintain the velvety action so desirable, while the friction between the corks and steel disks is sufficiently great to prevent any tendency to slip.

Renewing the oil and lubricating the clutch throw-out collar are the only attentions necessary. The fact that the cork inserts become saturated with oil makes it comparatively difficult to abuse this clutch, as compared with other types. However, its action will be affected if instructions in regard to the quality and quantity of lubricant are not strictly adhered to.

Never put more than a half-pint of mixture in at one time. Always drain the clutch to remove the used oil before filling in any fresh oil (half kerosene and half good engine oil).

Clutch oil consists of one half-pint of kerosene and lubricating oil mixed in equal proportions.

Clutch adjustment should be inspected occasionally. The adjustments are shown in the wording for Fig. 32.

Wear on the clutch parts is indicated by the pedal stopping farther away from the toe-board than usual. If the clutch is burned or abused, so that the corks swell up, the pedal will come back farther—nearer to the toe-board.

Do not slip the clutch when driving, except when absolutely necessary, and then only when you know it has sufficient lubrication to stand it. If you feel that you must do so, owing to lack of confidence in your ability to handle the car through congested traffic, remember that the lubrication of the throw-out collar will need more frequent attention.

The clutch throw-out sleeve is lubricated by the large grease cup. Clashing of gears and hard shifting is usually due to faulty lubrication at this point.

Note. **The usual cause of slipping of the lubricated disk type clutch** is a weak clutch spring or clutch pedal-linkage adjustment, which prevents the clutch plates from engaging. If this type of clutch **drags,** it is probably due to **oil being too thick.** If it **grabs** it is probably the result of lack of oil or improper clutch-spring adjustment.

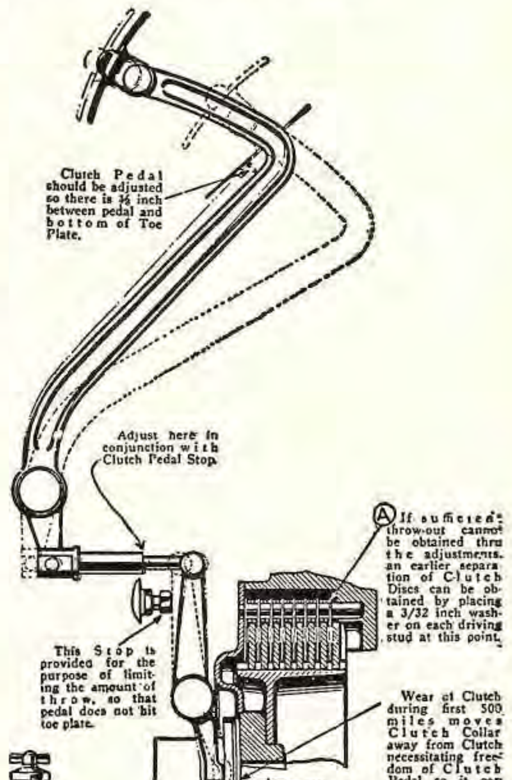


Fig. 32. The Hudson lubricated multiple-disk cork-insert clutch.

THE REO MULTIPLE-DISK DRY-PLATE TYPE OF CLUTCH

This clutch is of the multiple dry-disk type, consisting of thirteen steel plates, seven of which are lined on both sides with asbestos. The remaining **six** plates are of plain steel and are placed alternately between the lined disks. These disks are designed to run dry, and the application of oil, regardless of the kind, will tend to ruin them. Details of troubles and adjustments are given on next page.

Evidence of Trouble

1. **Slipping clutch:** This is often caused by lack of proper clearance between the clutch opening fingers and the release plate. This clearance should never be less than 1/16″ or more than ⅛″ when the clutch is in. This necessitates an adjustment of the clutch opening fingers (see clutch adjustment below).

   Another cause of slipping clutch is too little tension on the clutch springs, contained in recesses in the flywheel, as shown in Fig. 35. The nuts on the engine end should be tightened enough to prevent the clutch from slipping, but not enough to make the pedal difficult to operate. Never tighten the clutch-spring nuts until the release fingers have been adjusted to the proper clearance. Neither of the adjustments mentioned will have any effect if the lining on the disks is worn so thin that the clutch casing seats on the flywheel, as shown in Fig. 35, at (**A**) and (**B**). When worn thus, the clutch must be removed.

   Continual slipping causes the disks to get very hot, warping the steel disks, as shown in Fig. 33, and raising the rivets on the lined disks so that they cause the clutch to chatter, with the possibility of grooving the disk and giving them a permanent warp.
2. **Noisy clutch—particularly when released:** This is due to a worn clutch-thrust bearing (see Fig. 35). A removal of the clutch and replacement of the bearing is necessary.

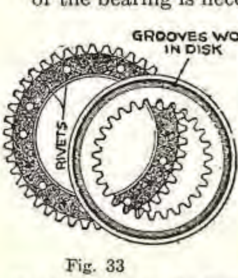


Fig. 33

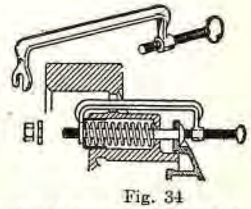


Fig. 34

Fig. 33. **If worn, the facing should be renewed, and the rivets countersunk below the surface to prevent grooving the steel disks. The steel disks should be renewed if grooved or warped.**

Fig. 34. **The assembly is facilitated by the use of a simple compressor, applied in the manner illustrated. It is cast iron, though a similar one could be forged from bar stock. The main thing is to use a compressor of some sort.**

To Remove Reo Clutch

1. Remove the floorboards.
2. Remove the starter driving chain.
3. Remove the two battery wires running to the starting motor.
4. After removing the two bolts holding the right end of the starter, and the single bolt at the left end, remove the starting motor.
5. Remove the short drive shaft, with its universals, that connect the clutch and gearbox.
6. Remove the brake rods.
7. Remove the bolts on the clutch cross-shaft and spring it up.
8. Remove the clutch cross-shaft.
9. Remove the nuts that hold the clutch-spring bolts at the rear of the flywheel. Remove bolts.
10. Pull the clutch out and remove it from the frame.
11. Place the clutch ring assembly on the bench with the clutch rings up.
12. Remove the snap ring, and then remove all friction rings. (Note how the rings are removed, so that they may again be built up in the proper sequence.)
13. Clean all parts with gasoline and scrape out the clutch-ring recesses both on the flywheel and the clutch hub.

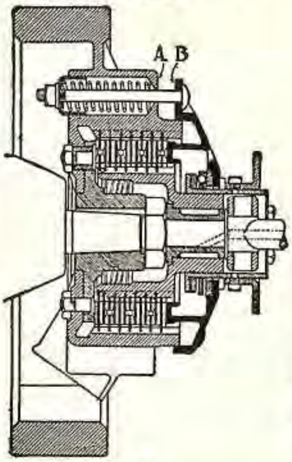


Fig. 35

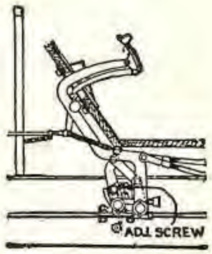


Fig. 36

Fig. 35. Clutch assembly. **When the disks are worn out, surface (A) touches surface (B).**

Fig. 36. **To adjust clutch-opening fingers, turn the adjusting screw on the clutch pedal until the clearance between the fingers and the release plate is about 1/16″ when the clutch is in. The release plate should then spin freely.**

To Repair Reo Clutch

If the asbestos faces of the disks are worn, they must be replaced. The split rivets holding them should be opened down below the surface, if the facing does not have to be renewed.

1. To replace facing: Cut off the heads of the old rivets, taking care that the disks are not sprung out of shape.
2. Examine each disk to see that it is not sprung or warped out of shape, and note whether the steel disks are grooved. If either is the case, the disks must be replaced.
3. Using each disk as a template, drill the rivet holes in its new facings. Countersink the facings slightly for the rivet heads. (The new facings can best be obtained from the car makers, and this should be done if possible.)
4. Using solid copper rivets, rivet the new facing to the disk.
5. Examine the ball and roller bearings of the clutch for wear and the clutch bushing for looseness. Replace with new ones, if any amount of wear is evident.
6. Use little grease in assembling the bearings, as the clutch must be run dry.

1. **When assembling the clutch:** Make certain that the rings are inserted in proper relation to each other. (An asbestos-faced disk goes in first.)
2. Slide the clutch back into place.
3. Using a clutch-spring compressor, as shown in Fig. 34, replace the nuts on the clutch-spring bolts. Do not tighten these nuts yet.
4. Replace the clutch cross-shaft.
5. Reconnect the brake rods.
6. Replace the drive shaft and universals.
7. Replace starting motor, wires, and driving chain.

To Adjust Reo Clutch

1. Adjust the opening fingers on the clutch throw-out collar, so that they strike the collar together. This is done by loosening the clamp bolts, holding them to the cross-shaft, and tapping them into alignment. If this is not done the gears will not shift readily.

2. Adjust the clearance of the opening fingers. This is done by loosening the lock nut on the adjusting set screw, as shown in Fig. 36, and turning the screw in to decrease the clearance, and out to increase it. This screw should be turned out until the clutch release collar spins easily on the drive shaft when the clutch is in.

3. Tighten the nuts on the clutch springs at the rear of the flywheel evenly, and until the clutch does not slip. These nuts should not be so tightened that the clutch pedal works with difficulty.

Maintenance

1. If the clutch starts to slip, adjust it at once.
2. Use no oil on the interior of the clutch, except as placed in the two oil openings in the drive shaft.
3. Do not drive with the foot on the clutch pedal. (*Motor World.*)

ADJUSTMENT OF BUICK "SIX" CLUTCH (1921)

The Buick "six" clutch is of the multiple-disk dry-plate type, consisting of steel plates operating between steel plates lined with asbestos and which are connected alternately to the flywheel and the clutch shaft.

Adjustment: When the facing on the clutch disks wears, adjustment can be made by moving the lock nut and the adjusting on the clutch-release rod to allow more clearance between the clutch-release bearing and the plates. When adjustment is properly made a clearance of 1/32" should be between the ball-thrust bearing and the rear plate against which it operates.

Lubrication: Neither oil nor grease should be put on the clutch disks. The clutch is lubricated by two grease cups, one located on the clutch-release yoke pin and one on the clutch-release bearing retainer, both of which should receive attention at least once every 500 miles. A few drops of oil applied to the pins on which the disks slide will prevent squeaking.

Clutch and brake pedals require soft cup grease. Remove the floor board and give grease cups one or two turns. Keep filled with grease. There is one cup on each pedal hub.

The clutch release fork pin requires soft cup grease. Remove clutch cover and give grease cup one or two turns.

The clutch release bearing retainer requires soft cup grease. Give grease cup (outside of transmission housing) one or two turns.

The clutch pedal position can be adjusted by means of the set screw at the rear end of the clutch housing.

The proper handling of the clutch pedal and accelerator so as to make the motor "pick up" its load quickly, and at the same time prevent it from "racing" when the clutch is released, requires practice.

In changing gears, and especially when starting the car from a standstill, always let the clutch pedal come back gently. If the foot is suddenly removed from the pedal, it will let the clutch take hold with a violent jerk.

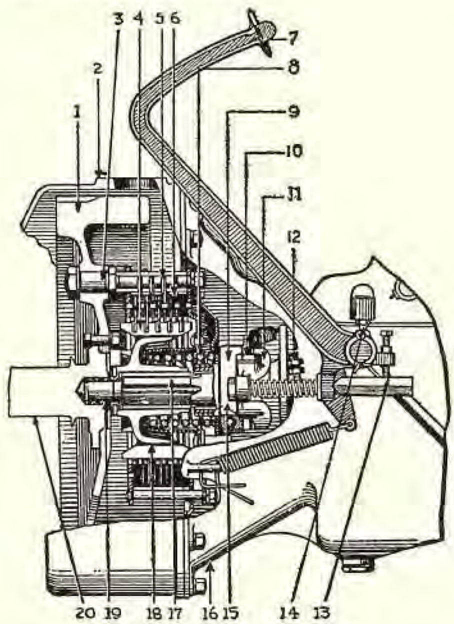


Fig. 37. The Buick "six" clutch.

(1) Fly wheel.
(2) Crank case.
(3) Flywheel driving stud.
(4) Clutch-driven plate.
(5) Clutch driving plate.
(6) Clutch-plate facing.
(7) Clutch pedal.
(8) Clutch spring.
(9) Clutch-release bearing.
(10) Clutch-release bearing retainer.
(11) Clutch-release fork.
(12) Clutch adjusting stud.
(13) Clutch-release adjusting nut.
(14) Grease cup.
(15) Clutch-release rod.
(16) Transmission case.
(17) Clutch gear.
(18) Clutch-driven hub.
(19) Graphited bushings.
(20) Crank shaft of engine.

THE STUDEBAKER "LIGHT SIX" CLUTCH

The Studebaker "Light six" clutch is of the single-disk dry-plate type.

Operation of clutch: The driven member is a single malleable-iron disk placed between two friction plates. Six coil springs are used to exert pressure on the clutch toggle plate, acting upon friction plates and a malleable disk located between the toggle plate and flywheel (Fig. 38).

The clutch is released by the toggle-lever collar being pulled back against the three toggle levers which operate the toggle plate, thereby relieving the pressure on the friction surfaces.

The toggle lever should be adjusted so that, with the clutch pedal released, there is a slight play between the ends of the levers and the toggle-lever collar. This play must be the same for each lever, so that the clutch is released equally at all points.

To make adjustment, first loosen the lock nuts on the toggle-arm adjusting screws. Then turn the screws to the left to increase the play between the toggle levers and the collar, or to the right to decrease it.

Under no circumstances should the levers be tight against the collar when the clutch pedal is released, as the clutch will be partially disengaged, and slipping will result.

In the case of a new car, or after new friction disks have been installed, it may be necessary, after 500 to 1,000 miles of running, to readjust the three levers which may bind on the collar as a result of the friction disks running into a smooth surface and becoming thinner. After the disks have worn smooth, no further adjustment will be necessary for some time.

When disks become badly worn it will be necessary to replace them with new ones, which can be obtained from a Studebaker dealer or branch. These disks require no treatment before or after being installed.

Clutch brake: The braking action on the clutch occurs when the grease retainer nut of the clutch throw-out bearing is brought in contact with the leather-faced flange, which is a part of the flexible coupling spider, keyed to the clutch drive shaft (Fig. 38).

There is no adjustment to the clutch brake, and it requires no care except that of replacing the leather facing when worn.

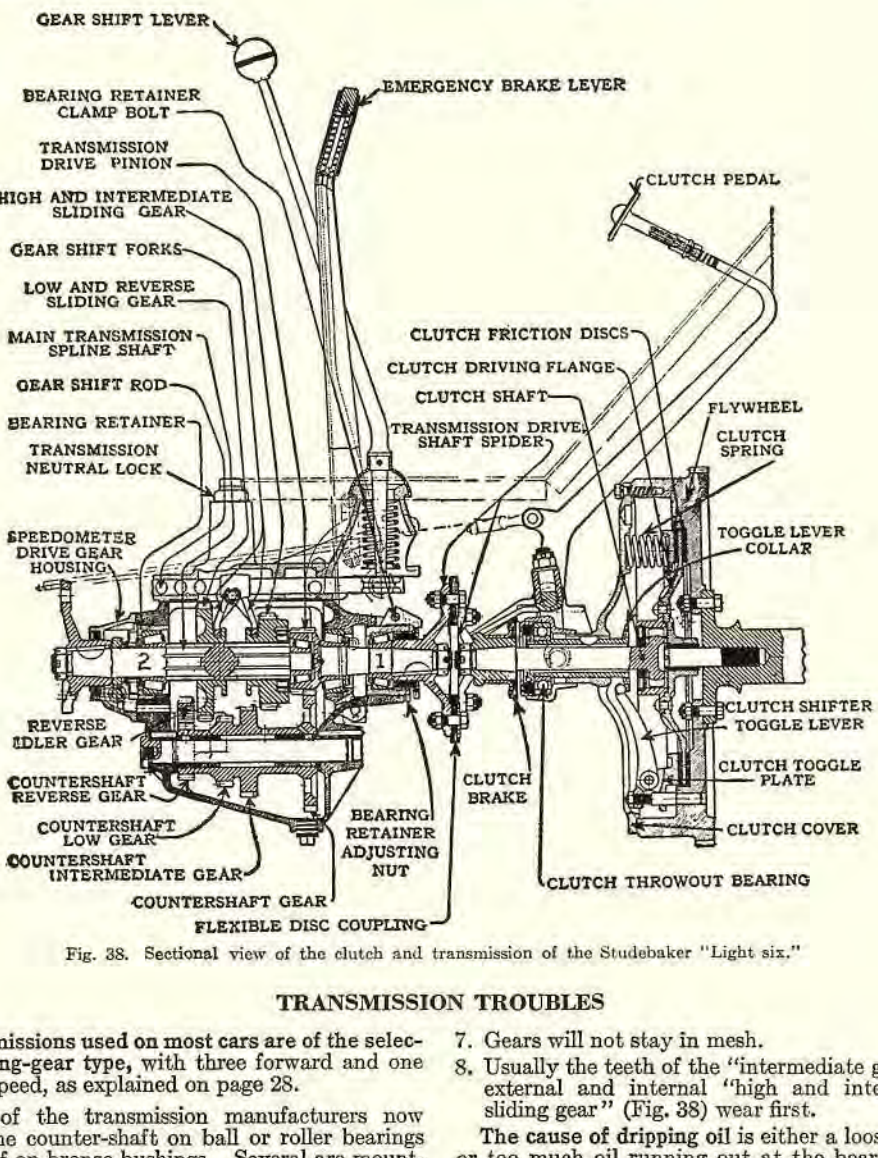


Fig. 38. Sectional view of the clutch and transmission of the Studebaker "Light six."

TRANSMISSION TROUBLES

Transmissions used on most cars are of the selective sliding-gear type, with three forward and one reverse speed, as explained on page 28.

Most of the transmission manufacturers now mount the counter-shaft on ball or roller bearings instead of on bronze bushings. Several are mounting the gear set separately from the engine and clutch which, however, are continued as one unit.

The usual troubles are:

1. Stripped gears.
2. Bearings worn, permitting shaft to drop out of line.
3. Dogs or gear teeth worn.
4. Dripping oil from the gearbox.
5. Cracked gears, worn teeth, sprung shafts.
6. Gear-shift rod out of adjustment.
7. Gears will not stay in mesh.
8. Usually the teeth of the "intermediate gear" and external and internal "high and intermediate sliding gear" (Fig. 38) wear first.

The cause of dripping oil is either a loose gasket, or too much oil running out at the bearing, or a worn felt gasket that may be sometimes used. The amount of oil usually carried in a transmission is a quantity sufficient to reach to a center line of the secondary shaft (Fig. 39). The lower gears will splash oil to all parts.

Other troubles: When dogs become worn (see part No. 139, page 26) so that they slip out of engagement, they may be dressed up or squared by grinding. Most transmissions now use internal gears, as shown in Fig. 38 ("drive pinion" and "high and intermediate sliding gear").

Noise: In gearboxes where the shaft ends are supported by single-row ball bearings, with no provision for end-thrust adjustment, and are noisy, **replace the bearings.**

Considerable wear in the bearings will change the distance between centers of the transmission shaft. In such a case **replace the bearings.**

Difficulty in shifting gears: There are three reasons for this: (1) a sticking or dragging clutch, caused by heavy oil; (2) the teeth of the shifting gears being burred; (3) considerable wear in the bearings, throwing the shaft out of line, which also causes noise. **Gears should be shifted without a particle of noise.**

Gears do not stay in mesh: This trouble is usually the result of weak or broken springs in gear-shifting shaft, **plunger or lock** (see 31, page 858). **Gear-shifting forks** (26, page 858) fit into collars on the sliding gears, and it is through them that the gears are moved to the different positions.

There are two types of gear-shifting shaft plungers or locks: (1) those placed on the top (31, page 858); (2) those placed on the side (Fig. 40, pg. 857). **A notch is cut in the gear-shift rod or shaft** (23, page 858) and a plunger and spring engages in the notch. On some transmissions a **steel ball** is forced into the notch by a spring, the **purpose** being to hold the gear-shift rod rigid so that gears will not move out of mesh after being shifted. The spring can be replaced if the gears fail to stay in mesh.

Worn gears and loose bearings will also cause the gears to fail to stay in mesh.

End play may be discovered by grasping the universal joint behind the gearset and attempting to move it forward or backward. If looseness is found, adjustment is needed. If end play is allowed to develop, the gears are likely to be stripped.

To determine the cause of clashing gears: Remove the cover plate over the clutch and, with the rear wheel jacked and the car in gear, let the clutch in and out. If the clutch continues to spin after it has been thrown out, look to the clutch brake, or see if there is too close an adjustment, or whether heavy oil causes the gears to drag.

Note. Do not allow a nut or any chips of metal to lodge in the transmission case. It will strip the gears if caught between the teeth. This also applies to the engine and the differential.

Do not use waste to wipe out the interior of a transmission. It leaves lint.

Removal and Replacement of a Transmission

Dowel pins and shims: Dowel pins are usually provided on either side of the transmission to insure its alignment. Sometimes, however, it is necessary **in squaring up the transmission with the engine** to insert a thick shim on one side; consequently it is important, when removing the gearbox, to notice whether **there are any shims,** and if there are, they must be replaced when the unit is put back.

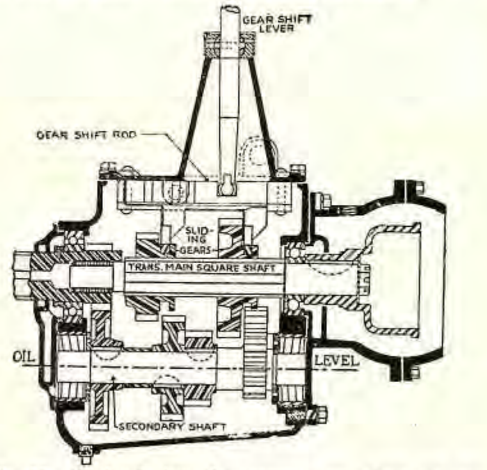


Fig. 39. Sectional view of a transmission. Note the oil-level line.

Bearings: The secondary-shaft in this example (Fig. 39) is carried on two Hyatt roller bearings. The bearing linings are a pressed fit in the case, and when they show wear they may be replaced at slight expense. The end thrust of this shaft is carried by two hardened steel washers, and a slight amount of end play is of no consequence.

Lubrication: The gearbox will usually hold about 2 qts. of oil, and should not be filled above the center line of the secondary-shaft. There are two oil rings provided on the main transmission shaft, and drains carry the oil back to the secondary-shaft bearings. Additional provision to prevent the oil from washing out through the bearings of the main shaft is made by thin steel washers which cover the inside of these bearings. See also pages 171, 847.

When replacing ball bearings in a gear-set case or on the shafts, care must be taken to see that the balls or races are not damaged from improper handling. Where the bearing is to be put on a shaft, the force should be applied to the inner race, using a piece of pipe and a hammer. If the bearing is to be forced into the gearset case, the driving effort should be applied to the outer or larger race in such a manner that no strain is imposed on the steel balls themselves.

Transmission-Gear Ratios

This subject is fully treated on pages 8, 9. See page 9 for examples of four-speed transmission.

STUDEBAKER LIGHT "SIX" TRANSMISSION

Type of transmission: The transmission is of the selective sliding-gear type, located at an intermediate position just behind the engine (Fig. 38). It consists of three shafts and a series of gears. Two of these shafts—the main transmission spline shaft and the pinion shaft—are in direct line with each other, the end of the main transmission spline shaft turning in the end of the pinion shaft. The third shaft, operated parallel with the pinion shaft and the main transmission spline shaft, is called the counter-shaft.

Neutral lock: The transmission is equipped with a neutral lock mounted in a hand-control base plate, and, when locked, it holds the sliding gears in neutral position (Fig. 40).

Transmission gears: The main transmission spline shaft carries two sliding gears of unequal sizes. These gears can be slid into mesh with gears of uneqal sizes on the counter-shaft. One of the sliding gears can also be moved into engagement with an idler gear supported by a transmission case, thus obtaining the changes of gear from "low" to "reverse."

Gear shift: See Fig. 3, page 630.

Lubrication of transmission: A heavy transmission oil should be used in the transmission. In addition, it is advisable to see that the transmission case is **thoroughly cleaned out** several times a season, as particles of steel from the gears, cuttings from the bearings, etc., all have a tendency to accumulate and, if not thoroughly cleaned out, will in time cause extra wear on the bearings. This can be done by taking out the cap screws on top of the transmission case cover and removing it altogether

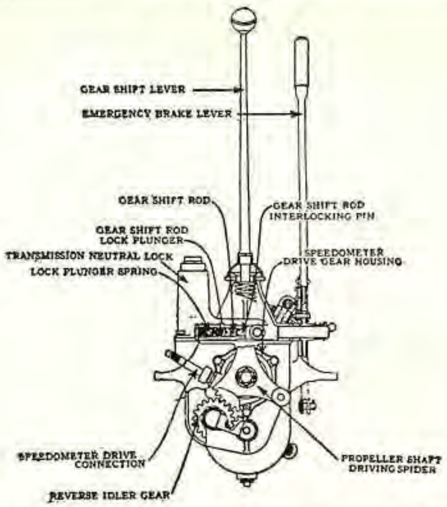


Fig. 40. Studebaker Light "six" transmission; rear view.

with the gear-shift assembly. Unscrew the plug at the bottom of the transmission. After the oil has been drained out, kerosene or gasoline should be flushed over the gears, and the entire case should be washed out with kerosene or gasoline very thoroughly. The plug should then be replaced; new oil should be put in the transmission, and the cover and gear-shift assembly replaced, care being exercised to see that an oil-tight joint is made between the transmission case and the transmission-case cover.

Amount of oil carried in transmission: When the proper amount of oil has been added, it will stand just at the top of the oil-filler plug, which is located on the left-hand side of the transmission.

To adjust the pinion shaft (1) (Fig. 38) for wear, remove the retainer clamp bolt, and turn the retainer nut in the front end of the transmission case in a counter-clockwise direction until all end play is just removed.

Adjustment of the main drive shaft (2) (Fig. 38) is made by removing the bolts which hold the speedometer drive-gear housing to the transmission case, sliding the cover back far enough to give room for a spanner wrench. Then turn the bearing retainer in a clockwise direction until all end play is just removed.

DODGE DRIVE SYSTEM[1]

To Adjust Dodge Clutch

The Dodge clutch is of the multiple-disk, dry-plate type. There are 7 disks held together by a heavy spring (6) (Fig. A, page 858). The 4 **driving** disks (9) (covered with wire-woven asbestos) are supported on 6 pins (3), pressed and riveted into the flywheel. The 3 **driven** disks (8) (plain) are carried on 3 pins (7) riveted to the clutch spider (4), which is keyed on the clutch shaft (32). Flywheel pins (3) are located outside, or above the clutch-spider pins (7), so that they can turn independently of the clutch-spider pins when the clutch is disengaged.

All disks are free to slide upon their supporting pins, and are held together by the clutch spring (6) when the clutch is "in."

To tighten the clutch spring: Compress it enough to allow the split washer (Fig. 41), which fits into one of three grooves cut on the clutch shaft, to be moved forward to the next groove. The two halves of this washer must fit securely into the groove so that the clutch-spring rear retainer fits snugly around it.

Care: Keep the foot off the clutch pedal except when using it, otherwise the disk facings and ball-bearing throw-out will wear excessively. Do not slip the clutch unnecessarily, as this causes the fabric to become glazed and to slip. Keep the drain in the bottom of the clutch housing open.

Lubricate the ball-bearing clutch release (12) by keeping the grease cup located on the toe-board to the right of the accelerator pedal well filled, and give it one complete turn every 100 miles. Make sure that the clutch-release grease tube (34) (Fig. A) is tightly connected and unobstructed.

Removal of Clutch and Gearbox

(1) Break the universal joint; (2) drop the emergency brake rod; (3) remove the exhaust pipe completely; (4) block up the engine at the rear, just in front of the bell flywheel housing; (5) remove the bolts in the rear engine arms (47); (6) remove the bolts holding the bell housing flange (10) to the crank case; (7) drop the foot-brake rod; (8) disconnect the flexible grease-cup tube running from the floor board to the clutch throw-out; (9) slide the unit to the rear and lift it out.

Disassembly of Dodge Clutch

(1) Remove the two lockscrews in the clutch throw-out yoke (visible from the clutch hand-hole); (2) remove the two nuts on the clutch throw-out yoke; (3) remove the clutch pedal (38) from its shaft and loosen the brake pedal (39); (4) drive out the clutch shaft (32) to the left; (5) lift out the clutch unit; (6) apply the clutch puller (Fig. 41) to the complete clutch disassembly; the puller consists of a cross-member with a bolt terminating in a hook perpendicularly placed at each extremity; the hooks engage pins on the clutch; (7) draw down on the puller nuts until the clutch spring is sufficiently compressed so that the split locking ring may be withdrawn; (8) remove the split locking ring; (9) ease up on the puller nuts, and then remove the clutch spring; (10) clutch plates may now be taken apart.

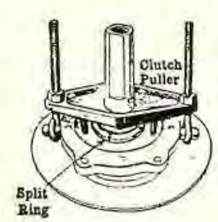


Fig. 41

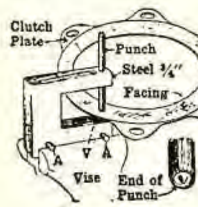
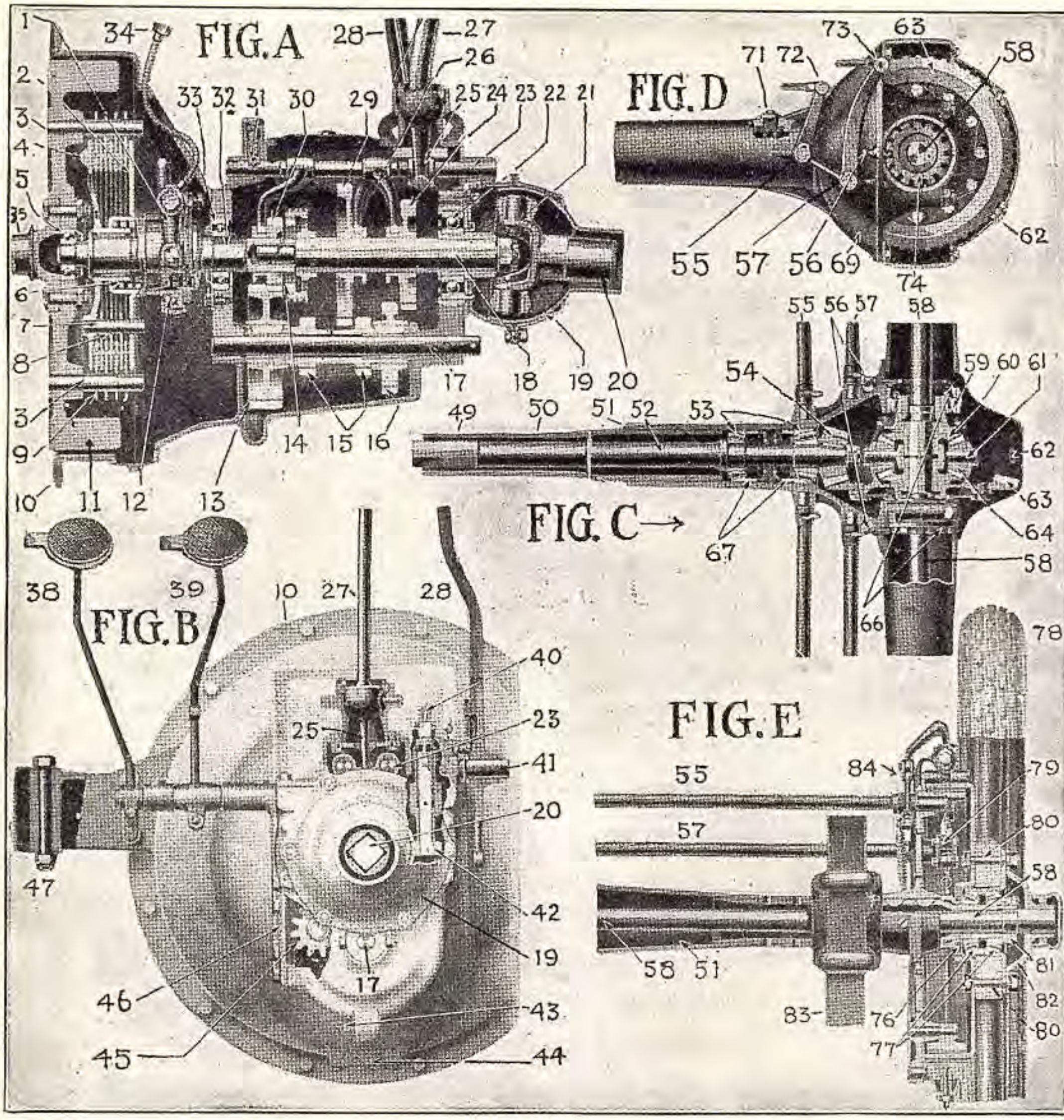


Fig. 42

To Replace Dodge Clutch

The facings come already cut and drilled, so it is merely a matter of riveting a new facing in place on the driving disks (9) (Fig. A). A tool especially designed for this purpose is shown in Fig. 42. The punch is made of a valve stem, hardened. In putting in the hollow rivets half of them should face one way and alternate ones in the opposite direction. This tool may also be used to rivet brake linings.

[1] Applies to 4-cylinder car, early model.



1. Clutch release fork.
2. Clutch pressure plate.
3. Clutch-driving disk pin.
4. Clutch spider.
5. Clutch-shaft front bearing.
6. Clutch spring.
7. Clutch-driven disk pin.
8. Clutch-driven disk.
9. Clutch-driving disk.
10. Housing, bolts to crank case.
11. Flywheel.
12. Ball-bearing clutch release.
13. Counter-shaft drive gear.
14. High-speed internal gear.
15. Counter-shaft low and reverse pinions.
16. Counter-shaft intermediate gear.
17. Counter-shaft.
18. Sliding-gear shaft, or transmission main shaft.
19. Universal-joint housing.
20. Universal hollow shaft; square drive shaft (49) fits inside.
21. Universal joint.
22. Sliding-gear shaft rear bearing.
23. Shifting shaft.
24. Intermediate sliding gear.
25. Shifting-shaft yoke.
26. Gear-shifting fork.
27. Gear-shift lever.
28. Hand-brake lever.
29. Low and reverse sliding gear.
30. High-speed sliding gear.
31. Shifting-shaft plunger.
32. Clutch shaft.
33. Clutch-shaft rear bearing.
34. Clutch-release grease tube.
35. End of engine crank shaft.
38. Clutch pedal.
39. Foot-brake pedal.
40. Speedometer drive shaft.
41. Hand-brake lever shaft.
42. Speedometer drive gear.
43. Transmission drain plug.
44. Clutch drain plate.
45. Reverse idler pinion.
46. Reverse idler-pinion bracket.
47. Support arm.
49. Square end of drive shaft, fits into (20).
50. Torque tube, fits to (19).
51. Rear-axle housing.
52. Drive or propeller shaft.
53. Drive-shaft roller bearings.
54. Drive pinion.
55. Foot-brake operating shaft.
56. Adjusting-ring lock screws.
57. Hand-brake operating shaft.
58. Rear-axle drive shafts.
59. Differential roller bearing.
60. Differential bevel gear.
61. Differential cross.
62. Lubricant level plug.
63. Bevel-driven gear.
64. Differential bevel pinion.
66. Bearing adjusting rings.
67. Drive-shaft bearing adjusting rings.
69. Differential carrier.
71. Adjusting ring lock.
72. Foot brake operating shaft lever.
73. Hand brake operating shaft lever.
74. Differential bearing adjusting ring lock.
76. Grease retainer.
77. Wheel roller bearings.
78. Tire.
79. Brake toggle joint—see page 884.
80. Rear wheel hub bolt.
81. Wheel-bearing adjusting nut.
82. Rear-wheel flange.
83. Spring.
84. Brake mechanism—see also page 884.

Dodge Rear Axle[1]

This will now be considered with special reference to Figs. **A**, **B**, **C**, **D**, and **E**, on page 858.

Noisy Rear Axle

When there is a constant singing or humming noise in the rear axle, with the humming increasing with speed, and the rear axle mesh seems stiff when the clutch is thrown out, it is usually due to the adjustment of the drive pinion (54) to the driven bevel gear (63) being meshed too tight.

When there is noise and back-lash, which is more noticeable when the clutch is "thrown out," and there seems to be a loose, jerky motion in the rear when the clutch is "thrown out," it is probably due to gears (54) and (63) not meshing tight enough.

Remedy: First see if there is oil on the teeth of the gears, by taking out the filler plug and placing your finger on the gear. Often heavy grease will not throw all the way round.

Adjustment: Ordinarily the adjustment of the drive pinion (54) is sufficient. If not, the driven bevel gear (63) must also be adjusted.

Note: **On other makes of cars having "helical" gears the same rules apply.**

In the later Dodge axle, only one adjusting ring is used at (67) Fig. C, the adjustment of propeller shaft bearings being made by hexagonal nuts at forward end of bearing retainer, it being necessary to remove the propeller shaft to make this adjustment.

To Adjust Drive Pinion

The whole drive shaft (52) (Fig. **C**) can be adjusted **endwise** to obtain the exact position of the driving pinion (54) which is rigidly attached to it, in relation to the driven bevel gear (63) bolted to the differential. Two adjusting rings (67), fitted against the two Timken bearings (53), can be screwed forward or backward to obtain the proper position of the bevel driving pinion (54). These rings can be reached by removing the ring lock (71) (Fig. **D**). All that need be done is to back off one adjusting ring (67) (Fig. **C**), and screw the other one ahead, in whichever direction it is desired to move the bevel driving pinion (54). Be sure that each is holding its bearing rigidly before replacing lock (71).

Adjustment of Bevel-Driven Gear

To test if the bevel gear (63) **is running quiet,** jack up the rear axle and run the engine, with the gears in direct drive, about 20 m.p.h., as indicated by the speedometer.

After adjusting the bevel driving pinion (54) as explained above, and if it is still noisy, remove the rear-axle cover plate and the two adjusting ring-lock screws (56), and readjust the bevel driven gear (63) to the new position of the pinion.

The large bevel driven gear (63) **can be moved either to the right or to the left in order to insure its quiet engagement with the driving pinion** (54), by operating the two bearing adjusting rings (66) (Fig. **C**) in a manner similar to those used in adjusting the drive pinion. After adjusting, they are locked in place by the adjusting-ring lock screws (56) (Figs. **C** and **D**).

Removal of Rear-Axle Shafts

The rear axle is of the seven-eighths floating type,[1] permitting the removal of the drive shaft (58) (Figs. **C** and **E**) without jacking up the car.

To remove rear axle shafts[1] (58) and flanges (82), simply unscrew the nuts on bolts (80), which hold the flanges to the hub of the wheel and remove them together with the axle shafts. If one axle shaft should stick, remove one on the opposite side, and drive or push the other one out with a long rod.

Lubrication of the rear axle: Use 5 pints,[2] if empty, of gear lubricant, or enough to fill the rear axle up to the level of the lower plug (62) (Figs. **C** and **D**). If grease leaks out from the rear wheels, the housing is too full.

To Disassemble Differential

(1) Remove axle shafts (58); (2) remove the inspection plate; (3) take the caps off the bearings and lift them out; (4) remove the cotter pins and nuts on the 4 studs which hold the differential unit together, and disassemble.

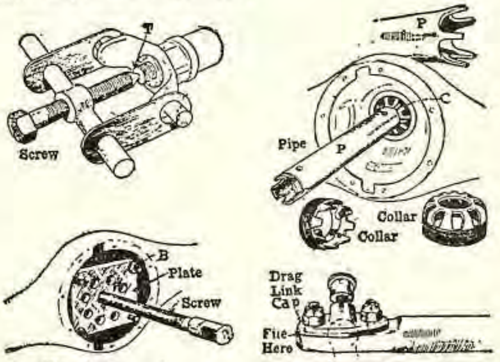


Fig. 43 (upper) Fig. 44 (lower)

Fig. 45 (upper) Fig. 46 (lower)

Fig. 43. Puller for front of universal joint.

Fig. 44. **To remove the drive pinion** (54), a plate is bolted to the 4 studs and pressure is applied to the shaft by the screw.

Fig. 45. **To remove the front bearing,** adjust collar (C) and turn to the left with a screwdriver. A special wrench for this purpose can be made of a piece of pipe (P).

Fig. 46. The drag link cap is filed to give adjustment.

Dodge Transmission

The Dodge transmission (page 858) main sliding-gear shaft is mounted on ball bearings at either end, and looseness means replacement of the bearings. The counter-shaft is mounted on bronze bearings. If the gearset is kept properly lubricated with clean oil, none of these bearings should need replacement in a good many thousand miles of driving. Not more than 2 quarts of gearset lubricant should be used in the case. The level should be inspected every 1,000 miles and, if it has fallen so low that the gears on the main shaft do not dip well into the lubricant, the supply should be replenished so that they do. The level should be kept ½″ below the main sliding-gear shaft.

REMOVING, DISASSEMBLING, AND ASSEMBLING TRANSMISSION (MITCHELL "F")

Removing the transmission from the car: Remove the two bottom floor boards and lift out the front-seat cushion as well as the stool on which it rests. This will completely expose the transmission.

Disconnect the rear universal-joint member and, placing a jack under the transmission, raise it just enough to take the load off the transmission hanger links. Remove the two large hanger link nuts on top of the frame cross-member.

The transmission, still connected to the torsion tube, can be lowered to the ground by lowering and then removing the jack. Take out the 8 cap screws holding the transmission to the torsion tube; the

[1] Applies to 4-cylinder car, early model. Semi-floating type used on later 4-cylinder car. To remove rear axle shafts, first remove wheels.

[2] 4 pints in semi-floating type of rear axle in the later 4-cylinder cars.

transmission can then be taken out from under the car.

Disassembling the transmission: With the transmission out of the car, remove the cover and clean out the lubricant. Removing the drain plug at the bottom of the transmission case will aid in this operation.

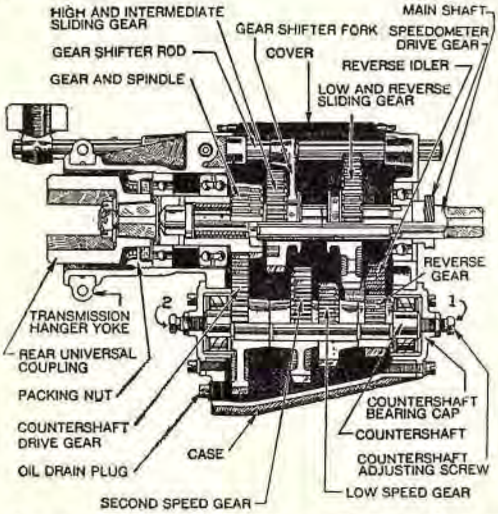


Fig. 47. Mitchell model "F" transmission used as an example.

Drive out the rear main-shaft ball bearing when the splined main shaft can be removed through the rear opening. In doing this the sliding gears will come off the main shaft and can be lifted out through the cover opening.

Care should be taken not to let the sliding gears drop as they come off the main shaft, since they may fall on the counter-shaft gears and get chipped. The small roller bearing supporting the front end of the splined shaft in the gear and spindle and the grease retainer may come out with the shaft, or may stay in the gear and spindle. Watch for them to see that they do not fall into the bottom of the transmission case and become misplaced.

Remove the pins holding the gear-shifter forks on their rods, and the rods can then be pulled out through the front of the case and the forks removed through the cover. In removing the rods it will be necessary to pull them out against the action of the spring locks which prevent the gears from coming out of mesh.

Remove the nut holding the universal-joint coupling to the front end of the gear and spindle and remove the coupling. Remove the lock holding the front-bearing packing nut and unscrew this nut.

Loosen the lock screws holding the large main gear and spindle double-row ball-bearing in place, and the gear and spindle complete with its bearings can then be removed by forcing it into the case and lifting it out through the cover opening.

Remove the front and rear counter-shaft bearing caps by taking out the cap screws which hold them in place. The counter-shaft roller bearings should be removed with the caps. The counter-shaft can then be moved back, tilted, and taken out of the case through the cover opening.

The gears can be removed from the counter-shaft only by the use of an arbor press. They should not be removed unless it is necessary to replace them.

The reverse idler gear can be removed by taking out the cotter pin in the end of the spindle and forcing the spindle into the case which removes the gear from it, when the gear and spindle may both be lifted out through the cover opening.

Assembling: When replacing the gear and spindle in the transmission case, do not set up the main-bearing lock screws tight enough to bind the bearing. They should be set up just tight enough to keep the bearing from turning in the case.

When reassembling the transmission and torsion tube, be sure that the speedometer drive gear on the transmission main shaft meshes with the small pinion in the front end of the torsion tube.

Adjusting the transmission: The only adjustment on the transmission consists of the two screws (1 and 2) (Fig. 47) located in the centers of the counter-shaft bearing caps. In reassembling the transmission, the counter-shaft should be so located in the case that the main counter-shaft drive gear is in full mesh with the large external gear on the gear and spindle. The adjusting screw should then be set up so that there is no end play on the counter-shaft, but allowing the counter-shaft to rotate freely without cramping or jamming.

The tension on the gear-shifting lever can be varied, and any tendency to rattle can be lessened by adjusting the splined nut found where the lever enters the floor boards. Remove the lock and unscrew this nut to decrease tension, or screw it down to increase tension and remove rattle. The ideal adjustment is such that there is little or no rattle and the lever does not bind or cramp in shifting gears.

Lubricating the transmission: The transmission is lubricated by filling it to a little above the center line of the counter-shaft with a high-grade semi-fluid lubricant of about the consistency of 600-W steam-engine oil. It will take about 2 quarts of oil to fill the transmission case to this point.

UNIVERSAL JOINTS

There are two types of universal joints in general use: the mechanical angular type, shown in Figs. 48 and 49 and the flexible-coupling or fabric type shown in Fig. 50.

The Spicer Universal Joint

A very popular type of universal joint is the Spicer, shown in Figs. 48 and 49. This universal joint can be used with an angular-drive or straight-line drive system, as explained on page 24.

The forward universal joint is provided with a dust cap (D) and a felt washer (W) on the rear end of the sleeve into which the end of the drive or pro-

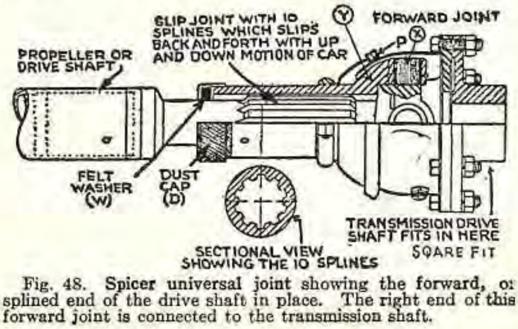


Fig. 48. Spicer universal joint showing the forward, or splined end of the drive shaft in place. The right end of this forward joint is connected to the transmission shaft.

peller-shaft slides. This cap should be turned to the right occasionally in order to keep the felt washer tight and prevent the leakage of grease. Both joints have flax packing (P) between the two parts of the pressed-steel casings.

This packing can be tightened by loosening the casing-adjusting screw (S) and turning the casing-adjusting nut or ring in a right-handed direction.

If the packing in the front universal joint is allowed to leak grease, the joint will not only suffer from lack of lubrication, but the grease will be thrown up on to the emergency brake, rendering the brake inoperative.

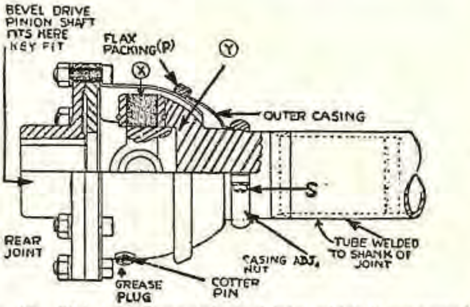


Fig. 49. This is the rear universal joint which is connected to the rear end of the drive shaft at the right end of the joint, and to the bevel-pinion drive shaft at the left end. Note that the splines are not used in this rear joint.

Lubrication: Every 1,000 miles remove the grease-hole plugs and fill with heavy gear oil or light cup grease. Too much grease will work out; about one-third full is the correct quantity.

Note. An "O" will be found on upper end of the propeller shaft tube (Fig. 48); a corresponding "O" will be found on the shank or rear end of the forward universal joint. When the propeller shaft and the universal joint are assembled, these two "O's" must be in line (as shown in Fig. 48), that is, the **yoke (Y) and journal (X) of the forward universal joint must be parallel to corresponding yoke and journal of the rear universal joint** (Fig. 49), otherwise the rear transmission bearing will be subjected to undue strain and excessive wear, and a jerky motion will be given to rear wheels.

Assembling: When the universal joints have been disassembled and are assembled again, care should be taken to see that the holes in the flange and the inside casings are matched up in such a way as to bring the **oil hole** (which is closed by a threaded plug) opposite an open space in the joint, and not opposite one of the lugs, which would prevent the introduction of grease through the hole. By removing this plug the user of the car can at any time inject additional oil or grease by the use of an ordinary grease gun, if the holes are matched.

Many of the joints are now fitted with a spring of suitable strength to give just the right pressure on the packing between the inner and outer casings. These require no attention from the operator. (Address of mnf'r.: Spicer Mfg. Co., South Plainfield, N.J.)

The Fabric Flexible Universal Joint

A type of flexible joint, connection, or coupling, as it could be termed, is shown in Fig. 50. This joint is generally used with drive shafts of the straight line drive, or what is nearly so, as explained on page 24. What angular movement there may be is the result of the flexibility of the flexible disks. These joints can be used with angular-drive systems (see page 24) where there is not too great an angular movement.

On each end of the driving, or propeller shaft, spiders (S) and (S1) are securely attached. Another spider (S2) is attached to the transmission shaft at the forward or driving end, and still another (S3) at the rear end which is attached to the drive pinion shaft.

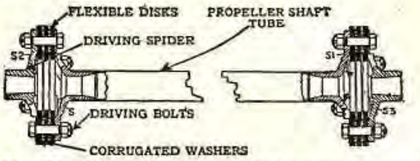


Fig. 50. The Thermoid-Hardy flexible connection, or joints that are used at each end of the propeller or drive shaft, instead of universal joints.

Three flexible disks, made of thermoid composition, are placed between the spiders and held securely by means of bolts and corrugated washers.

Note that with the use of these joints a splined shaft, as shown in Fig. 48 is not necessary.

By removing a few bolts the shaft may be removed.

Make sure that all bolts are kept tight, otherwise the holes in the fabric may tear out. New disks can be obtained at supply houses. Lubrication is not necessary.

The popularity of the fabric universal joint (Fig. 50) is to a large extent attributable to the poor lubrication methods used on many of the form-metal universal joints.

The lubrication systems, in some cases, were designed correctly enough, but, when assembled in the car, they were not within observation of the owner or driver and consequently received but scant attention. This could result in only one thing, and that was rapid wear with its accompanying knocks and lost motion. Some of the molded universal joints have been very much improved in this respect, and the Lincoln, for instance, makes provision for lubricating the front universal from the front gear case.

Disconnecting a Universal Joint and Clutch Mitchell Model "F" as an Example

Purpose of universal joint: Owing to the fact that the transmission is rigidly fastened to the front end of the torque tube and swings with it, there exists a certain amount of disalignment between the transmission and the clutch. For that reason a rigid drive or connection cannot be used, and a universal joint is employed. By means of hardened steel blocks sliding in hardened steel jaws the universal joint is given a flexible action which takes care of disalignment. See Fig. 51.

Removing the clutch and universal joint from the car: Disconnect the front universal joint member by compressing the grease retaining collar spring, taking out the half-shells and sliding back the cuff or housing. Slide the spring, rear grease-retaining collar, and cuff forward on the universal-joint shaft, and remove the whole universal-joint assembly.

Disconnect the clutch pull-rods by removing the clevis pins. Place two wood blocks 1⅜″ thick between the clutch cover and the ends of the clutch pull-rods, thus relieving the cover of spring, pressure when the 12 capscrews holding the drive in the three anchor pins, and the rings can then be readily removed.

Remove the nut holding the clutch hub on the crank shaft, when the whole clutch assembly can be slipped off the end of the crank shaft, the friction rings and disk remaining in the flywheel. To remove the friction disks, as when renewing them, drive in the three anchor pins, and the rings can then be readily removed.

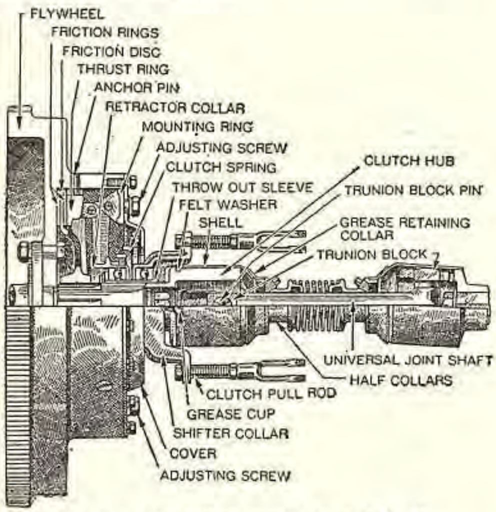


Fig. 51. Mitchell universal joint and clutch.

Disassembling the clutch: With the clutch removed from the car, exert pressure on the retractor collar and, removing the locking wire and blocks from the flange nut, unscrew this nut (left-hand thread), and the whole clutch can be disassembled as the pressure on the collar is released.

Adjusting the clutch: To adjust the clutch, loosen the two adjusting screws in the slotted holes in the clutch cover. Depress the clutch pedal, and push these screws ⅛″ to ¼″ in a clockwise direction to overcome slipping, and counter-clockwise to overcome dragging. Release the clutch pedal and tighten the adjusting screws.

When the screws have reached the end of their slots, a new pair of threaded holes will have entered the beginning of the slots. Transfer the screws to the new holes, and continue to adjust as occasion requires. When these holes, too, have reached the end of the slots, all possible adjustment will have been taken up and new friction rings should be put in the clutch.

After the clutch has been properly adjusted, it would be well to see that the clutch pedal does not strike the under side of the floor board, as this will cause the clutch to slip. If such is the case, it can be corrected by adjusting the clutch pull-rods until the clutch pedal operates freely through the floor board. (See also Index for Borg & Beck clutch.)

Lubricating the clutch and universal joint: The grease cup on the clutch pull-out yoke should be filled and turned down completely once a week, or every 500 miles.

Cup grease should be packed into the front and rear universal-joint housings through the plugs in the half-shells. This can be conveniently done with a grease gun, and should be done every 1,000 miles.

Removing Universal Joint Chevrolet "490" as an Example

For another example of removing a universal joint the Chevrolet 490 is shown as illustrated below. Note the procedure as explained under the illustration.

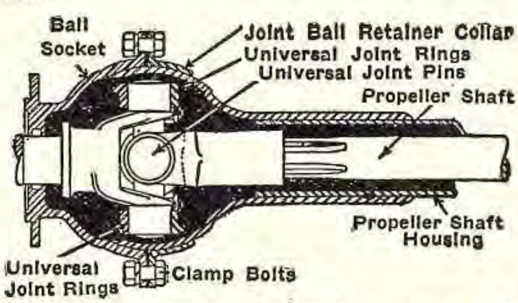
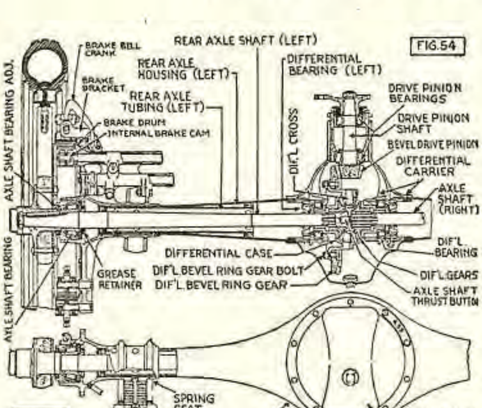


Fig. 52. The Chevrolet "490" metal universal joint. To remove, first remove the axle from under the car, take out the five cap screws holding the joint ball-retainer collar, and pull the ball joint from the socket. Remove the four clamp screws holding the two universal-joint rings together, and separate the rings. The nut holding the universal-joint yoke to the transmission shaft can then be removed and the yoke pulled off the shaft.

PARTS OF A REAR AXLE (See Page 863 for Explanation)



Figs. 53, 54. Names of parts of a rear axle (one-piece type housing, also termed "banjo" type). See also page 875.

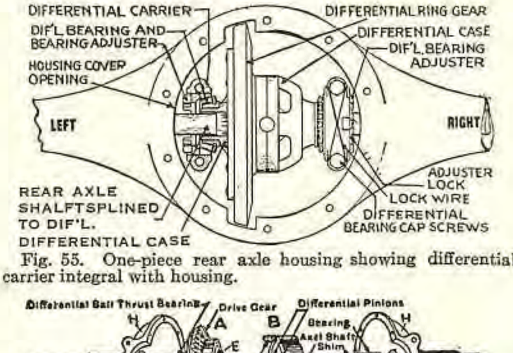


Fig. 55. One-piece rear axle housing showing differential carrier integral with housing.

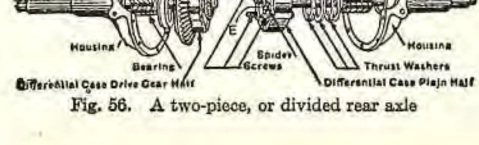


Fig. 56. A two-piece, or divided rear axle

LATER EXAMPLES OF CLUTCHES AND TRANSMISSIONS

Note: These pages, 862A to D, have been added since the preceding pages were prepared. Illustrations following exemplify later construction. Although it will be noticed that improvements and refinements have been made, the fundamental principles of operation are similar in many respects.

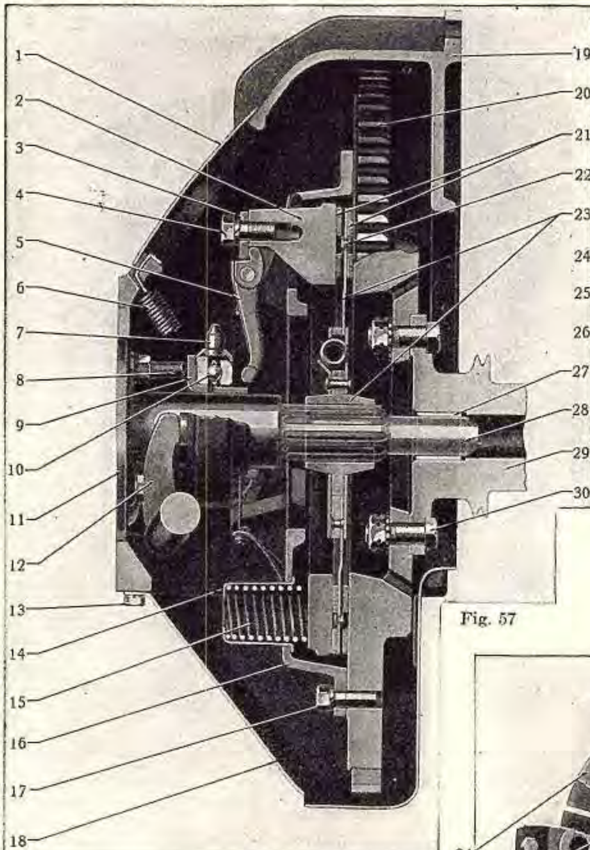


Fig. 57

Dodge Bros. Eight (1930) Clutch and Transmission

The clutch and transmission are built in a unit with the engine, termed a unit-power-plant.

Figs. 57, 58. **The clutch** is a single plate, dry type, comprising a pressure plate assembly 2, having six clutch springs 15, three clutch release levers 5, Fig. 57, and 39, Fig. 58, and a drop forged hardened steel splined hub. A spring-cushioned driving disc 23, having composition facing 21, riveted to each side, drives the splined steel hub and clutch shaft 28, Fig. 57, and 16, Fig. 60. The transmission driving gear 16, Fig. 60, is an integral part of the clutch shaft.

There is no **clutch adjustment,** except 1/8″ should be maintained between release levers 5, and clutch release bearing 10; adjusted through set screws 45 and 47. The clutch pedal should have 1 ¼″ to 1 3/8″ free movement before any resistance is felt; adjusted through stop screw 34.

1—Clutch hand hole cover
2—Clutch pressure plate
3—Clutch pressure plate pad
4—Clutch pressure plate pad screw
5—Clutch release lever
6—Clutch release bearing sleeve pull back spring
7—Clutch release bearing lubricant nipple
8—Clutch release bearing sleeve guide
9—Clutch release bearing sleeve
10—Clutch release bearing
11—Transmission main drive gear bearing retainer
12—Clutch release fork
13—Clutch housing dust pan screw
14—Clutch spring cup
15—Clutch spring
16—Clutch back plate
17—Clutch back plate screw
18—Clutch housing dust pan
19—Clutch housing
20—Flywheel
21—Clutch driving disc facings
22—Clutch driving disc facing rivet
23—Clutch driving disc and hub assembly
24—Clutch driving disc facing
25—Clutch driving disc stop pin
26—Clutch release lever spring
27—Transmission main drive gear pilot bushing
28—Transmission main drive gear or clutch shaft
29—Crankshaft
30—Flywheel bolt
31—Brake master cylinder reservoir cover tube
32—Brake master cylinder and reservoir
33—Signal lamp switch
34—Clutch and brake pedal stop set screw
35—Brake master cylinder outlet nipple
36—Clutch pedal adjusting collar
37—Clutch and brake pedal stop set screw lock nut
38—Clutch release fork
39—Clutch release levers
40—Clutch driving disc torsion spring
41—Clutch release lever pin
42—Clutch pressure plate pad screw
43—Brake pedal
44—Clutch pedal
45—Clutch pedal adjusting collar set screw
46—Clutch pedal adjusting collar set screw lock nut
47—Clutch pedal adjusting collar set screw
48—Clutch pedal adjusting collar clamp screw
49—Clutch and brake pedal pull back spring
50—Clutch and brake pedal stop bracket

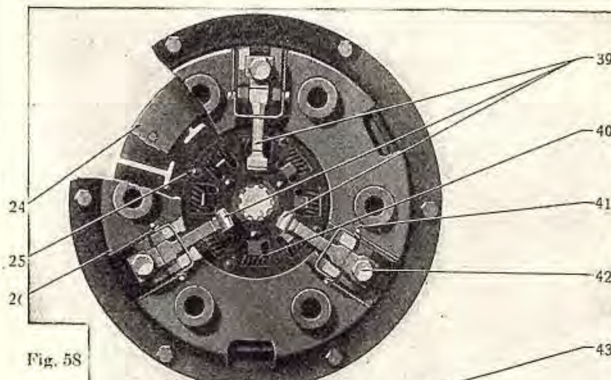


Fig. 58

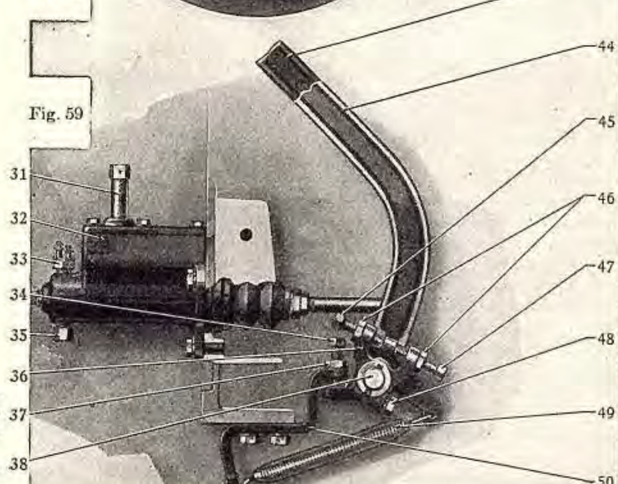


Fig. 59

Fig. 59. **Clutch pedal** 44, and **brake pedal** 43. The hydraulic four-wheel type of brake system is used. Brake pedal 43 is connected with a piston which operates in the master cylinder 32, actuating the brakes.

Lubrication of clutch is through nipple 7, with high-grade medium fibre grease every 15,000 miles.

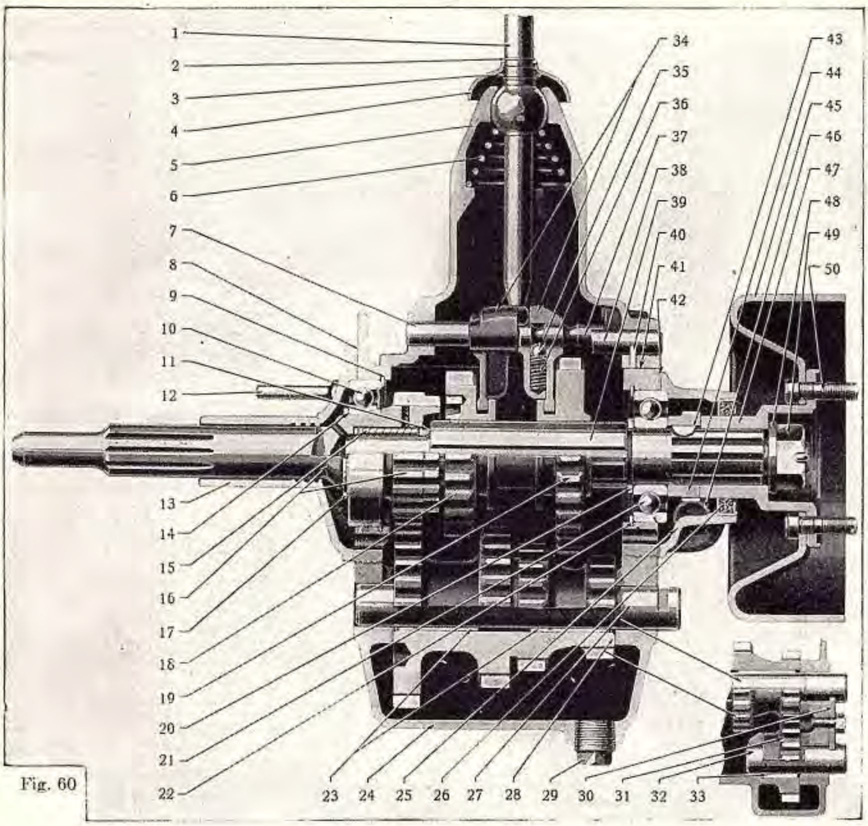


Fig. 60

Fig. 60. **The transmission** is a selective, sliding gear type built in a unit with the engine. There are three forward speeds and one reverse. The gear shift is the S.A.E. standard. The transmission drive gear 16 is an integral part of the clutch shaft. The high-speed gear 18 is of the internal tooth type, and the countershaft assembly is in constant mesh. The main shaft 39 operates on a ball bearing 21 in the rear, and a roller bearing 15 in the front (mounted in the main drive gear), and the countershaft gears are fitted with bronze bearings 23, and revolve on a stationary countershaft 27.

Lubrication of transmission: Fill to level of filler plug on left side with fluid gear lubricant. In winter, in very cold climates, this should be thinned by diluting with one-half pint of colorless kerosene. Once a season the case should be drained, washed with flushing oil, and refilled with fresh lubricant. For the proper grade of lubricant consult a Dodge dealer.

The names of the parts of the transmission are given below.

1—Gearshift lever
2—Gearshift lever dust cover snap ring
3—Gearshift lever dust cover spring washer
4—Gearshift lever dust cover
5—Gearshift housing
6—Gearshift lever spring
7—Gearshift rail—direct and second
8—Transmission main drive gear bearing retainer gasket
9—Transmission main drive gear bearing retainer ring
10—Transmission main drive gear bearing
11—Transmission mainshaft pilot bearing spacer
12—Clutch release bearing sleeve guide
13—Transmission main drive gear bearing retainer
14—Transmission main drive gear bearing snap ring shim
15—Transmission mainshaft pilot bearing
16—Transmission main drive gear and clutch shaft (integral)
17—Transmission main drive gear bearing snap ring
18—Transmission mainshaft sliding gear—direct and second
19—Transmission mainshaft sliding gear—first and reverse
20—Transmission mainshaft rear bearing washer
21—Transmission mainshaft rear bearing
22—Transmission mainshaft rear bearing retainer ring
23—Transmission countershaft gear bushings
24—Transmission case
25—Transmission mainshaft rear bearing retainer
26—Transmission mainshaft rear bearing oil washer
27—Transmission countershaft
28—Transmission countershaft gear
29—Transmission case drain plug
30—Transmission countershaft and idler shaft lock plate
31—Transmission reverse idler gear
32—Transmission reverse idler gear shaft
33—Transmission reverse idler gear bushing
34—Gearshift forks
35—Gearshift rail selector ball
36—Gearshift rail selector ball spring
37—Gearshift rail—first and reverse
38—Gearshift interlock rail
39—Transmission mainshaft
40—Gearshift rail lock plate
41—Gearshift housing gasket
42—Transmission mainshaft rear bearing retainer gasket
43—Speedometer drive gear key
44—Speedometer drive gear
45—Transmission brake drum
46—Speedometer drive pinion
47—Transmission mainshaft companion flange
48—Transmission mainshaft companion flange washer
49—Transmission mainshaft companion flange nut
50—Propeller shaft bolt (transmission end)

Studebaker Clutch and Transmission (Series 61, 70, 80 and 90)

Clutch: double plate dry type in 80 and 90 and single plate in series 61 and 70 (not illustrated), and transmission (Fig. 61) are built in a unit with the engine, termed a unit-power-plant.

The transmission is of the sliding gear type with three forward speeds and one reverse. The S.A.E. standard gear shift is used on all Studebaker cars with **additional** shifting lever positions for cars equipped with the free-wheeling transmission, briefly discussed on page 642B. The **free-wheeling** transmission is used on the President, Commander and Dictator. The maufacturers claim that there is a saving on gasoline and oil and longer life of the engine.

The free-wheeling type of transmission is so-called because it permits the car to glide freely and quietly, with low engine speeds, although the transmission is in gear and the clutch engaged.

When the gears are in the free-wheeling position the engine drives the car in the usual manner, but after the engine has pulled the car up to the desired speed it may be permitted to idle and rest while the car "free wheels" on, unrestricted by having to drive the engine at an equivalent speed. The effect is much the same as that obtained by disengaging the clutch. The transmission accomplishes this automatically, quietly and instantly whenever the car speed exceeds the speed of the engine. When the throttle is closed, the car continues to glide freely until its forward speed finally comes down to the engine idling speed.

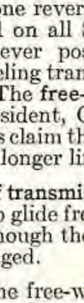
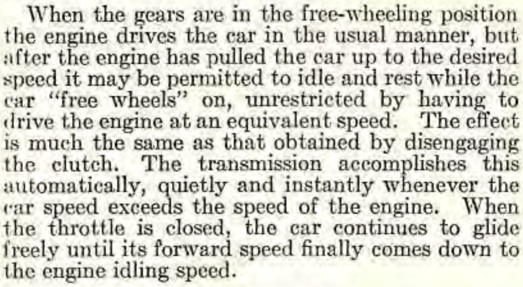
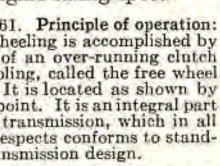



Fig. 61. **Principle of operation:** Free-wheeling is accomplished by means of an over-running clutch or coupling, called the free wheel unit. It is located as shown by arrow point. It is an integral part of the transmission, which in all other respects conforms to standard transmission design.

Basically, the free-wheel unit is made up of **two main sections:** an outer casing and an inner core, each independent of the other. Between this outer casing and inner core are three series of four rollers each, which run in tapered grooves or raceways.



The **outer casing** is driven by the engine; the **inner core** drives the propeller shaft, which transmits power to the rear wheels. When the engine is "pulling," the three sets of hardened steel rollers are forced into the narrowed ends of their respective raceways, exerting a positive driving force on the inner core, which transmits the power to the wheels.

When the throttle is closed, the engine, of course, immediately slows down, and with it the outer casing. The natural forward motion or momentum of the car keeps the inner core spinning, carrying the rollers to the wide ends of their tapered raceways. This instantly releases the grip which provides the drive. The car is freed from the engine and continues to glide forward. Yet the clutch is engaged and the gears are in mesh.

Free-wheeling is entirely automatic, and **begins the instant car speed exceeds the speed of the engine.** Step on the accelerator again, and as soon as the engine speed equals the speed of the car, the outer casing again wedges the rollers into the narrow ends of the raceways and instantly the engine is pulling the car. **In other words, the engine can drive the car but the wheels cannot drive the engine,** except when the transmission is in positive or conventional drive positions.

The free-wheeling feature is included in both the second-gear and third-gear positions. If, however, the operator **does not desire to make use of the free-wheeling feature, pressing a small button** in the top of the shifting lever ball permits the shifting lever to be moved slightly farther back than normal for second-gear (Fig. 66), or slightly farther ahead for third-gear (Fig. 67). These are the **positive or conventional drive positions,** as in the usual type of transmission, and the transmission operates to drive the engine as a brake. This is a particularly important feature when it is desired to use the engine to brake the speed of the car, as in descending a steep hill or mountain.

The shifting lever positions for the positive or conventional positions, and the free-wheeling positions follow.

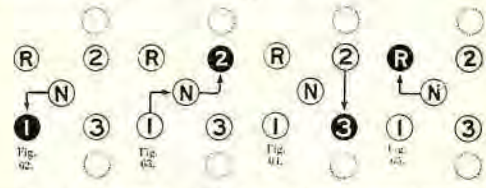


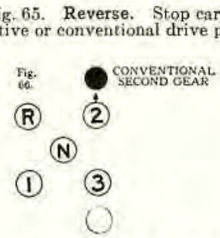
Fig. 62. **First-gear.** This is a positive or conventional drive position.

Fig. 63. **First to second-gear, free-wheeling.** Disengage clutch and shift as in the usual manner.

Fig. 64. **Second-gear to third-gear, free-wheeling.** It is not necessary to disengage the clutch when changing from one free-wheeling position to another, as from second-gear to high gear or high gear to second-gear, it is only necessary to reduce the engine speed by **fully releasing the pressure on the accelerator:** however, if the operator so desires, the shifts may be made with equal ease, using the clutch. The button located at the top of the shifting lever should not be pressed down when making the shifts described above.

Note: If the operator wishes to shift from free-wheeling second-gear to free-wheeling third-gear before the car speed equals the engine speed (possible when getting under way very slowly from a stop), the clutch may preferably be disengaged, and the shift made in the usual manner.

Fig. 65. **Reverse.** Stop car. Disengage clutch. This is a positive or conventional drive position.



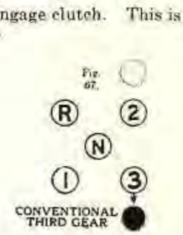


Fig. 66. **Second-gear free-wheeling to second-gear conventional (positive) drive.** Clutch is not disengaged. To shift to the conventional drive second-gear, the transmission should first be in the second-gear free-wheeling position. Increase speed of engine until it is pulling car. Then **press down on the button** on top of gear-shift lever. Apply a forward pressure to the lever. While continuing to apply the forward pressure on the gear-shift lever, release the foot accelerator slightly. The lever will then continue forward into conventional second-gear location.

Fig. 67. **Third-gear free-wheeling to third-gear conventional (positive) drive.** This gear selection is made in the same manner as in Fig. 66, except that the gear-shift lever is pulled back to the third-gear conventional drive position rather than pushed forward.

Conventional third to free-wheeling third, or from conventional second to free-wheeling second: Disengage clutch for either of these operations, then pull the lever back, if in second, or push it forward, if in third-gear, to the desired position. A **click** will be heard when the free-wheeling position is reached.

The movement of the shifting lever in making these shifts is a very short one.

The button on the gear-shift lever should not be pressed down to make the shift from a conventional drive position to a free-wheeling position.

The shift from free-wheel third-gear to conventional second-gear may be required in mountainous territories where the operator desires to use the engine as a brake to reduce speed of car on down grades. Shift can best be made without disengaging clutch. Shift to second-gear free-wheel position and then increase speed of engine until it is pulling car. Press down on button on top of gear-shift lever and, applying a forward pressure to lever, release foot accelerator and lever will move into the conventional second-gear position.

Cadillac Clutch and Transmission, Series "452" V-16

Clutch: Dry plate type; 10″ diameter with two driven discs.

Transmission: Known as the **syncro-mesh** transmission, **purpose** being to secure **noiseless shifting** of the gears by automatically synchronizing (or equalizing) the speeds of the two members which are to be coupled together before the shift is made. After the shift is made, the syncro-mesh mechanism automatically releases.

This synchronizing effect, Fig. 68, is brought about by a pair of friction clutches of simple cone-type, which are actuated by the control lever through a cam mechanism. As the control lever leaves the neutral position, it engages one or the other of these clutches just long enough to synchronize the two members, so that when the final movement of the control lever is made, the teeth which interlock to take the drive are traveling at exactly the same rate of speed.

The synchronizing principle applies to all shifts into intermediate or high; in other words, to the following shifts: low to intermediate, intermediate to high, and high to intermediate. There is no synchronizing mechanism for low or reverse gears because shifts into these gears are usually made when car is standing still. (See also page 642D.)

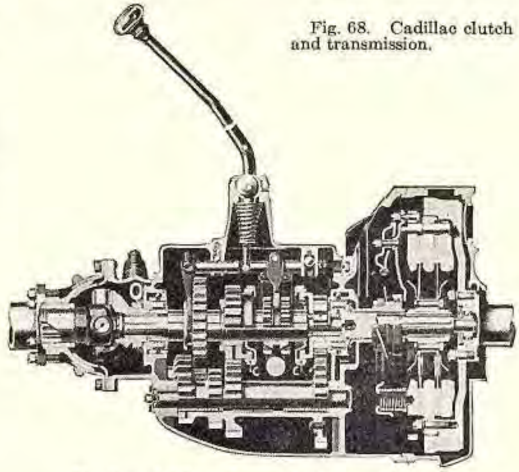


Fig. 68. Cadillac clutch and transmission.

Packard Clutch and Transmission, "Eighth" Series

Clutch: Dry plate type. Models 826, 833 are equipped with single-plate clutch; models 840, 845 have a double-plate clutch. (See Fig. 69 below.)

Transmission contains a selective gear set giving four speeds forward and one reverse.

The four-speed gear shift (Fig. 70). Low or first speed is geared lower than first or low speed on former cars using the three-speed transmission. It is used for unusual heavy work; second speed is geared higher than former first. It is used for starting; third speed is geared higher than former second. It is used for accelerating; fourth-speed drive is direct from engine to rear axle, the same as the former third speed. It is used for high speed and moderate speed driving. For specifications of Packard and other cars see pages 1055–1062. For **driving compartment** see page 642C.

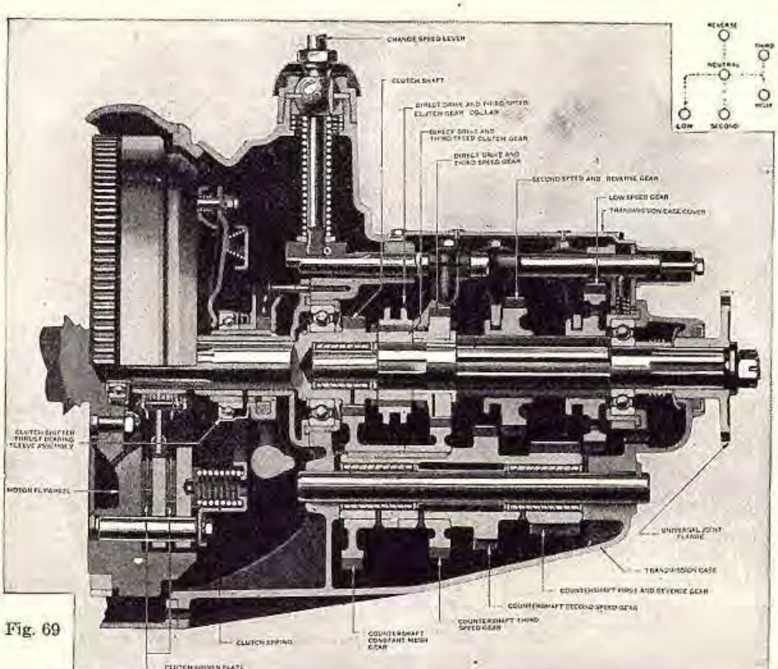


Fig. 69

Fig. 69. Packard clutch and transmission. Fig. 70 (top right-hand corner). Packard gear shift.

INSTRUCTION No. 73

REAR WHEELS, DIFFERENTIALS AND REAR AXLES FOR PASSENGER CARS: Types; Adjustments, and Repairs[1]

TYPES OF REAR AXLES

This subject is also treated on pages 15 and 16. Types are the "plain live" (used on the model "T" Ford); the "semi-floating," which is used most; the "three-quarter floating," and the "full-floating."

To find the make and type used on different cars see Index, "Specifications of Passenger Cars."

The S. A. E. distinctions between the types of rear axles are as follows:

Dead axle: An axle carrying road wheels with no provision in the axle itself for driving them.

Live axle: General name for type of axle with concentric driving shaft. See also pages 15, 16.

Plain live axle: Has shafts supported directly in bearings at center and at ends, carrying differential and road wheels. (The plain live axle is further described on page 15.)

Semi-floating axle: Has differential carried on separate bearings, the inner ends of the shafts being carried by the differential side gears, and the outer ends supported in bearings.

The semi-floating axle shaft carries torsion, bending moment, and shear. It also carries tension and compression if the wheel bearings do not take thrust, and compression if they take thrust in only one direction.

Three-quarter floating axle: Inner ends of shafts carried as in semi-floating axle. Outer ends supported by wheels, which depend on shafts for alignment. Only one bearing is used in each wheel hub.

The three-quarter floating axle shaft carries torsion and the bending moment imposed by the wheel on corners and uneven road surfaces. It also carries tension and compression if the wheel bearings are not arranged to take thrust.

Full-floating axle: Same as three-quarter floating axle except that each wheel has two bearings and does not depend on the shaft for alignment. The wheel may be driven by a flange or jaw clutch.

The full-floating axle shaft is relieved from all strains except torsion, and in one possible construction, of tension and compression.

Advantages of the semi-floating axle (by Packard Motor Car Co.): In the semi-floating axle, the wheel hubs can be made slightly smaller and, because of the location of the bearings, the stresses in the rear axle can be kept lower than in the full-floating type.

There is a slight advantage also in the bearings, as the full-floating type have to use a bearing with a smaller ball, since it must fit around the rear-axle tube. In the semi-floating type, the bearing has a smaller bore, and therefore larger balls can be used, as the bearing has only to go over the axle shaft.

Another advantage is that the rear wheels can be more readily removed when replacements are necessary, wheels being replaced oftener than shafts. Still another advantage claimed is that of lubrication, as the outer bearings can be lubricated from the inside, and an oil retainer can be placed on the outside, while the full-floating type must have a separate supply of lubricant for the rear-wheel bearings.

Rear-axle ratios (see pages 8 and 9). **Types of drive** (see page 6).

Rear-axle housing is made in "one-piece" or "two-piece" type. Fig. 53, page 862, shows a one-piece type, and Fig. 56, a two-piece type. The halves (H) are termed **right and left halves.**

The bevel-gear housing (Fig. 54) is that part where the bevel gears are enclosed. The **differential carrier** is that part which carries the differential. On some it is bolted to the axle housing, as in Fig. 19, page 871, and on others it is integral with the axle housing, as in Figs. 54, 55. The **rear-axle tube** is shown in Fig. 54, one right, the other left. **Rear-axle shafts** (semi-floating in this example) are right and left. The **rear-axle housing cover** is the plate over the one-piece housing. The **rear-axle spring seat** may be under or on top of the housing. Other parts are shown in Figs. 53, 54.

Removing Rear-Axle Shafts

On "full-floating" and "three-quarter-floating" type of rear axles, the axle shafts can be withdrawn without removing wheels.

On most of the "semi-floating type" of rear axles, the axle shafts can be withdrawn without removing rear-axle assembly, but wheels must first be removed and then the outer wheel bearing nuts and bearings (see pages 15, 16, 864, and 883).

On a "plain live axle" having a two-piece or divided rear-axle housing, the complete rear-axle assembly must be removed in order to remove the rear-axle shafts. See pages 880 and 1096.

Removing Differential

On those types of floating rear axles having a "one-piece" housing and a **cover plate** and where the "differential carrier" **is integral with the rear-axle housing,** the differential can be removed by removing the axle shaft, then removing the differential bearing caps from the carrier integral with the axle housing (Fig. 55), after which the differential can be withdrawn at the rear of the housing.

On those types of rear axles having a one-piece housing with "differential carrier" bolted to rear-axle housing (Figs. 18, 19, page 871), the differential with drive pinion can be removed by withdrawing axle shafts, loosening differential carrier, and removing complete assembly (Fig. 19, page 871), through the **front** part of the axle. Then the differential can be disassembled and adjusted on the removed carrier.

On those types of rear axles having a "two-piece" or divided rear-axle housing which is bolted together in the center, the complete rear-axle assembly must be removed from the car in order to remove the differential, as shown in Figs. 56, page 862 and 41, page 880, Fig. 28, page 921.

TIMKEN REAR-WHEEL BEARINGS; ADJUSTMENT AND LUBRICATION[2]

As an example of the semi and full-floating types of rear axles, and the method of attaching the axle shafts to the rear wheels, and of how the bearings are placed, we will use the Timken rear axles and wheels.

Semi-Floating or Fixed Hub Types

Timken fixed-hub or semi-floating rear axles are used on light and medium-weight passenger cars. In this type of construction the wheel is keyed to the

[1] See Index under "Truck axles." See pages 1103–1106 for Wheel bearings; adjustment and lubrication.

[2] Applies to early models.

axle drive shaft, the shaft revolving in a bearing mounted in the housing just inside the wheel. See Fig. 1, page 864. This bearing should be cleaned, greased, and adjusted at least once a year; more often if the service is severe.

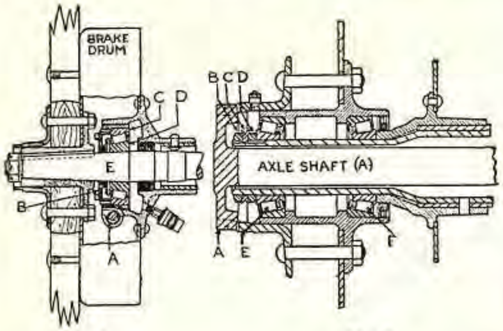


Fig. 1 Fig. 2

Fig. 1. Timken rear-wheel hub as used with the semi-floating rear axle (see also page 883).

Fig. 2. Timken rear-wheel hub as used with the full-floating type of axle.

To clean the bearing, remove the wheel from the axle shaft, using a wheel puller if necessary.[1] Now release the locking finger (A) which prevents the bearing adjusting ring (B) turning, and unscrew this ring from the housing, carrying with it the bearing cup (C). The ring having been removed, **pull out the axle shaft** (E) on which is pressed the bearing cone (D), and the rollers. With a stiff brush and gasoline or kerosene clean off all old grease from the bearing cup, cone, and rollers, and from the end of the housing into which the adjusting ring is screwed. In order thoroughly to remove all old grease, the bearings should occasionally be placed in a solution of washing soda and water and brought to a boil.

Lubrication of bearings: After carefully cleaning and drying the bearing, cover well with good, clean cup grease free from acid and dirt, grit, and other solid matter. Also pack the end of the housing with grease.

Adjustment: Now replace the shaft with the bearing cone and rollers and screw on the adjusting ring carrying the bearing cup. The **adjustment** of the bearing is made by turning up this ring.

In adjusting wheel bearing, remember that the two drive shafts, right and left, come in contact in the center of the differential spider (see Fig. 3, page 865). If the bearing on one side is adjusted in too far, while the bearing on the other side is too far out, the spline end of the shaft will project through into the other side of the differential. This will either lock the differential or cause the end of the shaft to be twisted off. Care must be used, therefore, to take up the same amount on both right and left-hand bearings.

Screw up the bearing adjusting ring (B) (Fig. 1) until all end play is taken out of the shaft and until the shaft turns stiffly when revolved with a wrench placed on the nut on the shaft end. Then back off the ring one notch and lock in this position by means of the locking finger. The wheel may now be replaced, care being taken to tighten up well on the nut on the end of the shaft and to lock it with a cotter pin.

[1] See Index under "Wheel pullers."
Applies to early models.

Full-Floating Type

Timken full-floating rear axles are used on heavy passenger cars. In this axle the entire weight of the car is carried on the axle housing; each rear wheel has two bearings mounted in the hub similar to the front wheel (Fig. 2). These bearings should be cleaned, re-greased, and adjusted at least once a year—more often if the service is severe.

To remove the bearings, take off the hub cap (not shown) jack up the wheel, and pull out the axle drive shaft (A). Wipe the grease from the end of the housing tube and the lock nuts. Now take off the outer lock nut (B), the thin lock washer (C), and the inner lock nut (D). The wheel may now be removed. Kneel directly in front of it and, grasping the rim with both hands, pull toward you. Be careful not to allow the outer bearing (E) to fall to the floor, which may bend or otherwise damage the cage.

To clean parts: With a stiff brush and gasoline or kerosene, clean all the old grease from both outer and inner bearings and from the inside of the wheel hub. Occasionally both bearings should be placed in a solution of water and washing soda and brought to a boil. This cleans off any grease behind the rollers which may not have been removed by the brush.

Lubrication of wheel bearings: When the bearings have been thoroughly cleaned and dried, replace the inner bearing (F) on the axle tube, covering it well with good clean grease free from all acid, grit, or solid matter. Care should be taken to see that there is no dirt on the paddle. Repack the space in the hub between the two bearings and cover the outer bearing with grease.

Replacing wheel: Now replace the wheel, and, holding it firmly in position, slide the outer bearing on the tube end, pressing it firmly into the hub. Screw up the inner lock nut, turning it up tight against the bearing so that the wheel binds, at the same time revolving the wheel to be sure all working surfaces on the bearing come into contact.

Now back off the nut enough to allow the wheel to turn freely, but not enough to give any noticeable looseness or end play. Replace the lock washer and screw up the outer lock nut tightly against it.

Bearing adjustment: Before replacing the axle shaft, be sure that your bearing adjustment is right. The wheel should be loose enough to oscillate, that is, when spun, it should come to a stop and then start to turn back in the opposite direction, but not loose enough to have any amount of shake. Check this adjustment after tightening up the outer lock nut, as it is sometimes possible, when using a large wrench, to turn the nut so tightly against the inner nut as to destroy the adjustment.

Lubrication of wheel hubs, etc.: Having obtained a good bearing adjustment, cover the end of the tube and the lock nut with grease, and slide in the drive shaft. Fill the hub cap with grease and screw it on the hub, being careful to get it tight.

Cautions

1. Don't jam lock nuts so tight that the wheel binds. A wheel should oscillate when given a slight spin (in other words, come to a stop and turn slowly back in the opposite direction).

2. Don't allow the lock nuts to be so loose that you can shake the wheel and feel the play in the bearings. Too loose an adjustment will damage a bearing just as rapidly as too tight an adjustment.

3. Don't take rollers, cone, cage, or cup from one bearing and substitute these parts in another bearing even though it bears the same number. After a bearing has once been used, the parts differ from an unused bearing one to two one-thousandths of an inch—not enough to see, but enough to cause trouble and expense if parts are substituted. If a bearing must be replaced, because of damage, replace the entire bearings.

4. Don't hit the cage with a hammer to drive a bearing on a spindle; you will bend the cage and damage the bearings.

5. Don't use a screwdriver or other sharp tool back of the cage to pry a bearing off a spindle—you will bend the cage. If a bearing cone sticks, be sure the tool is placed behind the edges of the cone. A slight pressure is sufficient to release the cone from the spindle.

6. Don't let bearings fall on the floor; you may bend the cage which keeps the rollers in line.

7. Don't use grease or other lubricant that contains acid or has acid-forming qualities. Use only a good grade of lubricant; see pages 1104–1106, "*Wheel Bearings.*"

8. Don't drive cups in hubs or other retainers, nor cones on spindles, with a hammer where a pressed fit is required.

ADJUSTMENT OF TIMKEN BEVEL-GEAR REAR AXLES[1, 2, 3]

There are three conditions which make adjustment of drive pinion, differential gears, and bearings necessary: (1) noise; (2) excessive backlash in gears; (3) loose pinion or differential bearings. Noise is the most common condition. Be sure the drive-pinion shaft bearings and differential bearings are properly adjusted.

Timken-Detroit fixed-hub or semi-floating rear axles are built in two sizes—series 5151 and 5152 for light cars, and 5301 and 5302 (Fig. 4) for cars of medium weight. **Full-floating axles** for heavy cars are built in one size only—series 5762 (Fig. 5). The construction of these axles is shown in detail in Figs. 4 and 5. The **principles of adjustment** are the same in any case; the figures show the slight differences in the details of design.

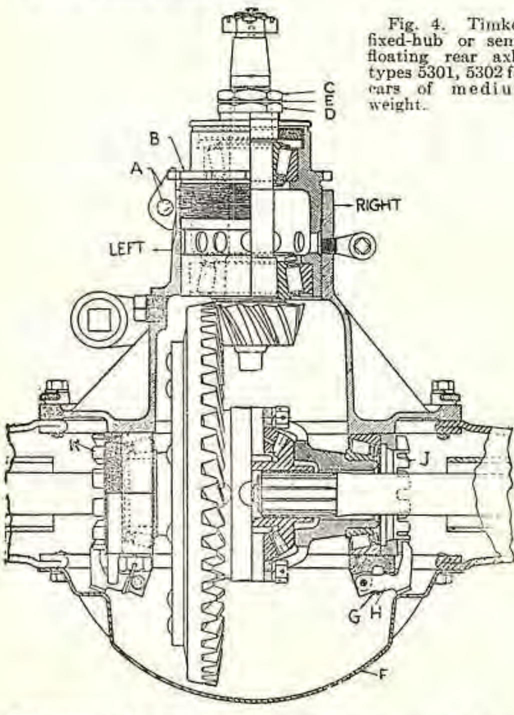


Fig. 4. Timken fixed-hub or semi-floating rear axle, types 5301, 5302 for cars of medium weight.

To adjust for elimination of noise, remove the clamp bolt and lock at (A), and turn the sleeve (B) containing both the pinion bearing and the pinion shaft one notch to the left. Replace the clamp bolt and lock, and run to see if the noise is lessened or increased. If the noise is less, turn the sleeve to the left until the quietest point is found; if it is increased, turn the sleeve to the right until the best point is found. Do not forget to replace the clamp bolt and lock each time before running to test your adjustment.

To take up excessive backlash, remove the cover (F). Now loosen the differential-bearing cap bolt-lock wire (G), and disengage the lock (H) from the adjusting rings (J) and (K). When this has been done, loosen the right-hand adjusting ring (J) and tighten the left-hand ring (K), thus forcing the ring gear against the pinion. Turn both rings the same number of notches until the proper amount of backlash, approximately five one-thousandths of an inch, has been obtained. After adjusting, be sure that the lock is replaced and is held by the wires before replacing the cover.

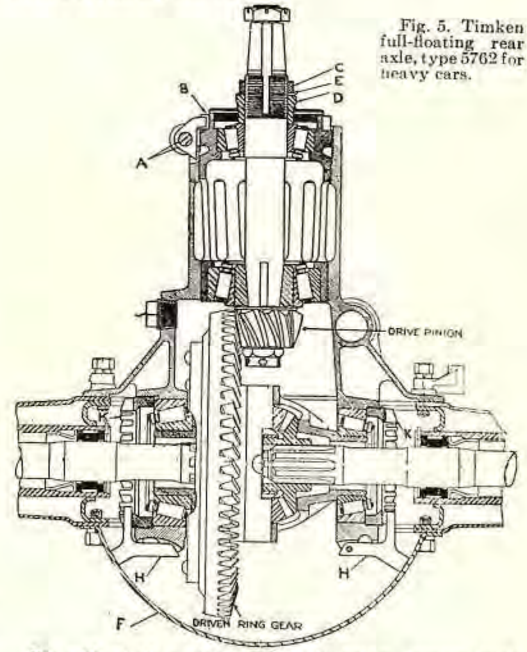


Fig. 5. Timken full-floating rear axle, type 5762 for heavy cars.

To adjust the pinion-shaft bearing, loosen lock nut (C) and then tighten up on adjusting nut (D) until the shaft will turn freely but with only very slight end play. The end play should be about five one-thousandths of an inch after tightening the lock nut. Tighten up the lock nut (C) and peen over the washer (E), so as to lock both nuts.

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[1] Timken axles (Figs. 4, 5) could represent either a semi-floating or a full floating axle because the differential supports the inner ends of axle shafts. The next principal feature which determines whether it is a semi-floating or full-floating axle is found in the type of hub used. See also pages 15 and 863.

If the semi-floating wheel hub (Fig. 1, page 864) **is used,** it is termed a semi-floating axle.

If the full-floating wheel hub (Fig. 2, page 864) **is used,** it is termed a full-floating axle.

[2] Applies to early models.

[3] **Rear-axle lubrication** (see p. 867).

If noisy gears result from this adjustment of the bearings, eliminate the noise by the adjustment described.

Adjustment of the differential bearing is made by tightening up on the adjusting rings (J) and (K) after releasing the lock (H). Tighten up on these rings until the differential turns freely, but without end play. If excessive backlash results from this adjustment, take up as previously outlined.

Gears are properly adjusted (1) when the axle is quiet; (2) when the gear teeth engage for their entire length; (3) when there is but little backlash between the gears; (4) when there is no end-play in the pinion shaft; (5) when all adjustments are securely locked.

After making adjustments, make sure that all locking keys, cotters, wires, etc., are replaced and that all bolts and cap screws are properly drawn up. If a car is run to try the effect of any adjustments, all bolts and cap screws must be properly tightened.

Lubrication: The pinion and ring gear and the differential gears and their bearings are lubricated by the oil in the axle housing. Keep the housing filled to the level of the oil hole in the bowl with a good quality of rear-axle lubricant. See also p. 867.

To lubricate the drive-pinion bearings, keep the sleeve (B) well filled with a good quality of rear-axle lubricant. Lubricant can be introduced into this sleeve through the street ell at the side of the carrier casting, and this point should receive special attention when the axle is first put into service. Be sure that the sleeve is filled to the height of the lip, and put in additional lubricant from time to time to make up for any leakage.

Adjustments of Later Models of Timken Bevel-Gear Rear Axles

The rear axle drive pinion and bearing adjustments (Figs. 6, 7, 7A) are on later types of Timken bevel-gear rear axles than those shown in Figs. 4 and 5; however, they also are early models.

Adjustment of Timken drive-pinion shaft bearing (Fig. 6): Remove cap screws (O) and (X) which hold the bearing cage (L). After removing cage, add or remove shims (M) until properly adjusted, which is about .003" loose, or the thickness of thinnest shim.

Adjustment of drive pinion gear (Fig. 6) **to eliminate noise and backlash,** is made by loosening cap screws (O) and turning (B).

Adjustment of differential bearings is made by tightening up on adjusting rings (J) and (K) as explained above.

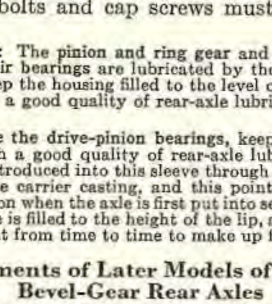


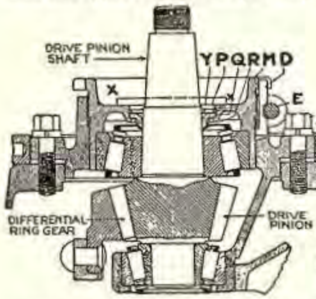
Fig. 6. Timken Model 5014, rear-axle drive pinion adjustment. Note oil seal (Q). Adjustment of bearings, by removing shims (M); adjustment of mesh of drive pinion and ring gear, by turning (B).

Adjustment of Timken drive pinion for backlash and elimination of noise (Fig. 7): Loosen cap screws (A) and turn adjusting ring (B) about 2" to the left. Tighten (A) and run axle to determine whether noise has increased or lessened. If lessened, continue adjustment by turning (B) to left until quietest point is found. If noise is increased, then adjust (B) to right to obtain quietest running position. Tighten (A).

Adjustment of drive pinion shaft bearing (Fig. 7): Remove lock bolt (E) and lock (D), and turn adjusting cap (M).

Adjustment of differential bearings is made by tightening up on adjusting rings (J) and (K), as explained.

Oil Seal: In Figs. 6 and 7 there is a hydraulic cup leather (Q) oil seal used on drive-pinion shaft. The seals need no attention, as a special tension spring (Y) keeps the leather cup tight. After long use it may be necessary to replace (Q). If so, remove lock wire (P) and outer tension spring (Y). This releases the tension on the cup leather (Q) which can be removed. To remove axle-shaft oil seal, it is first necessary to pull out axle shaft from housing. This oil seal is also used on fixed hub types of axle shafts, as on page 883.



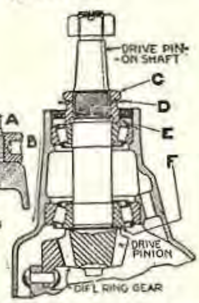


Fig. 7 (left). Timken Models 5114, 5140, rear-axle drive pinion. Note oil seal (Q). Bearing adjustment, by turning (M); mesh of drive pinion and ring gear, by turning (B).

Fig. 7A (right). Timken Model 0500, rear-axle drive pinion. Bearing adjustment, by turning (E); mesh of drive pinion and ring gear, by removing or adding shims (F).

Adjustment of Timken drive pinion shaft bearings (Fig. 7A): First straighten lock washer (D). Loosen lock nut (C). Tighten adjustment nut (E) until shaft turns freely without noticeable end-play. Tighten (C) and peen over (D).

Adjustment of drive pinion for backlash to eliminate noise (Fig. 7A): Move drive pinion in toward ring gear by adding shims (F). To move drive pinion in opposite direction, remove shims (F) as required.

Adjustment of differential bearings is made by tightening up on adjusting ring (J) and (K), similar to explanation on this page.

The Timken Axle Shafts

From the differential the power is carried to the wheels by the axle shafts. They must be strong enough to resist the greatest possible torque under any conditions of travel. Yet they should be as light as is consistent with perfect safety.

Where the shaft enters the differential, it is enlarged, the end is splined, and steel is left back of the splines.

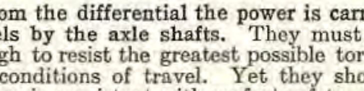


Fig. 8

At its wheel end the shaft of the **full-floating axle** is enlarged to form an integral (not welded) disk or "driving dog" (Fig. 8), which fits into the driving plate of the hub and turns the wheel (Fig. 2, p. 864). In the fixed hub or **semi-floating** type of axle shaft, the wheel end is keyed (Fig. 8) to the wheel (Fig. 1, p. 864).

ADJUSTMENTS OF REAR-AXLE BEVEL GEARS AND BEARINGS (GENERAL)

The general principles of adjusting differential assemblies remain essentially the same as has been described in the foregoing, that is: **pinion bearings** are adjusted by shims or by a nut; **differential bearings** are adjusted by threaded adjusting caps or sometimes by shims; the **pinion is moved** rearward or forward by shims to decrease or increase lash and obtain the proper tooth contact; the **ring gear is moved** to the right (to decrease lash) or to the left (to increase lash) to obtain the **proper tooth contact,** by threaded adjusting caps or sometimes by transferring shims from one side to the other. The **major differences** are the details in the instructions for adjusting, the clearances allowed, and the tools required. The information regarding proper and improper bevel **gear-tooth contact,** as described on pages 869 and 870, applies to present (1936) bevel gears.

Types of pinion-shaft bearings: There are several bearing arrangements used in mounting pinion shafts. There are two types of mountings, namely, (*1*) **stub shafts,** in which all of the bearings are to the front of the pinion, as shown in Fig. 7A: (*2*) **straddle-mounted shafts,** in which there are bearings on both sides of (straddling) the pinion, as shown in Figs. 6 and 7. There are several kinds of bearing combinations used, the most common of which are: (*1*) two tapered roller bearings on a stub shaft to withstand both radial and thrust loads, as shown in Fig. 7A; (*2*) straddle mounting with two tapered roller bearings in front of the pinion to take thrust and some of the radial load and a straight roller bearing to rear of pinion to take most of the radial load; (*3*) stub mounting with a double-row ball bearing to take thrust loads and a straight roller bearing to take radial loads, as shown in Fig. 8A; (*4*) stub mounting with a double row, wide spaced, ball bearing; (*5*) stub mounting with two single-row angular contact ball bearings.

Types of differential bearings: Practically all differential assemblies are mounted with a bearing on each side of the ring gear, as shown in Figs. 4 and 5 and other illustrations of rear axles in this book. There are two kinds of bearings in most common use for this purpose, namely, (*1*) tapered roller bearings, as in Figs. 4 and 5, and (*2*) angular-contact ball bearings, as in Fig. 8A.

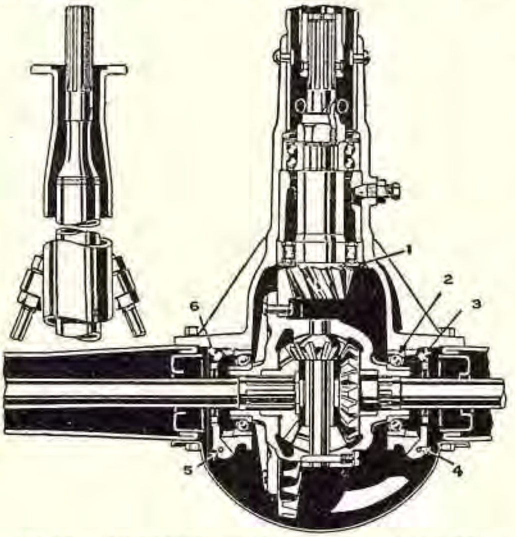


Fig. 8A. Differential mounted on angular contact ball bearings; pinion mounted on ball bearings and a straight roller bearing. Type of gearing is spiral bevel. At the left, is shown the front part of the torque tube and the radius rods. (*Buick Series "40" 1936.*)

Adjustments

The detailed instructions vary to some extent on different cars, particularly for different types of bearings. Therefore, manufacturer's instructions should be followed. *Pinion-setting micrometer gauges* are often used for determining "depth" of pinion contact as described in some manufacturer's instructions; but when not available, adjustment by observing the tooth contact is satisfactory.

Tooth contact can be determined by painting the gears with white lead or red lead and rotating the gears, which will scrape off the paint at the points of contact. Before attempting adjustment, thoroughly analyze the contact, as explained on pages 869 and 870, so as to determine what adjustments are necessary. See also "Ring gear backlash adjustment, using a dial indicator."

Adjustment procedure: The following instructions are not applicable in all cases but represent a typical example of adjusting an angular contact ball-bearing differential assembly, as shown in Fig. 8A.

Pinion-bearing adjustment: No adjustment is required of the pinion bearings shown in Fig. 8A.

Differential side bearing adjustment: (*a*) Remove adjusting nut locks (*4, 5*) Fig. 8A. (*b*) Back off right bearing-cap screws (not shown) 1 1/2 turns and tap cap lightly with hammer to free bearing races (*2*) and adjusting nut (*3*). (*c*) Mark position of both adjusting nuts (*3, 6*). (*d*) Watch outer race of right bearing turn with adjusting nut, as nut is slowly backed off, and stop when race stops turning. Mark this new position of the adjusting nut and return to original position. Repeat, backing off adjustment nut, and again stop when bearing race stops turning with nut. This should be same as before, and the number of notches between original position and "free" position of nut are the "notches tight" of the bearing. *Correct adjustment is not less than one nor more than two notches tight.* (*e*) If the bearing race did not turn when backing off the adjusting nut, the bearings have "lapped" free, or one of the bearings has "locked" and turned on the hub of differential case. Before investigating further, determine how loose the bearing was by drawing up the adjusting nut until outer race just starts to turn with the nut. (*f*) Equalize the adjustment between right and left bearings, that is, if race started to turn with first movement of nut "*in*" but did not turn when backing "*out*" the nut, tighten right nut one notch and tighten left nut one notch—total two notches tight. (*g*) Draw down cap screws lightly and tap both caps with hammer to permit seating of bearings, then tighten down cap screws. NOTE: When differential side bearing adjustment is found to be less than one notch tight, investigate the cause. Look for side bearing loose on hub of differential case or ball bearing failure. (*Buick Shop Manual, 1936.*)

Pinion adjustment: To move the pinion toward the ring gear, instal shims at (*1*). To move the pinion away from ring gear, remove shims from (*1*).

Ring-gear backlash adjustment (using a dial indicator): (*a*) Thoroughly wash all oil from gear teeth of gear and pinion with clean gasoline. (*b*) Inspect adjustment of differential side bearing, as instructed above. (*c*) Clamp dial indicator, which is graduated in .001", to axle-housing rim so that indicator button bears against the working surface or a ring gear tooth near the outer edge of the gear and to indicate movement in the direction that the gear rotates. (*d*) Lightly rock the gear back and forth to take up all clearance between teeth of gear and pinion, using care that the indicator is so adjusted to give accurate reading. This is the direct reading of *backlash and should not be less than .006" or more than .010" for new gears*, with slight increase over .010" for gears which are worn.

To decrease backlash, the ring gear should be moved to the right by backing off the right adjusting nut (*3*) and tightening the adjusting nut (*6*) the *same number* of notches. *To increase backlash*, back off (*6*) and tighten (*3*) the *same number* of notches.

Diagnosis of Rear-Axle Noise

When diagnosing rear-axle noise, be certain that the noise is not caused by the tires, engine, fan, or transmission. The next three paragraphs are taken from the 1936 *Buick Shop Manual:*

Tire noise changes with different road surface conditions, but **rear-axle noise** does not. *Rear-axle noise* usually ceases when coasting with gears in neutral at speeds under 30 miles per hour. *Tire noise* continues, but with lower tone, as car speed is reduced. Axle noise always changes when comparing "*pull* and "*coast*." Tires which have the surfaces of the non-skid divisions worn with one end higher than the other are usually noisy. This is particularly true with low tire pressure. Pressures up to 60 lb. may be used for comparable test purposes. Front tires are as likely to sound like rear-axle noise as are rear tires.

Transmission and engine noises occasionally are confused with rear-axle noise. To best isolate these noises, first observe approximate car speed and condition where supposed rear-axle noise is most pronounced; then, with the car in a quiet place to avoid interfering noises, and car stationary, hold out the clutch with transmission in high gear and run engine up and down slowly through engine speeds corresponding to car speeds at which axle noise was most pronounced and observe for sound similar to axle noise. Next shift gears to neutral and again run engine at similar speed, while slowly letting clutch engage to observe for idling noises of transmission.

Noises which cannot be isolated as above are likely to be found in rear axle. (See also p. 873.)

Rear-axle lubrication: *Use only lubricants recommended by the car manufacturer.* The S.A.E. viscosity numbers generally used, under normal operating conditions, for transmission and differential gears, pinions, worm drives, and roller and ball bearings used in connection therewith, are S.A.E. 140 for summer and S.A.E. 90 for winter. See page 1062B. Where manufacturers specify *extreme pressure (EP) lubricants,* such as for hypoid and other gears with a high tooth pressure and temperatures, it is important that only such lubricants should be used in order to prevent scoring the tooth surfaces. *When adding EP lubricants,*[1] *it should be the same kind;* otherwise flush it out thoroughly. See also pages 1104–1106 for **lubrication of front and rear wheel bearings.**

It is important to drain and flush the axle at certain mileage intervals, as given by the manufacturer. Some manufacturers specify that, after draining, flush with flushing oil (not kerosene). Remove plug in back of housing and drain with suction gun, or remove capscrews at lowest point in differential housing and blow out with low-pressure air.

[1] **There are two types of EP lubricants:** "*powerful extreme pressure lubricants,*" having very high load-carrying capacities; and "*mild extreme pressure lubricants,*" which have a higher load-carrying capacity than straight mineral oils but less capacity than that of powerful EP lubricants. ***Consult car manufacturers' recommendations, as there is a definite use for each type.***

TIMKEN ROLLER BEARINGS

The subject of bearings is treated on page 19. An explanation of the Timken roller bearing which takes a thrust or radial load is given below.

The different places on a car where roller or ball bearings are generally used are the front wheels, the transmission, the pinion drive shaft, the differential, and the rear wheels.

The parts of a Timken roller bearing are shown in illustration below (Fig. 9), and are as follows: (1) the cup or outer race; (2) the roller bearings; (3) the cone or inner race. (**Note:** On the later designs of Timken bearings, the nibs are omitted from the ends of the rollers and a wingless steel cage is used.)

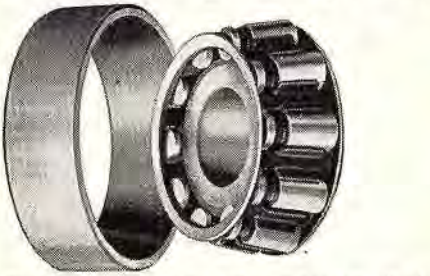


Fig. 9. **Timken tapered-cone type of roller bearing.** Used for wheel bearings, axle bearings, and different parts of the car. The part to the left is called the cup or outer race in which the rollers revolve. Note that the cone, or inner race, is the part underneath the rollers. This part fits onto the shaft and the cup fits into the bearing space.

The cone should have a **floating-fit** on all **non-rotating shafts,** such as front-wheel spindles and full-floating rear-axle sleeves.

The cones should have a **press fit** on all **rotating shafts,** such as semi-floating rear-axle drive shafts, pinion shafts, worm shafts, belt-pulley shafts, and transmission shafts; except where it is necessary to move the cone on the shaft to make adjustment, in which case the cone should have a light-press fit. (Be sure that all cones are seated firmly against the shoulders on the shafts.)

Cups: The ideal mounting for all Timken cups is a press fit in such mountings as wheel hubs, pinion housings, differential housings, belt pulleys, worm-shaft housings, and transmissions. Where the cup must be moved to make adjustment, it should have a **light press fit.** (Be sure that all cups are seated solidly against the shoulders in their mountings.)

On mountings where shim adjustment is used, the cups are usually pressed into a retainer or cup-holder which, when installed, is bolted to the housing with shims between the flange of the retainer and the housing. Adjustment on such mountings is made by moving the retainer farther into the housing until all end play is taken out of the bearings.

This can be done by removing the retainer and taking out one or more shims. If adjustment is made too tight, causing a bind in the bearings, one or more shims should be added.

The subject of direct mounting and indirect mounting of bearings on a worm shaft is explained under the discussion of truck rear axles (Timken), as is also the subject of how to compute the worm-gear ratio.

The adjustment and lubrication of the front and rear wheel bearings, transmission, and differential are given in the explanations of the different Timken axles and wheels in this instruction, and also in the instruction dealing with front wheels and under the truck rear-axle subject.

ADJUSTMENT OF COLUMBIA THREE-QUARTER FLOATING REAR AXLE

The Columbia rear axle, illustrated below, is the model 50,000 Columbia three-quarter floating type of rear axle, as used on passenger cars weighing 3,200 to 4,000 lbs., equipped for road service. Some of the cars using this axle are the Cole, King, Premier, National, Du Pont, Kenworthy, and Ogren.

To remove axle shafts: Unscrew the six acorn nuts on the axle flange and pull out the shafts (Fig. 10).

To remove the differential assembly: Having first taken out the axle shafts, remove the ten cap screws on the face of the carrier, as indicated on 2, Fig. 10, remove the cam brackets which extend over the face of the carrier and which come off freely after the cap screws are out, and the carrier will then fall out of the housing. All brake connections may remain intact during this operation.

To adjust drive pinion bearings: This is required only when the drive pinion shaft is loose, that is, when you can move the drive pinion shaft forward or backward. This can be determined by prying between lock nuts and carrier (Fig. 10). This adjustment is made with the two nuts (Fig. 10) where it reads: "Never loosen these two nuts unless end-play has developed."

To adjust drive pinion: Remove the locking plate (2, Fig. 10) on the neck of the carrier, held in position by two screws and lock washers, loosening the locking bolt next to this plate which clamps the pinion adiuster in the neck of the carrier. Insert a flat tool, usually a blunt screwdriver, into the notches on the pinion adjustment and turn either to right or left as you wish the pinion closer to or farther away from the ring or master gear.

Turn the pinion adjustment to the right, if you desire to move the drive pinion forward (toward front of vehicle), or to the left, if you desire to move the drive pinion backwards and thus bring the back faces of the drive pinion and ring gear to proper position. Move the adjustment only one or two notches (not complete turns) in one direction or the other until the quietest running position has been secured. Replace the locking plate and tighten the locking bolt.

Adjustment for noise: Put the pinion closer for "drive noise," and farther away for "coasting noise," see "Gear Contact."

To adjust ring gear: Do not make this adjustment unless absolutely necessary and after having tried the other adjustments. The thrust of the drive pinion always forces the ring gear toward the **left** rear wheel (left as when seated in car); consequently the adjustment is usually towards the **right-hand** rear wheel in practically every case, owing to excess wear on the left-hand differential bearing. This adjustment is made by turning the left-hand differential bearing adjustment (**A**) (Fig. 10). Sometimes the adjustment may have to be made on the right-hand adjustment (**A**) (Fig. 10); this should not be done however, unless you can pry against the ring gear and it shows a slight end play toward the right.

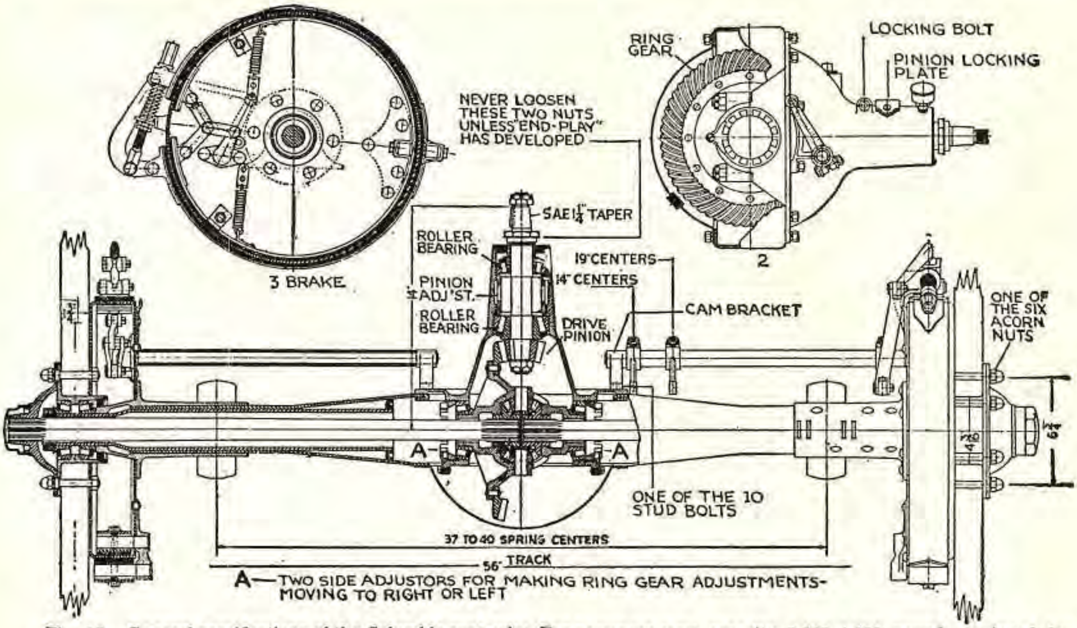


Fig. 10. **General specifications of the Columbia rear axle:** For passenger cars: capacity 3,200–4,000 pounds, equipped for road without passengers; three-quarter floating type; one-piece rear-axle housing, with full-length reinforcing tubes; heavy-duty tapered roller bearings; alloy steel spiral bevel gears, case hardened and heat treated; adjustment provided for pinion and differential; alloy steel pinion shaft and drive shafts scientifically heat treated; sixteen-inch adjustable internal and external brakes. See page 891 for description of the brakes. **Lubrication:** Use Whitmore's No. 9 in summer, and Whitmore's No. 33 in winter, or Mobiloil "C," or Polarine "A," or Enarco medium.

Note. To reach the differential bearing adjusters **(A)** (Fig. 10), it is first necessary to remove the locking wires and to loosen two cap screws and remove the caps (not shown in the illustration).

If it has been finally determined that the ring gear must be moved to secure proper gear contact, the whole assembly must be moved, by releasing the adjuster locks on each side and then backing off one of the adjusters **(A)** a notch or two in the direction you wish to move the ring gear, following this by screwing **in** (toward the ring gear) on the adjuster **(A)** on the **opposite** bearing. Thus you are moving the whole assembly and maintaining the bearing adjustment.

The differential ring gear is always placed on the left side of the differential (left side as when seated in the car), because the crank shaft and propeller shaft revolve clockwise, and thus drive the rear wheels forward. See Fig. 10, and also Fig. 3, page 6. Owing to this fact, the thrust is always to the left side of the differential, and thus there is more wear on the left bearing.

BEVEL GEAR CONTACT

Proper gear contact and properly lubricated gears will assure the efficient transmission of the engine's power to the rear driving wheels, providing that the differential and pinion bearings are performing their functions properly.

In order to understand more clearly the meaning of **"gear contact,"** the following terms are illustrated and described.

Terms Used in Describing Gear Contact

Pitch line: A line drawn near the middle of the tooth (see Fig. 11).

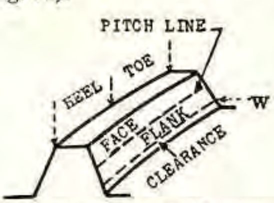


Fig. 11. Descriptive terms as used in connection with gear teeth.

Working depth: That part of a tooth which is opposite the end of the tooth with which it meshes, see **(W)** (Figs. 12 and 11).

Clearance: The distance from the working depth to the bottom of the tooth (see Figs. 12 and 11).

Face: That part of a tooth which lies between the pitch line and the end of the tooth (see Fig. 11).

Flank: That part of a tooth which lies between the pitch line and the working depth (see Fig. 11).

Toe: The inside or smaller half of a tooth (see Fig. 11).

Heel: The outside or larger half of a tooth (see Fig. 11).

Backlash: The difference between the thickness of a tooth and the space into which it meshes (the play) (Fig. 12).

Fig. 12

Fig. 13

Fig. 12. **Explanation of backlash, clearance, and working depth (W).**

Fig. 13. **Full-face contact** (shown in black).

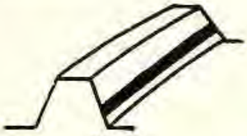


Fig. 14

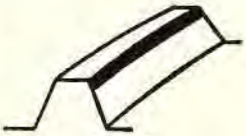


Fig. 15

Fig. 14. **Flank contact** (shown in black).
Fig. 15. **Partial face contact** (shown in black).

Fig. 16

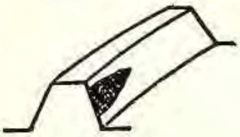


Fig. 17

Fig. 16. **Toe contact** (shown in black).
Fig. 17. **Heel contact** (shown in black).

Gear Contact as Applied to Columbia Rear-Axle Gears[1]

The complete driving assembly is adjusted, locked and tested at the Columbia plant, then tested and readjusted if necessary by the manufacturer, under the vehicle; consequently it is not often necessary for the user to adjust any of these parts, except possibly the bearings.

The pinion shaft and gear revolve in a fixed carrier and may only be moved directly forward or backward. The **ring gear** also revolves in the same fixed carrier and may only be moved directly toward one rear wheel or the other. The **bearings** hold these parts from moving in other directions, consequently, proper **gear contact** may be secured by moving the pinion or ring gear in the proper directions, as the axis of each should remain fixed.

Familiarize yourself with the names of the gear-tooth faces (Fig. 11), so that you may understand the other illustrations (Figs. 12 to 17).

Backlash: All contacting gears must have a certain amount of **play** or **space** between the teeth, that is, the tooth of one gear must never entirely fill the space between two teeth of the mating gears (see Fig. 12). This avoids excess wear, breakage, noise, or decreased efficiency. Too much "backlash" is just as destructive as too little. The practical limits of "backlash" to which gear manufacturers work are .005″ minimum to .015″ maximum (five to fifteen one-thousandths of an inch). There may be slight variations from these figures.

The desired gear contact under load is a full-face contact along the entire length of each contacting tooth (see Fig. 13). If the gear cutting, heat-treating, and mounting has been perfect, the proper "backlash" is shown when gear teeth show good contact—running from 75 per cent to full-face contact of tooth.

Flank contact (Fig. 14) is caused by the pinion gear being **adjusted too far back** (toward the rear of the vehicle). This condition often **decreases** the "backlash" and usually causes a grinding noise.

Partial face contact (Fig. 15) is caused by the pinion gear being **adjusted too far forward** (toward the front of the vehicle). This condition **increases** the "backlash" and may cause tooth chipping.

Toe contact (Fig. 16) is caused by moving the ring gear **too far toward the right** rear wheel. This also **decreases** the "backlash," and may cause tooth chipping or breakage.

Heel contact (Fig. 17) is caused by moving the ring gear **too far toward the left** rear wheel and **increasing** the "backlash" to undesirable limits.

Never adjust gears until you know the existing tooth contact. To determine this, remove the rear cover plate and thoroughly clean the pinion and ring gear of oil. Mix powdered red lead with light oil to the consistency of paste and paint a number of the teeth on the ring gear.

Jack up the car (both wheels) and run in high gear for a few minutes, then throw into reverse and run for a minute or so, applying the brakes at intervals to make **close** tooth contact, then examine the teeth on the ring gear and the paint will clearly show the tooth contact existing.

Then remove the inspection **plug (oil-filler plug)** and actually view the contact when possible, by throwing light on the pinion gear while the cover plate is removed. If not correct, cautiously proceed to adjust the pinion gear or ring gear, as previously explained.

ADJUSTMENT OF SALISBURY REAR AXLE; THREE-QUARTER FLOATING TYPE

The trade name or term applied to this construction would be "Pressed Steel Type," and is **three-quarter floating** in design.

To remove the axle shafts: This can be accomplished without the use of the jack, as the full weight of the car can still be left on the wheels, or with the axle shafts removed, since there is no possibility for the wheels to come off. Remove the wheel-drive flange (**F**) (Fig. 18) by unscrewing nuts (**N**). The flange with the axle shaft can then be pulled out.

To remove the wheel for any purpose, such as for replacing the wheel bearing, this can be done after the flange and axle shaft are removed. The wheel, with the hub and bearing, is held in place on the axle tube by lock nuts and washers. With these removed, the wheel with hub and bearing can be pulled off.

To remove the bearing from the hub, first remove the spring wire, and the bearing lock nut can then be unscrewed and the bearing removed.

The differential gear carrier (Fig. 19) **as a unit can be removed from the axle proper,** after first disconnecting the propeller shaft and universal joint, by removing the carrier screws which bolt it to the housing. First, however, the axle shafts must be pulled out.

In order that the spiral bevel ring gear (**G**) (Fig. 18) **and drive pinion** (**P**) may operate correctly, they must be in perfect alignment, that is, the differential axis must be in the same plane as the pinion axis; at the same time there must be a correct amount of back lash between the pinion and the gear. To that end two means of adjustment are provided.

The differential on which the ring gear (G) (Fig. 18) **is mounted may be moved toward either side,** as required, by turning one of the adjusting nuts (**A**) to the left, and turning the other to the right an

[1] From Columbia Axle Co.'s Service Manual, by permission. Copyrighted, 1922.

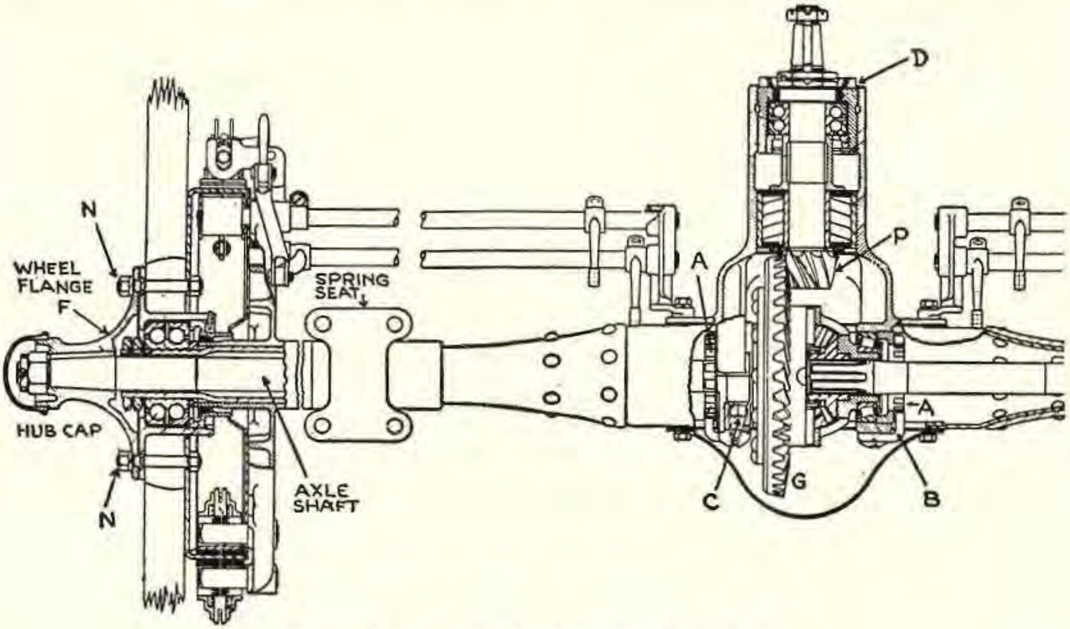


Fig. 18. Salisbury rear axle; three-quarter floating type.

equal amount, after the locking fingers (B) have been removed, and the screws (C) in the bearing caps have been loosened.

The drive pinion (P) may be moved forward or backward by turning the adjusting sleeve (D) in which the pinion shaft is mounted. Moving the pinion-shaft adjusting sleeve or the differential adjusting rings one notch is equivalent to approximately four one-thousandths (.004") inch at the point of contact between the pinion and ring gear.

The amount of back lash necessary to insure quietness of action is ordinarily between ten one-thousandths (.010") and twenty one-thousandths (.020") of an inch, depending upon the cut of the gears and the variation which takes place in their manufacture. The proper amount of back lash or clearance should be arrived at, however, only after it is known that the ends of the teeth on the pinion are flush with either the inner or outer ends of the teeth on the ring gear.

To arrive at the proper running position of these gears, in order that their teeth may have a full line contact and at the same time operate with quietness, see explanation given on pages 870, 874.

Brakes on Salisbury Rear Axle

There are four points of adjustment on each set of brakes (Fig. 20). The adjusting screws (E) and (H) are the means of providing the proper **clearance at the rear of the internal and external bands** when released, and should be adjusted to allow an opening between the brake drum and the linings on the brake bands of not more than 1/32".

The adjusting nuts (K) which control the setting of the **lower halves of the external bands** are next to receive attention in the proper order of adjustment. The jam nuts must be loosened and the adjusting nuts regulated to give a maximum clearance of 1/32" around the lower halves of the bands. Should the linings touch the drums at any point, as a result of their not being a true circle, a screwdriver should be inserted and the band forced away. When the adjusting nuts are properly regulated, they should be relocked by the jam nuts.

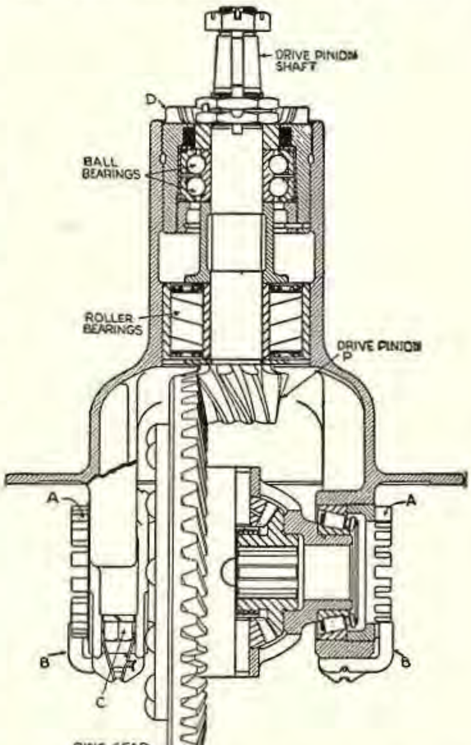


Fig. 19. Differential gear carrier unit. The words "differential gear carrier," or "gear carrier," refer to the unit in which the gears are carried. On this axle, note that the entire unit is removable.

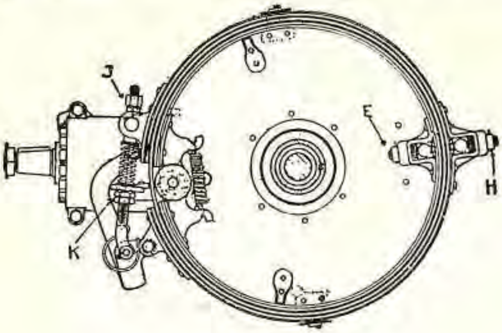


Fig. 20

The clearance between the top halves of the external bands should be regulated to a maximum of 1/16″ by means of the nuts (J). This difference in clearance of 1/32″ between the upper and lower halves is rendered necessary by the action of the bell cranks, which tend to tighten the upper half to the drum sooner than the lower half is tightened.

When the brakes are released, the pedal should be close to the floor board and the centers of the eyes of all levers on the cross-shafts in the frame should be from 1″ to 1¼″ to the rear of the shafts. The levers carried on the brake spiders should be as far back as allowable with the rods furnished, and these rods should not be shortened when the brake linings wear. This would disturb the proper setting of the brake levers and would prevent proper brake action. All adjustments should be made at the bands where the wear occurs.

ADJUSTMENTS OF THE OLDSMOBILE MODEL "47" REAR AXLE

The rear axle used on the Oldsmobile model "47" car is a three-quarter floating type, in which the differential is carried on separate bearings, and the inner ends of the axle shafts are supported by the differential side gears. The outer ends of the axle shafts are supported by the wheels which are mounted on large roller bearings and revolve on a race or bearing fastened to the axle housing. With this type of construction it will readily be seen that the drive shafts are subjected only to the driving torsion, and the bending moment imposed by the wheel on corners and uneven roads. The axle housing supports all the load of the rear end of the car.

Torsion tube and third member: The drive pinion shaft is mounted in a set of two bearings (see Fig. 21). At the pinion end is a large radial bearing, in which the shoulder of the pinion rides. This is the pinion bearing and serves to give the alignment to the shaft and pinion. A little farther up the shaft is mounted a double radial bearing which takes all thrust imposed upon the propeller shaft by the action of the pinion in the ring gear. All of these bearings and the adjusting mechanism are incased in a strong housing to which is attached a long tube entirely enclosing the propeller shaft. The tube assumes the torque imposed on the axle.

The differential assembly is mounted on two large Hyatt roller bearings, designated in Fig. 21, as (M). The side thrust on this bearing that is naturally set up by the wheels on uneven roads is taken up by the differential thrust bearings (F) and (I).

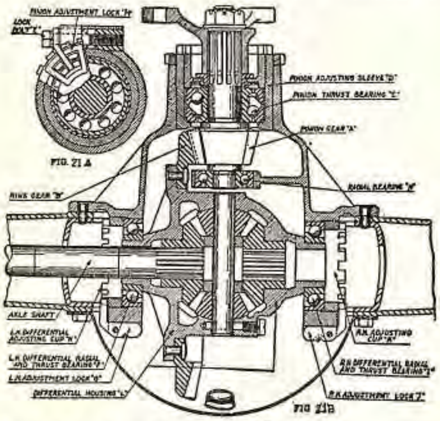


Fig. 21A. Oldsmobile (Model 30) rear axle not referred to in text. This axle is of the semi-floating type, equipped throughout with New Departure ball bearings. The housing is of the one-piece or "banjo" type.

To remove axle shaft, pull the wheel from the tapered end of the shaft; remove four screws holding the brake support disk; the axle shaft can then be removed from the housing.

To adjust drive pinion (see Figs. 21B and 21A), remove adjustment lock (M) and turn pinion adjusting sleeve (D).

To adjust ring gear, turn adjusting cups (H) and (K).

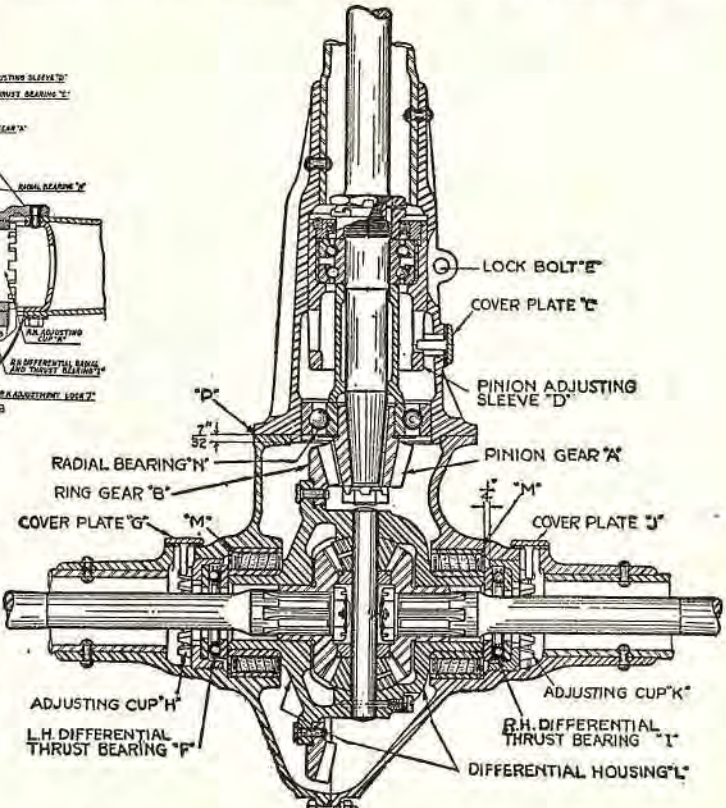


Fig. 21. Oldsmobile (model 47) rear axle as referred to in text.

The axle shafts are driven directly by the two differential gears, through which the splined ends of the shafts pass, being securely fastened by large castle nuts and special washers. The outer ends of the shafts are tapered and keyed into the hubs of the wheels, the hubs being held from slipping off the shaft by a nut, which is held in place by a star washer, one lip of which is bent up against the nut. This star washer has a spline which fits the keyway and keeps it from turning.

Adjustment Instructions

Adjustment of axle or differential gears: First find out under what conditions the noise appears, and investigate to see whether the axle is properly filled with heavy or semi-fluid oil. The capacity is one quart up to the level of the filling or inspection plug.

1. **Noise occurs on straight pull ahead:** The difficulty generally results from the teeth of the pinion gear (A) bottoming in the ring gear (B). This may be relieved by loosening the lock bolt at (E) and then opening the cover plate at (C), in the third member housing, and turning the pinion adjusting sleeve (D) outward two notches, or more if necessary, a notch at a time. Do not touch the adjustment of the differential-bearing cup.

2. **Noise occurs on straight coast ahead:** The difficulty is generally the result of the teeth of the pinion gear (A) not meshing deep enough in the ring gear (B). This may be overcome by loosening the lock bolt at (E), and then opening cover plate at (C) in the third member housing and turning the pinion adjusting sleeve (D) inward two notches or more, if necessary, a notch at a time. Do not touch the adjustment of the differential-bearing cup.

3. **Noise occurs on turning corner to right or left:** This is generally the result of end play at the differential thrust bearing (F) or (I). Open the cover plates (G) and (J), and then loosen or back off the adjusting cup (K), four or five notches toward the outer end of axle. Then tighten or turn the adjusting cup (H) against the differential housing (L) until all back lash has been take up between the pinion (A) and the ring gear (B). Now back off or loosen cup (H) by turning out three notches toward the end of the axle. Now tighten the adjusting cup (K) by turning toward the center until it is snug, with the wheels revolving.

4. **Adjusting after installing new ring gear:** With the two halves of the axle disassembled from each other, screw both the adjusting cups (H) and (K) toward the outer end of the axle housing, or until the distance from the inner edges of the cups (H) and (K) to the 1/16" metal stop rings (M) for the Hyatt bearing is ¼". With the adjusting cups in this position, no difficulty will be experienced in assembling the two halves of the case with the differential and axle shafts assembled. Firmly bolt both halves together and then assemble the third member in position and tighten. The axle is now ready for adjustments as in paragraphs 1, 2, or 3. above.

5. **Installing new pinions:** In installing a new pinion gear (A) where it has not been necessary to remove the pinion shaft, leave the adjustment of the ring gear as it is, and adjust as explained above in paragraphs 1 and 2, as may be necessary, depending on whether the noise occurs on coasting or on straight pull ahead.

6. **Installing new pinion when necessary and to remove pinion shaft from third member:** Reassemble so that the rear side of the radial bearing (N) in which the pinion (A) revolves is set approximately 7/32" from the extreme end of the shoulder on the flange of the third member. The backs or ends (see Fig. 28, page 874) of the teeth on the ring and pinion should be flush when assembled. To get this, measure from the face of the pinion-housing flange on the gear case at (P) to the bottom of the teeth at the outside diameter of ring gear (Q) (Fig. 28). Adjust the pinion so that a like dimension is obtained from the face of the pinion housing to the flange to the point of the tooth at the outside diameter (R) (Fig. 28).

Following are a number of suggestions relative to adjustments and inspection. **Read carefully.**

When axle is torn down: Inspect all bearings and parts very carefully when removed, and when reassembling use only the parts which are in good condition.

Single-row ball bearings may have a slight angular movement, or a rock as the action of a ball joint, but must not have any radial looseness or movement up and down.

Clean bearings thoroughly with gasoline, and make sure that the races and balls are in good condition and free from all foreign matter. The bearing should spin freely and quietly.

Roller bearings should be washed in gasoline, and races and rollers should be inspected for defects or foreign matter. These bearings should not have more than .003" movement radially.

The thrust bearings at the end of the differential should also be cleaned and inspected.

The life of the gears in a way depends on the bearings, and a worn or defective part replaced is money well spent.

The gear housing must be free from all chips, dirt, etc., for a little foreign matter here will ruin the entire unit in a very short time.

When assembling, make sure that every part is in its place and securely locked.

Preliminary adjustment of gears: The backs or ends of the teeth on the ring and pinion should be flush when assembled (see Fig. 28). To get this, measure from the face of the pinion-housing flange on the gear case to the bottom of the teeth at the outside diameter of the ring gear. Adjust the pinion so that a like dimension is obtained from the face of the pinion-housing flange to the point of the tooth at the outside diameter.

Adjust the differential to the left, so that the pinion can enter freely, and then assemble the third member to the axle.

Shellac the point between the two halves of the gear housing and make sure that the faces at the pinion-flange connection are flush. If they are not, there will be a leakage of oil.

Adjustment of gears: Move the differential to the right or left, as required, to get from .005" to .008" back lash (Fig. 31, page 874).

Through the oil-filler hole in the gear housing, paint both sides of the four teeth in the three equally spaced locations on the ring gear. Use thin white lead.

By turning the bevel gear around several times the lead will be wiped off of the gear tooth, showing where the contact or load is taken on the tooth. The contact to work for is as shown in Fig. 23 or a contact showing slightly heavier on the toe than on the heel, but over the full length on the tooth.

Fig. 24 shows a heavier contact at the heel of the tooth. This denotes too much back lash between ring and pinion, and will eventually break off the heel. To overcome this, move the differential toward the pinion, but be sure to have some back lash.

If the contact still shows heavy at the heel, change gears, as some part of the axle is out of alignment.

Fig. 25 shows a heavy contact at the toe or small end of the tooth. This is not bad, but the load should not be centered here as it will eventually break off the toe. To correct, move the differential away from the pinion, but under no circumstances should a gear be run with heavy contact at the heel resulting from too much back lash.

Fig. 27 shows contact at the top of the tooth, and Fig. 26 shows it on the flank. Either of these will cause noisy gears. To overcome, adjust the pinion toward the center line of the axle for Fig. 27, to get full-depth contact, as shown in Fig. 23. Noise almost always can be eliminated by the adjustment of the pinion.

Testing after Adjusting the Mesh of Gears

After this has been accomplished, install the axle under the car, connect to power plant, and, with wheels off the floor, start the engine. Apply the brakes slightly, adjusting these so that there is an equal amount of friction at both wheels. Watch the tooth contact through the filler hole in the gear housing. If correct results have not been obtained, paint the gears again and readjust the gears as mentioned previously. The car may be run not to exceed one mile without oil as a check on the adjustment.

If further adjustment is necessary, it should be made, as the gears must have contact over the full length of the tooth to carry the load. Oil will not deaden the noise, but is a lubricant.

Gear Contact as Explained in the Oldsmobile Instruction Book

The following illustrations and legends will make clear the meaning of terms used in connection with these explanations.

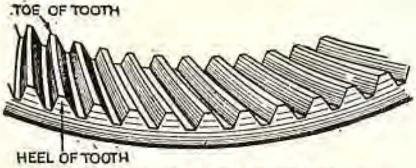


Fig. 22. Section of spiral-tooth ring gear.

Fig. 23 Fig. 24 Fig. 25

Fig. 23. Shows correct contact. Gears set up this way give best results for noise and wear.

Fig. 24. Shows heavy contact on heel of tooth. Gears set up this way will eventually break off at the heel. To correct, move the ring gear toward the pinion, but make sure that there is back lash, as gears cannot run tight.

Fig. 25. Shows heavy contact on toe of tooth. Gears set up this way will eventually break off at the toe. To correct, move the ring gear away from the pinion.

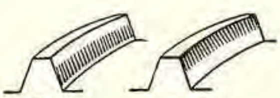


Fig. 26 Fig. 27

Fig. 26. Shows heavy contact on the flank of the gear tooth. Gears set up in this way are noisy. To correct, pull the pinion out until contact comes to the full working depth of the gear tooth without leaving the lowest point of contact. See Fig. 23.

Fig. 27. Shows heavy contact on face of gear tooth. Gears set up in this way are also noisy. To correct, move the pinion in until the contact reaches the lowest point on the gear tooth. See Fig. 23.

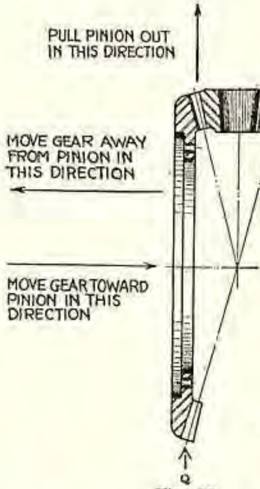


Fig. 28

Fig. 29

Fig. 28. See text for explanation.

Fig. 29. The heel of the gear tooth is the large end, and the toe is the small end.

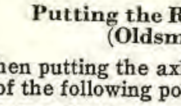


Fig. 30

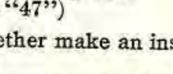


Fig. 31

Fig. 30. Showing the working depth, face, flank, and clearance.

Fig. 31. Backlash.

Putting the Rear Axle Together (Oldsmobile "47")

When putting the axle together make an inspection of the following points:

1. **Before the ring gear is mounted on the differential,** inspect the ring-gear seat of the differential case to determine whether it runs true with the bearing hubs. If it runs out more than .002", face it off in a lathe to make it run true.
2. **When riveting ring gear on the case,** make certain that it is riveted tight. Ring gear should not run out more than .008", using the bearing hubs of the differentials as centers.
3. **When driving the pinion on the shaft,** see to it that it does not ride the key; also that it is driven on tight. The pinion must not run out more than .004" on the shaft.
4. **Inspect all bearings for wear:** Bearings which are pitted or chipped should be replaced by new ones. Ball bearings and straight roller bearings should not have more than .003" play between the inner and outer races.

5. **Outer races of bearings must be a snug fit in bearing holes,** and the inner races must also be a tight fit on the shafts or differential hubs.
6. **Make sure that all parts which go on the inside of the gear housing are thoroughly cleaned.** Any chips, grit, or other hard substances grind out the bearings and gears very quickly.
7. **All studs and nuts must be a good fit in the threads** so as to hold the gears and bearings in place. If these are loose, they will let the gears vibrate.
8. **When all the parts mentioned above are looked after,** assemble the parts in the axle.

   Paint four teeth on the ring gear in three different places, with a thin coat of white lead, and start to adjust the gears until all paint is wiped off of the portions shown shaded in Fig. 23. Wherever the paint is wiped off is where the contact occurs.
9. **After the axle is adjusted:** Put it under the car and jack up the rear wheels; paint the teeth of the ring gear again, which can be done through the oil-level hole; apply the brake load while running the car jacked up in this manner, and note where contact occurs. If it changes much from what it was when assembled, it shows that there is looseness in the axle, and it must be corrected.
10. **After all this is done,** the car may be taken out for a one-mile test without grease in the axle housing, except on the bearings, which should be packed when assembled. This will tell what can be expected as far as noise is concerned. Grease will not deaden the noise very much, it only acts as a lubricant. If you find it advisable to make further adjustments to make the axle quieter, before filling up the case with oil and turning the car over to a customer, paint the gears up again and make certain that you have contact as illustrated in Fig. 23.

    Full tooth contact is required to carry the load.

Unless there is something radically wrong with the rear axle, it need not be taken apart. However, if the gears are worn or damaged they should be replaced. In the majority of cases the only work necessary on the rear axle consists of replacing the lubricant and adjusting the gears.

ADJUSTMENTS OF STUDEBAKER "LIGHT SIX" REAR AXLE

The rear axle consists of a bevel-drive pinion, and ring gear, differential gears, and rear-axle shafts, all of which are enclosed in an oil-tight case. The rest of the rear axle is made up of rear wheels, bearings, brakes, and tires.

The rear axle is of the semi-floating type. Axle shafts are provided with end-thrust adjustments (in case of wear on the bearings) located at each end of the axle housing (Fig. 32). Note that at the inner end of each axle shaft is a hardened steel thrust-button. This serves to prevent wear on the axle shaft at this point, and also minimizes adjustment of the bearings.

To remove end play: Any excessive end play in the shafts may be taken care of by removing the rear wheel (in the tool kit is a puller provided for this purpose); then take out the clamp bolt (Fig. 32), and turn the adjusting nut to the right until proper adjustment is reached.

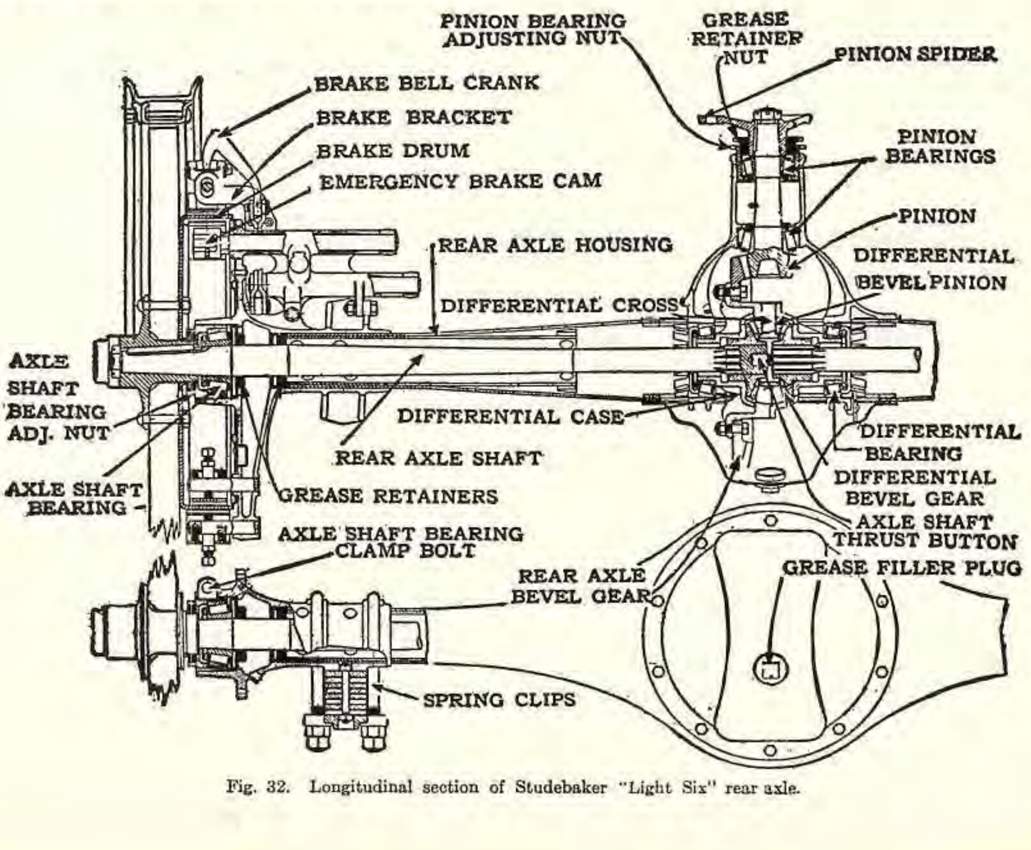


Fig. 32. Longitudinal section of Studebaker "Light Six" rear axle.

Care should be exercised to see that the same distance is maintained between the outer face of each adjusting nut and the end of the rear-axle housing. If this is not done, the rear wheels may be shifted out of line with the front wheels.

Adjusting bevel-drive pinion and ring gear: If wear develops between the bevel-drive pinion and ring gear, it will necessitate adjusting the bevel-drive gear and pinion closer together (Fig. 32). This adjustment may be made by removing the differential case cover, cleaning out all old grease, and loosening the two differential clamp nuts. The differential adjustment nuts can now be moved either out or in, whichever way the bevel gear is to be moved. When one adjusting nut is turned out, the other is turned inward the same amount. This does not affect the tightness of the Timken bearings, but simply moves the whole differential sidewise.

In reassembling parts, be sure that the bearing retainer lock is properly put in place.

The end-play adjustment of the drive pinion may be taken care of by removing the clamping bolt and retainer lock, and turning the bearing cage in a counter-clockwise direction, until proper adjustment is reached (Figs. 33 and 32).

The differential consists, essentially, of a case, made in two halves, bolted together, and a spider or cross with four arms which are clamped between the two halves of the case. A small bevel pinion runs on each of the arms of the spider and meshes with a side bevel gear carried in each half of the differential case. The case is mounted on Timken bearings and carries a bevel driving gear on its outer circumference. Axle shafts, which drive the wheels, extend through the case and fit into the side bevel gears which are bored out and splined to receive them.

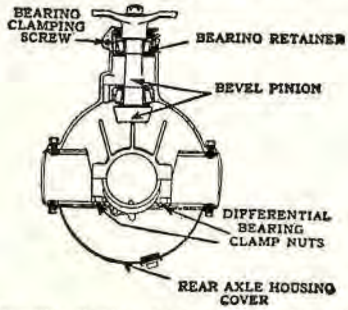


Fig. 33. Section of rear axle through pinion.

Care of differential: It is advisable, at least once a season, to clean the differential thoroughly. This can best be done by removing the cover at the rear of the housing and washing it out with gasoline. Repack with fresh lubricant (light grease or heavy oil), being careful to replace the cover with the gasket in perfect condition. It should be lubricated regularly through the plug in the cover with a good light transmission grease or a very heavy oil. Grease can be inserted through the plug hole only with a grease gun. This tool is in the regular tool kit accompanying the car.

ADJUSTMENTS OF MITCHELL MODEL "F" REAR AXLE

The Mitchell "F" rear axle is of the full-floating type and carries roller bearings inside and outside.

Note: This could be termed a seven-eighths floating axle; see pages 15, 16.

Removing the rear axle from the car: Run a rope under the rear end of the frame, and with a block and tackle raise the rear end of the car clear of the ground.

The rear axle will be held up by the rear springs, so that the caps of the spring saddles on the axles can be readily removed. While the car is raised and there is plenty of room to work, disconnect the brakes by removing the clevis pins where the brake rods join the levers on the axle.

Lower the transmission as in removing it from the car, disconnecting the front universal joint (see page 862). The complete universal joint will drop with the transmission.

Lower the car until the wheels rest on the ground and the rear springs have dropped far enough so that the spring seats clear the axle. Roll the axle back on the wheels until it is in back of the spring seats, when the car should again be raised until the fenders clear the wheels and the axle can be rolled out free of the car. It is well to block the car in that position to avoid the danger of it dropping.

Disassembling the rear axle: The following instructions are for the complete disassembly of the various units which make up the rear axle. In making any specific adjustment or repair, only as much of the work as may be necessary for the job in hand should be done.

With the rear axle clear of the car, remove the transmission from the forward end of the torsion tube by taking out the eight cap screws which hold it in place. Remove the torsion tube from the rear-axle housing by taking out the eight cap screws which hold it in place. The grease retainer will remain in the torsion tube and the propeller shaft can be drawn out at the rear of the tube. It will be found convenient to mount the rear axle assembly on horses at this point.

Removing wheels: Take off the nuts holding the driving flanges to the rear wheels and pull out the flanges together with the drive shafts. Care should be taken not to tear the paper gaskets between the flanges and the wheels, as these gaskets are necessary to prevent the escape of lubricant from the wheel hubs.

If it is desired to remove the flanges from the drive shafts, the hub cap should be removed and the large nut under it taken off, together with the washer under the nut. The flanges may then be pressed off the drive shafts in an arbor press.

Removing wheel bearings: With the shafts and flanges out, the nuts on the ends of the rear-axle tubes controlling the adjustment of the wheel bearings will be exposed. Remove the nuts and tongue washers after taking out the lock springs, when the wheels complete with roller bearings, grease retainers, and brake drums can be pulled off the ends of the rear-axle tubes.

The grease retainers and bearings can then be taken out of the wheels. Unless they are worn or damaged, the bearing outer cups should not be removed from the hubs, as they are pressed in at the factory.

Removing differential: Remove the cover from the back of the differential and clean out the grease by scooping it out of the bottom of the rear-axle housing and draining the remainder off through the drain plug. Remove the lock wire holding the differential-bearing cap nuts from turning, and remove these caps together with the differential adjustment locks.

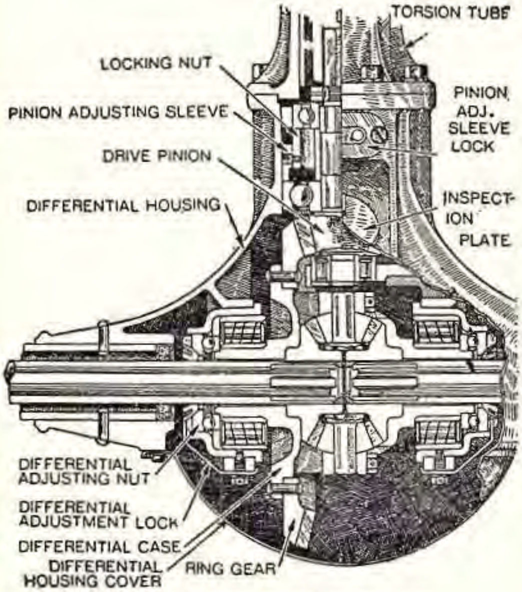


Fig. 34. Mitchell model "F" rear axle.

Back off both adjustments to give the differential end play and, cramping the differential assembly slightly to the right, so that the rivet heads will clear, lift the assembly out of the axle through the rear opening. The differential can be completely disassembled by taking out the eight cap screws holding the two parts of the split case together.

The ring gear being riveted to the differential case, it should not be removed unless it is necessary to replace the gear due to wear or breakage. In cutting off the old gear, great care must be taken not to spring the flange on the differential case to which the gear is riveted. Before mounting the new gear, swing the case between centers on a lathe and check the face of the flange to see that it runs true. If it does not, a light truing cut should be taken off the face of the flange. In riveting the new gear in place, care should again be taken not to spring the flange. To make sure, the case with the gears mounted should be again swung in a lathe and tested to see that the face of the gear runs true.

Removing drive pinion: Remove the locking plate holding the pinion adjusting sleeve in place, and screw this sleeve out through the front of the rear-axle housing. The pinion with its shaft and bearings will come out with it.

Remove the locking ring from the pinion-bearing lock nut and take off the nut and the grease retaining washer. The pinion which is integral with the pinion shaft can then be removed from the adjusting sleeve, together with the large rear bearing, and the bearing can be removed from the pinion shaft. The small roller bearing at the rear of the pinion can be removed by taking off the locking ring and sliding the bearing off the end of the shaft. Take the small front bearing out of the adjusting sleeve. The set screw holding the bearing-sleeve lock nut in place can be removed and the nut taken out of the sleeve.

Removing the rear-axle gears alone: With the axle in place under the car, the ring gear together with the differential can be removed from the rear-axle housing, as described in the foregoing instructions, after the drive shafts have been taken out.

To remove the pinion it will be necessary to drop the transmission, disconnect the torsion tube where it joins the rear-axle housing, and unscrew the pinion adjusting sleeve, together with the pinion and bearings, through the front of the torsion tube.

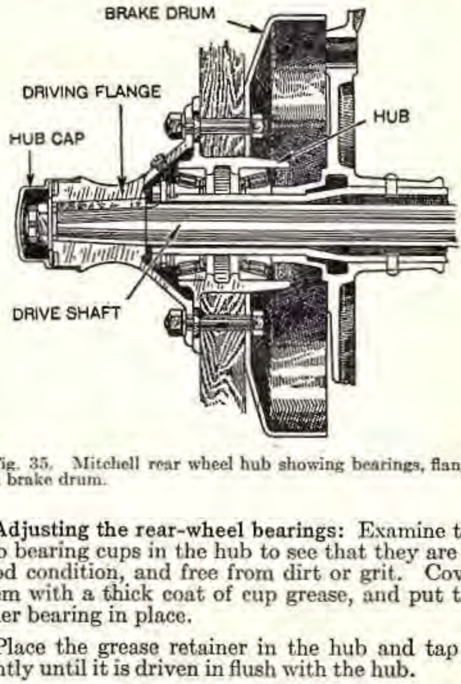


Fig. 35. Mitchell rear wheel hub showing bearings, flange, and brake drum.

Adjusting the rear-wheel bearings: Examine the two bearing cups in the hub to see that they are in good condition, and free from dirt or grit. Cover them with a thick coat of cup grease, and put the inner bearing in place.

Place the grease retainer in the hub and tap it lightly until it is driven in flush with the hub.

Place the wheel on the end of the axle tube and slide it in position, being careful to see that the brake drum is centered in the brake bands. Place the outer bearing in position, put on the lock washer, and then the nut, and draw it up until it is flush with the end of the tube. If the wheels revolve freely and there is no end play, the adjustment is correct and the nut on the end of the tube can be locked with the locking ring.

With both wheels thus mounted, put in the drive shafts and flanges, and fasten them with the nuts and lock washers to the wheel-flange bolts.

Adjusting the pinion bearings: In reassembling the drive pinion with its bearings and adjusting sleeve, put the small front bearing in the adjusting sleeve so that the projecting side of the inner race is about flush with the end of the sleeve having a thread on the outside. This face of the bearing is usually marked "Thrust Here." Screw the adjusting-sleeve lock nut in the adjusting sleeve so that it clears the small bearing by at least ¼".

Mount the large bearing on the pinion shaft with the projecting side of the inner race toward the pinion. This surface of the bearing is usually marked "Thrust Here." Slide the tubular inner spacer on the pinion shaft following the large bearing.

Mount the pinion adjusting sleeve with the small bearing in place on the pinion shaft, followed by the grease-retaining washer and the pinion-bearing lock nut, which should be drawn down tight and locked in place with the locking ring, making sure that the adjusting-sleeve lock nut is not bearing against the small ball bearing when the pinion-shaft lock nut is tightened.

By prying through the openings in the pinion adjusting sleeve, screw the adjusting-sleeve lock nut back against the small bearing until there is no end play between the bearings, but they rotate without cramping. Lock the lock nut in place with the small set screw. This is the adjustment for taking up wear in the pinion bearings.

The small bearing on the end of the pinion shaft can then be mounted in place and locked with its locking ring.

Adjusting the driving gears: With the differential bearing caps mounted in place, the ring gear can be moved to the right or left by screwing and unscrewing the serrated adjusting nuts. The pinion is moved into mesh by turning the pinion adjusting sleeve to the left (as the operator faces the front of the car) and vice versa. The ideal adjustment is attained when the two gears mesh along the full length of the pitch line of their teeth and the back faces of the teeth are flush with just a few thousandths back lash. Before locking the adjustment it should be checked by revolving the ring gear a few times to be sure that none of the washers have moved out of place and give a false adjustment.

In general, movement of the pinion in and out of mesh causes small change in the back lash, but a large difference in the pitch-line bearing. If the pinion is out of mesh too far, the bearing of the teeth will be out toward the point of the ring-gear teeth, above the pitch line. If the pinion is too far in mesh, the teeth mesh at the root of the ring-gear teeth below the pitch line.

Movement of the ring gear in and out of mesh causes comparatively small difference in the pitch-line bearing, but causes a large change in the amount of back lash. With the ring gear **too far out of mesh,** the ring-gear tooth will bear at its outer side, showing there is too much back lash. With the ring gear **in mesh too far,** the ring-gear tooth will mesh at its inner side, showing that there is not enough back lash.

When the gears are **properly adjusted** and the adjustment is checked by rotating them, the adjustment of the pinion should be locked by mounting the locking plate, being sure that the finger on the lock goes down through one of the openings in the pinion adjusting sleeve. The ring-gear adjustment should be locked by locking the serrated adjusting nuts with the locking fingers fastened to the bearing caps with set screws.

Lubricating the Mitchell rear axle: Once every season, or every 5,000 miles of running, the lubricant in the differential should be removed and the differential should be cleaned out. Fill the differential with about three pints of semi-fluid lubricant of about the consistency of 600-W steam-engine oil. The old lubricant can be removed through the rear-axle housing cover and drained through the drain plug in the bottom, while the new lubricant can be poured in through the opening in the cover after the cover has been mounted on the rear-axle housing. At that time some lubricant should be poured in through the pinion-adjustment lock plate to lubricate the pinion bearings.

Lubrication of the Mitchell rear wheels: Once every season, or every 5,000 miles, the rear wheels should be removed from the axle, cleaned out, and packed with fresh cup grease. If grease leaks out around the brakes, it is a sign that the level of the lubricant in the differential is too high, or that the cup grease in the wheels is thinned out. In the former case some of the lubricant should be drained off, while in the latter case, fresh lubricant can be added through the plug in the driving flange.

DIFFERENTIALS: DISASSEMBLY AND ASSEMBLY

The principle of operation of a differential is explained on pages 17 and 18.

The type of differential gear in general use is the bevel-gear type with helical or spiral teeth. The differential or compensating gear assembly is shown in Fig. 36.

The differential **ring gear** (see Fig. 13, page 18, and Fig. 3 page 6) is always **placed on the left side** (when seated in the car).

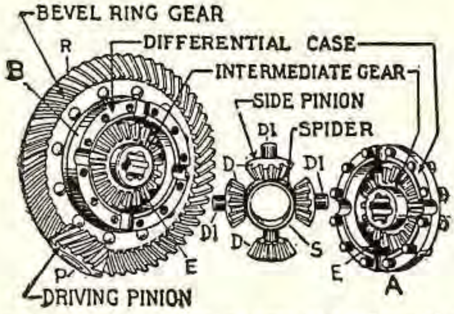


Fig. 36. Showing the **internal parts of a differential** and how the axle shafts fit into each of the intermediate gears and how part (A) is bolted to part (B). Note the pinion shafts (D1) to which the differential bevel gears (D) are fitted, and which rotate on these pinion shafts.

The bevel pinions (D) are then meshed with the two intermediate and larger bevel gears (E), the latter being connected to the axle shafts.

The **drive** pinion (P) is connected with the drive shaft, and the driving power is thus applied to the large ring gear through the differential housing, to the intermediate bevel gears (E), to the axle shafts, and thence to the rear wheels.

The action of the differential, or compensating gears (D) is explained on pages 17 and 18.

Note in this example and in the case of most all other differentials, that the large bevel-ring gear (R) and the drive pinion (P) are of the bevel type of gears with helical or spiral cut teeth instead of straight teeth.

When replacing a driving pinion (P) with one of a different diameter or a different number of teeth, it is always necessary to replace the driven ring gear (R) also, because the teeth will mesh too tight at either the big end of the tooth or the little end of the tooth, owing to the fact that the teeth are cut at a different angle when not mated.

When replacing drive pinion (P), it is of course necessary to remove the drive shaft on which the drive pinion is mounted.

Replacing driven-ring gear (R): Ring gears are usually riveted to the differential housing. Thus it is necessary to remove the assembly for this operation.

Either the cold or hot rivet can be used. At the factories where they have special power riveting machines, the work is done with cold rivets and in one-tenth of the time. The average blacksmith or repairman, however, will probably find it better to heat the rivets, which is often done where there is only a hammer to work with.

In placing a ring gear on a differential, one of the greatest causes of noisy gears is the fact that the differential flange to which the ring gear is attached is often out of true and should be carefully trued up before fastening the ring gear to it. See page 873 for adjusting after installing.

Removing differential. There are two types of rear-axle housings, the one-piece type (Figs. 53, 54, 55, page 862) and the two-piece type (Fig. 56, page 862). The differential can be removed from axles of the one-piece type by removing axle shafts and then removing the rear-axle housing cover plate (Figs. 53, 55, page 862). On the two-piece type, as shown in Fig. 41, page 880, Fig. 39, page 1096, and Fig. 28, page 921, the rear-axle assembly must first be removed. See also page 863.

REMOVING THE DIFFERENTIAL (CHEVROLET "FB" AS AN EXAMPLE)

The Chevrolet model "FB" rear axle. Note that the axle shaft is keyed to the hub (Fig. 37) and the bearing runs between the housing and wheel hub, and not on the axle shaft. The inner ends of axle shafts are supported by heavy-duty roller bearings (Fig. 38).

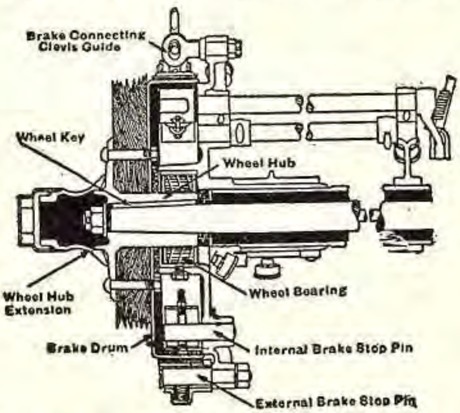


Fig. 37. On the "FB" and "490" the outer bearing is on the wheel hub extension. On the later Superior model a heavy-duty ball-bearing runs directly on the axle shaft and supports outer ends of axle shafts (see pages 15, 863, for classification of types of rear axles).

To remove the differential it is first necessary to remove the various parts as explained below.

To remove the rear axle assembly: Place two jacks under the rear spring brackets and raise rear of car enough to take the weight off the springs.

Remove the clips and bolts holding the springs to the axle and disconnect the brake pull rods, which operate between the foot pedals, hand-brake lever, and rocker shaft on the propeller-shaft housing.

Disconnect the brake pull rods from the operating levers on the rear-axle housing by removing the yoke pins. **Slide the axle assembly from under the car.**

Remove the four propeller-shaft housing bolts, clamping the housing to the axle housings, and lift the assembly off (see Fig. 38).

Remove hand hole plate shown in Figs. 38, 39. Clamp housing in a vise with hand hole on top. Remove the thrust-bearing adjusting cage lock bolt.

Turn the propeller shaft so that the hole in the pinion-shaft adjusting nut is in line with the milled slots in the end of the thrust-bearing cage.

Secure a small steel pin ⅜″ square and 1″ long, and place it through the slots into the hole in the shaft. With a large adjustable wrench gripping the splined end of the propeller shaft, turn counter-clockwise or from left to right. This will cause the thrust-bearing adjusting cage to turn with the propeller shaft. Continue to turn until the cage is free, permitting the entire assembly to be removed through the drive-gear end of the housing. Should there be any difficulty in unscrewing the cage, insert a large screwdriver into the split clamp at the point where the thrust-bearing adjusting-cage lock bolt was removed, and open the jaws of the clamp.

To remove the propeller shaft, remove the small wire passing through the head of the adjusting-nut lock screw. Remove the lock screw. Unscrew the pinion-shaft adjusting nut as far as it will go. Pull out the cotter pin holding the drive-gear nut and remove the nut. Slip a flat piece of steel between the back of the drive pinion and the lower end of the propeller-shaft housing. With a lead hammer or a piece of wood held against the end of the propeller shaft, drive the pinion shaft.

The bearings and spacing washers can then be taken off the shaft. The rear wheels are keyed on the tapered ends of the axle shafts and held in place by a castle nut and cotter pin.

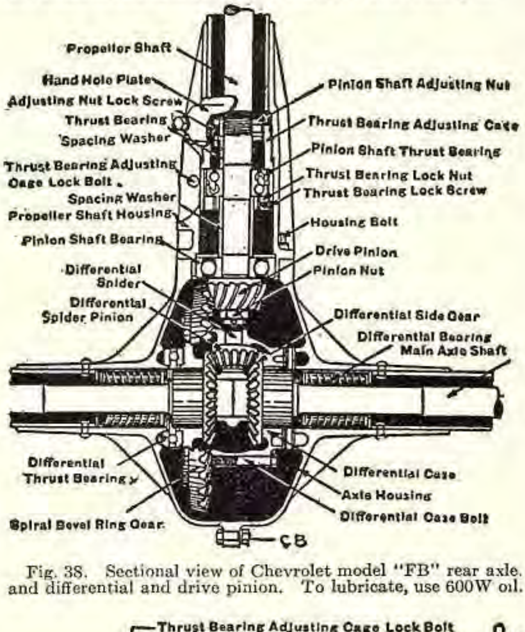


Fig. 38. Sectional view of Chevrolet model "FB" rear axle and differential and drive pinion. To lubricate, use 600W oil.

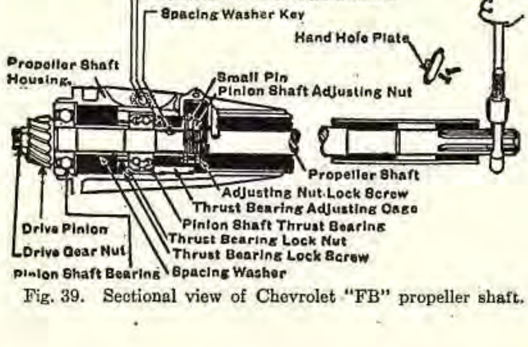


Fig. 39. Sectional view of Chevrolet "FB" propeller shaft.

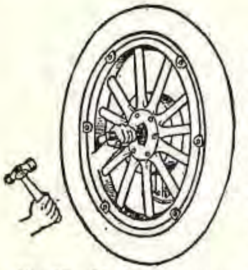


Fig. 40. Method in removing the Chevrolet rear wheel.

To remove the rear wheels, remove the hub caps. On model "FB" also remove the hub extension by using the hub cap wrench and turning counter-clockwise. Remove the cotter pin holding the nut on the shaft. Loosen the castle nut, but do not remove it entirely.

With a bar held against the castle nut, as shown in Fig. 40, deliver several sharp blows on the bar. When the wheel is free on its key remove the castle nut and the wheel can be pulled off.

The axle housings (H) (Fig. 41) are in two halves, right and left, held together by a number of clamping bolts (**CB**) (Fig. 38). Remove these bolts and slide the axle housing off the shafts.

In order then to remove the differential, note that the differential gear case is in two halves (A) and (B) (Fig. 41), held together by clamping bolts or screws, which when removed permit the cases to be separated.

The two parts (A) and (B) can then be separated, after which the axle shafts with the two halves can be withdrawn.

The differential gears (E) are keyed and pinned to the axle shafts. After removing the pins, the gears (E) can be pressed off the axle shafts.

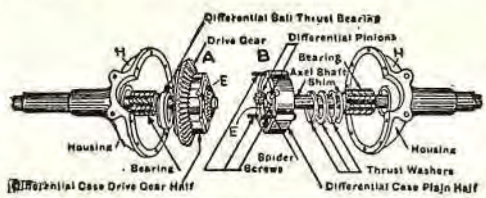


Fig. 41. Illustrating how the differential case is divided into two parts (A) and (B), and which parts must be separated in order to remove the differential. The axle shafts are then removed from the gears (E). (A two-piece, or divided rear axle housing.)

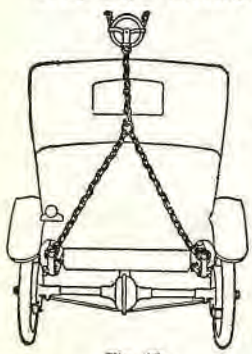
DISASSEMBLY AND ASSEMBLY OF A MAXWELL "25" REAR AXLE AND DIFFERENTIAL

The Maxwell "25" rear axle is a three-quarter floating type of rear axle, yet the axle housing is a divided, or two-piece type of rear axle (see Fig. 50).

Note: On later models (cars 447204 up) a one-piece housing rear axle is used.

Evidence of Trouble

1. **Any excessive grinding or humming** indicates that the gears are either worn, broken, or poorly adjusted.
2. An intermittent catch, occurring perhaps only every 100 miles, indicates that parts of one or several teeth are broken, and are catching in the gears.
3. Actual failure of the axle to operate. (Any of these necessitates a **removal of the axle from the car,** tearing down and replacement of defective parts, with readjustment.)



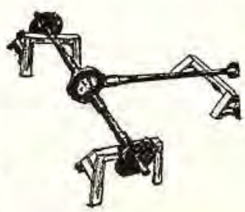


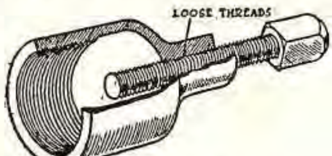
Fig. 42 Fig. 43

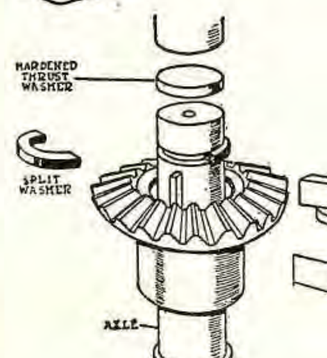
Fig. 42. The car is readily lifted by a chain block and sling. One man can do the work, and the car is held without danger of falling.

Fig. 43. Three horses form a serviceable **axle stand,** though a special stand could readily be made. Never attempt to dismantle or assemble a part on the floor, but get the work up where it is accessible and clean.

To Remove Axle

1. Block the front wheels.
2. Raise the rear of the car as shown in Fig. 42.
3. Disconnect the brake rods at the point of connection to the brakes.
4. Remove the clips holding the axle to the springs.
5. Draw the axle and housing out to the rear. The drive shaft slips out from the universal, and must be caught to prevent possibility of injury to the splined end.
6. Place the axle on three horses arranged as shown in Fig. 43.
7. Remove the hub caps.
8. Remove the axle nuts.
9. Using puller shown in Fig. 44, remove wheels.





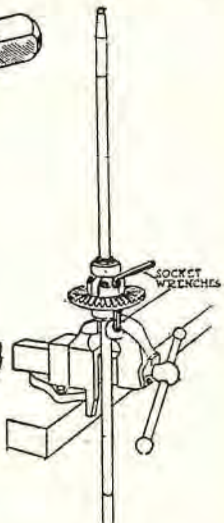


Fig. 44 (upper) Fig. 45 (lower) Fig. 46

Fig. 44. The feature of this rear-wheel puller is that the screw is hardened tool steel, loosely threaded into the cap. The end play permits a sharp blow on the screw to loosen the sticking wheel.

Fig. 45. Do not attempt to remove the side bevel gear from the axle drive shaft until the split washers have been removed in the manner shown.

Fig. 46. The differential may be most readily assembled and adjusted, if caught in the vise in this manner. Two socket wrenches are used to do the work.

10. Remove the torque tube and drive shaft. Save the gasket.
11. Catch the grease in a pail.
12. Remove the nut from one end of the axle truss rod.
13. Remove the differential-housing bolts.
14. Pull off the differential-housing halves.
15. Place the differential in a vise as shown in Fig. 46; pull the cotter pins from the bolt ends and remove the differential casing nuts, allowing the two halves to come apart.
16. Remove the split washers from the end by driving the gear down, as shown in Fig. 45.
17. Remove bearings and all parts; wash and clean with gasoline.

General Repairs

1. **After cleaning, examine all parts for wear.** Go over the gear teeth, to see if any are broken or worn. Also note whether the drive-shaft bevel gear has been wearing evenly along the teeth. The face of the teeth should be bright all over. Any breakage or perceptible wear necessitates a replacement of the gear.
2. Draw the drive shaft from the torque tube. Clean and examine the bearings.
3. If the axle has been disabled by a collision, the shaft should be caught between lathe centers, tested, and trued up, if bent.
4. If any serious bend is found in either of the shafts, the two halves of the rear-axle housing should be bolted together, tested for alignment in the lathe, and straightened.
5. When the large ring gear on the differential must be replaced, its bearing on the differential casing should be trued up in the lathe, as shown in Fig 47.

The Reassembly

1. Replace the shaft bearings, differential housing halves, and shaft gears, making certain that the split washers are in place.
2. Replace the differential cross-gears on the differential cross and holding shaft in a vise, as shown in Fig. 46, and bolt the halves together. (Be certain that the thrust washer is in place between the ends of the shafts.)
3. When the halves are bolted together, there should be about 1/64″ end play between the two halves of the shaft. If they are tight, take the differential apart and file a little from the end of each shaft.
4. Rebolt the halves, and holding as shown in Fig. 48, turn the two shafts in opposite directions. The axles should turn easily all the way around.

   Note. If sticking is noted in any place, catch the assembly in a vise, as shown in Fig. 46, and with the tang of a file, find by feeling which cross-gear is causing the sticking. If new cross-gears have been installed, try changing the sticking gear for a new one from stock. (Or if new side gears have been installed, try changing the side gear.)
5. Replace the cotter pins in the differential casing. Clip the ends over, away from the cross-gears.
6. Using horses as shown in Fig. 43, slip the halves of the rear-axle casing in place, after packing all bearing and gears with non-fluid oil.

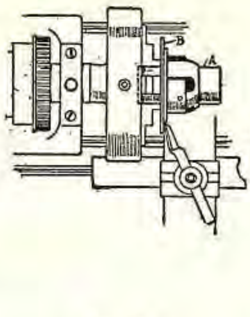


Fig. 47

Fig. 48

Fig. 47. Breakage of the ring gear usually springs the **differential housing flange.** By catching the entire housing in the lathe and **trueing it up** by the surface (A), the ring gear seat (B) may be refaced with a light cut.

Fig. 48. **In testing the adjustment of the differential gears,** grasp the assembly in this manner, and turn the axles in opposite directions. They should turn freely all around.

7. Bolt the halves together. (Do not pull one nut up tight until the others are snug.)
8. Now get the torque tube and drive shaft ready for assembly. The shaft should turn freely in the housing. All bearings should be packed in grease.

   Note. If a new drive-shaft pinion has been fitted, make certain that the bent ends of the cotter pin in the end of the drive shaft do not interfere with the thrust bushing (see Fig. 49).

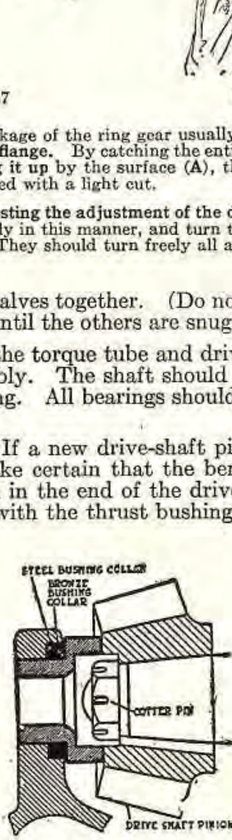


Fig. 49. The cotter pin in the drive-shaft pinion lock nut should not interfere with the thrust bushing, and the bushing collars should be inserted in the manner shown.

9. Fill the axle housing with a good grade of non-fluid oil until the ring gear dips well into the oil.
10. Place first the bronze washer on to the drive-pinion thrust bushing, then the steel washer, and insert the bushing into the rear-axle housing.
11. Replace the torque-tube gasket and slip the torque tube and drive shaft into the axle. Bolt in place.
12. When all bolts are tight, the drive shaft should turn freely under the action of a pipe wrench. If any sticking is noticed, additional gaskets should be placed between the torque tube and the axle. If any slack exists in the gears, the gasket should be replaced by one made of thinner paper.
13. Make certain that the brake levers work freely. Oil well. Note whether the brake bands are wearing evenly and are in good condition. Reline, if necessary.

14. Replace the wheels. Fill the hub caps with medium cup grease.

    (Note. It is always advisable to grease the rear springs with graphite and grease at this point.)

15. Roll the axle beneath the car and, with one man guiding the drive shaft, slip it into the universal. The splines may not line up at first, and hence it may be necessary to crank the engine slowly by hand until the two slide together.

16. Let the car down on to the axle; bolt the spring shackles to the axle; reconnect the brake levers.

    (Note. For the first 200 miles, at least, fill and screw down the grease cups two or three times, to make certain that all bearings have an abundance of grease.)

The points on the differential assembly that should be particularly watched are indicated on the illustration to the right (Fig. 50).

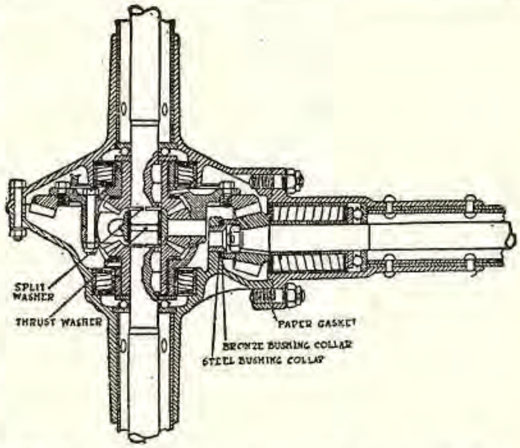


Fig. 50. A floating type of rear axle (see page 15 why a two-piece or divided rear axle housing).

THE POWRLOK OR "M AND S" DIFFERENTIAL

With an ordinary differential as shown on page 18, when one rear wheel gets into a soft spot it will turn or spin. With this differential, nothing of the kind happens because the angle of the worms (D) and (M) is such that, while the side gears on axle shafts (A) and (B) can drive the worms, the **worms cannot drive the gears on axle shafts (A)** and (B). As a consequence, the differential is locked, or the axle is like a solid axle, so far as the movement of the wheel in relation to the differential is concerned.

When both wheels are firm on the ground and can travel freely, the differential is enabled to act in the usual manner when turning corners, etc., by reason of the fact that the **gears on the axle shaft (A) and (B) can drive the worms.**

This device (Fig. 51) prevents skidding to a great extent and insures positive traction at all times.

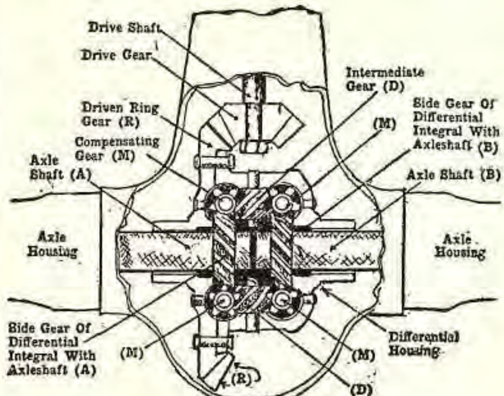


Fig. 51

OIL LEAKAGE FROM REAR AXLE; ADJUSTING FRANKLIN REAR AXLE

Preventing the grease or oil in the differential housing from making its way to the brake bands and thus causing inefficient braking was a big problem to manufacturers some years ago, but the difficulty has been overcome largely in all the present types. In all the axle housings on the market, some precaution is taken to prevent this leaking, usually, by means of a **felt washer,** termed an "oil retainer" or "grease retainer," and in nine cases out of ten when a leak occurs despite this, the condition is caused by placing **too much oil or grease** in the housing, or by using too light **a** grade of oil. Some axles use a heavy oil and others a light grease.

Methods of preventing oil leakage can be observed by referring to the various illustrations of rear axles. Note felt washers in rear axles on pages 883, 877, 875, 871, 869, 864, 858.

As an example of a method of preventing oil leakage, the Franklin rear-axle system will be used.

The Franklin series "9-B" has a semi-floating axle. Adjustments are possible on the wheel bearings, bevel gear and pinion, and the differential carrying bearings. The felt washers on the axle are also taken up from time to time (Fig. 52, next page).

To take up the pinion-shaft packing, loosen the lock for the washer retainer and screw in the retainer until the packing fits snugly around the shaft. To replace the packing it is necessary to disconnect the drive line and remove the universal-joint flange.

The axle-shaft felt washer is taken up by removing the wheel with the special wheel puller. The felt washer on the inside of the wheel hub is replaced. The retainer that holds the other felt washer into the end of the axle housing can be removed by taking out the three small screws. If this felt washer shows wear, it should be replaced.

If oil comes out of the axle at the drive-pinion shaft or at the wheels, examine the level of oil in the gear case. This should be within 2″ of the filler hole. Examine also the packing on the pinion shaft and the felt washers on the axle shafts.

Bearing and Pinion Adjustment

The bearings for the rear-axle drive shaft should be adjusted so that there is very little rock or play. The fact that the rock is perceptible is not necessarily an indication that the wheels are too loose. To

adjust the bearings, screw their retainers up tight and then loosen them two notches each. See that each axle shaft extends the same distance from the housing. Take the measurements for this from the faces of the bearings to the ends of the axle housing. When the adjustment is completed, see that the bearing-retainer locking device is securely screwed into position.

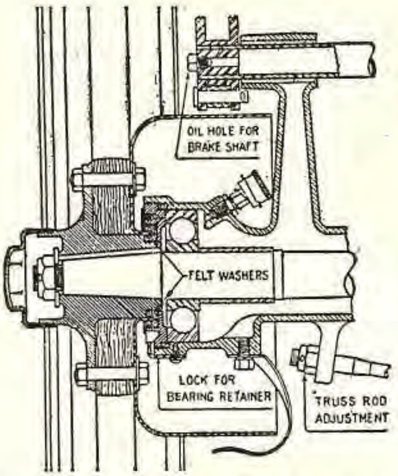


Fig. 52. Sectional view of the Franklin model "9B" rear wheel, showing the location of the felt washers.

The bevel gears on the Franklin are positively adjusted by shims. There are no screw adjustments except the one that takes up bearing wear on the pinion shaft (Fig. 53).

To mesh the pinion deeper into the bevel-drive gear, withdraw the pinion unit and remove one of the thin shims between the pinion housing and the rear-axle housing. The meshing of the gear and pinion may be inspected through the large plug hole in the left front side of the gear case. The edges of the gear teeth should be approximately flush.

To move the bevel gear sideways, take out the drive shafts and the bevel-gear unit, after which the unit can be shimmed in the necessary direction.

Pinion-Shaft End Play

If the bearings of the drive-pinion unit permit the pinion shaft to have end play, the axle is prone to become noisy, particularly when the brake is applied and when the car is coasting. To take up this end play, disconnect the rear universal joint and take off its flange. Then remove the housing, and after loosening the lock nut, make the adjustment with the nut. These bearings are very sensitive to adjustment and must not be made too tight. This adjustment is sometimes more easily made if the pinion unit is taken out and put in a vise.

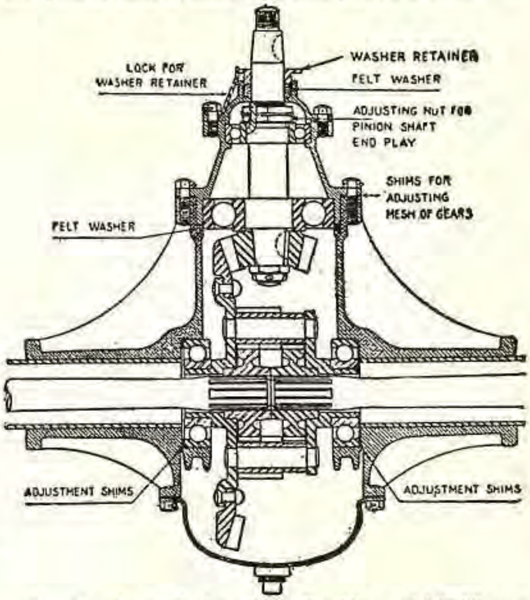


Fig. 53. Sectional view of the Franklin model "9B" rear axle, showing the points of adjustment.

Truss-Rod Adjustment

The truss rod under the gear case should be examined every 1,000 miles, and should be adjusted so that it sounds taut when struck. Keep it adjusted this way, but avoid pulling it up too tight, as the strain is likely to cause the gear case to leak oil.

The wheel-hub bolts should be tightened after the first 1,000 miles of running, and after that can be tightened every 5,000 miles. (*Motor World.*)

TIMKEN-DETROIT REAR WHEELS WITH OIL SEALS

Later types of semi-floating or "fixed hub" types of rear wheels than those shown on page 864, are Fig. 54 which has a single bearing, and Fig. 55 which has two bearings. The numbers are 5014, 5140, 5142, and 5143.

A feature of these types is the hydraulic compression cup leather (Q) which, when properly assembled, is absolutely oil-tight. The oil seal is also used on the Timken rear-axle drive pinion shaft (see page 910). See also the **shim adjustments of bearings.**

To clean and lubricate (Fig. 54): **Remove wheel** from axle shaft. Remove cap screws (H) which hold the bearing cage (I) in place. Now remove the cage, carrying with it the cup (J). **Pull out axle shaft** (L) on which is pressed the roller bearing. Clean, as on page 864. Cover bearing with cup grease. Pack end of housing with grease. Replace shaft (L) with bearing cone and rollers and cage (I) carrying bearing cup.

Adjustment of bearings: Add or remove shims (K). Screw up (H) until shims (K) are tight and shaft turns freely when revolved with a wrench placed on nut (N). When this condition is attained, add one of the thinnest shims to one of the bearing cages; this will give approximately .005" end-play. Replace wheel and tighten nut (N), and lock with cotter pin.

When making adjustment it is advisable to remove the oil seal by removing locking washer (P), cup leather (Q), and spring (R).

Applies to early models.

To clean (Fig. 55): **Remove wheel** from axle shaft. Now **remove** cap screws (H) which hold the outer wheel-bearing cage (A) and the inner wheel-bearing cage (B) in place. **Pull out axle shaft** (L), carrying with it the bearing cages, cones, and **cups.** This assembly is removed in one unit. Now place the axle shaft in a vise and remove the two short cap screws (C). The outer cage (A) and the inner cage (B) can now be taken apart.

Adjustment of bearings: Add or subtract shims as the case may be, being careful not to get the bearings too tight. Proper adjustment is .005" loose, or the thickness of the thinnest shim. Clean as on page 864.

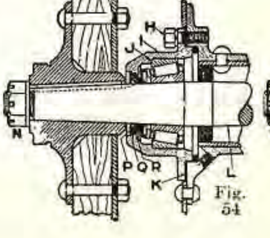


Fig. 54

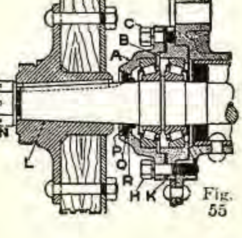
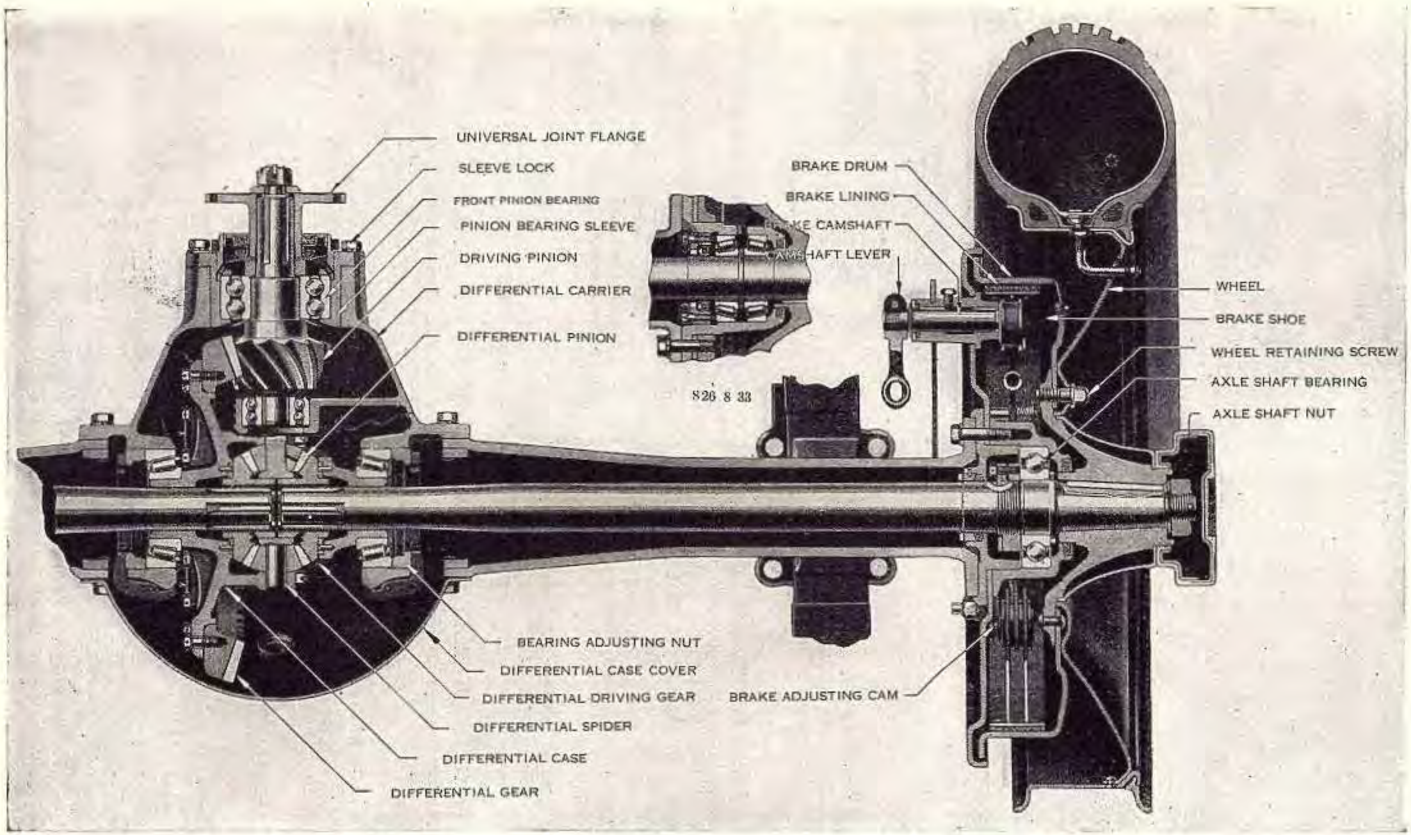


Fig. 55



Note: Pages 883A and 883B have been added since the preceding pages were prepared. The illustrations shown, with each part lettered, exemplify later construction. Although it will be noticed that improvements and refinements have been made, the fundamental principles of operation are similar in many respects.

Fig. 56. **Rear axle showing differential and brake section of the Packard eight,** models 826, 833, 840 and 845. The rear axle is a semi-floating type. The housing is made of pressed steel. Driving forces and the torque of the rear axle are transmitted through the rear axle springs.

The differential is mounted on tapered roller bearings supported in the differential carrier, which is bolted to the front face of the rear axle case. On the models 840 and 845 the axle shafts are mounted on ball bearings at the outer ends of the case, while the axle shafts of the models 826 and 833 are supported by taper roller bearings. All axle shafts are fitted to the differential gears at the inner ends by means of splines. The rear wheels are keyed directly to the axle shafts.

The differential driving pinion is straddle-mounted on ball bearings and meshes with the differential driving gear which is bolted directly to the differential. These gears are adjusted at the factory and should require no further attention other than to receive proper lubrication.

The **hypoid gear** design used for the driving pinion and differential gear has produced silence of running superior to the spiral bevel gear.

The standard rear axle gear-ratio for the 826, 833, 840 and 845 models is 4.69 to 1; special ratios of 4.38 and 5.08 to 1 are furnished as special equipment.

See **specifications** of different cars, pages 1055–1062.

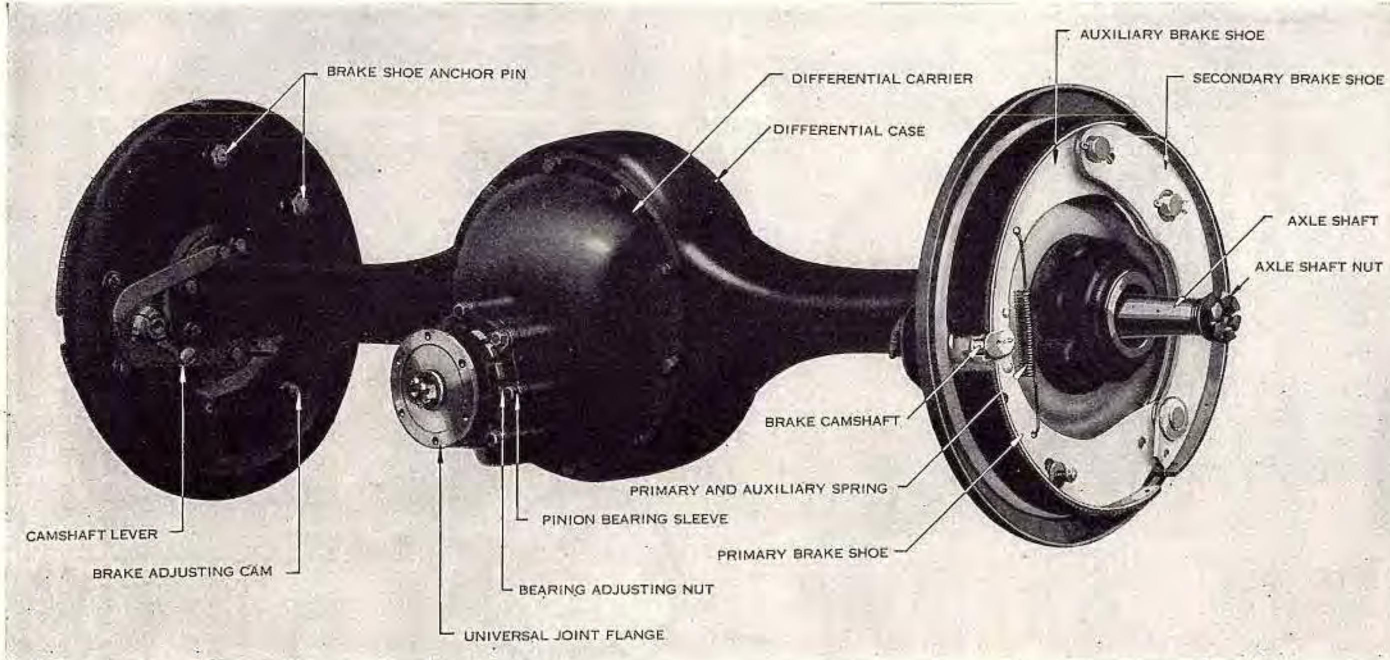


Fig. 57. **Rear axle, showing brake construction of the Packard eight, models 826, 833, 840 and 845. The mechanical, three-shoe type of brake is used.**

Cleaning: It is a good plan to drain the oil from the rear axle case every 10,000 miles and to flush out the case with kerosene. This can be done by removing the rear cover plate. After replacing the cover plate, refill to the level indicated by the filler plug in the rear cover.

Axle shaft outer bearings: Whenever the wheels are removed, the axle shafts should also be removed and the bearings on the shaft outer ends repacked with grease. It will be noted that the construction traps the grease around these bearings, so that it is not required to pull the wheels specifically for the purpose of lubricating the bearings more often than once every 10,000 miles.

Oil level: Too high an oil level in the rear axle case is the most common cause of leakage, so the level should always be checked (to see if up to plug level in rear but not above it) and the consistency of the oil inspected before other steps are taken to remedy a leaking axle.

Oil leakage at the outer end of the driving pinion shaft, aside from being due to high oil level in the case, is caused by improper functioning of the oil throw-off and return mechanism, which takes the oil working along the pinion shaft and returns it to the axle case. An inspection of this mechanism should deal principally with the fit of the parts in the axle case forward extension and on the pinion shaft. Light drive fits are required. Oil return holes should be cleaned if clogged by thick oil or dirt.

Oil leakage at the axle shaft outer end, with the proper oil level in the case, indicates improper stuffing box action, and the shaft should be removed and the stuffing box, which comes out with it, repacked or tightened as required.

INSTRUCTION No. 74

BRAKES: Types; Care and Adjustments

TYPES OF BRAKES

There are two kinds of brakes generally used on automobiles: (1) the **external** brake; (2) the **internal** brake. See also pages 12, 13.

The external brake is usually a contracting band brake consisting of a steel band, lined with an asbestos fabric that is placed around the circumference of the brake drum which is mounted on the rear wheel hubs, as shown in Fig. 1.

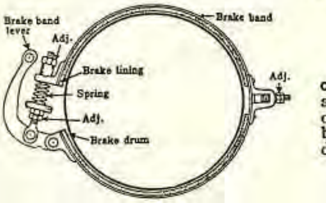
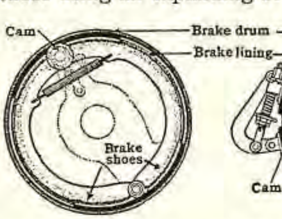


Fig. 1. An external contracting brake where a brake bandlever draws or contracts a brake band around the brake drum.

The operation of the external brake band is usually by means of the brake-band lever connected with the foot-brake pedal. There are different methods employed for connecting this lever, and although the construction may vary, the principle or purpose —of contracting the band around the brake drum— is the same. The purpose of the **spring** is to return the brake band to a free position when the brake-band lever is in normal position.

The internal brake is of two general types: (1) those using expanding brake **shoes** (Fig. 2); (2) those using an expanding brake **band** (Fig. 3).



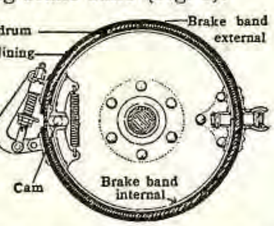


Fig. 2. (Left) An internal expanding brake where brake shoes are expanded within the brake drum by a cam.

Fig. 3. (Right) An internal expanding brake where a brake band is expanded within the brake drum by a cam. Note the external contracting brake (similar to Fig. 1) on the outside of the brake drum.

The internal brake using expanding metal brake shoes is shown in Fig. 2. Note the shoes are hinged. Brake shoes are generally lined with brake lining.

Metal-to-metal brakes are seldom used on pleasure cars. Some motorcoaches and large busses use metal-to-metal brakes.

Operation of this internal shoe type of brake (Fig. 2) is by means of a **cam** which is usually connected with the hand-brake lever (on two-wheel brakes). When this lever is operated, the cam separates the two ends of the brake shoes, causing the shoes to expand inside of the brake drum. The **spring** returns the shoes to a free position when the lever and cam are in normal position.

The internal brake using an expanding brake band is shown in Fig. 3. The internal brake band is made of steel, lined with an asbestos-fabric brake lining.

Operation of this internal brake band (Fig. 3) is by means of a **cam** similar in action, as explained in Fig. 2.

Another method of operating the internal brake band is by means of a toggle joint action (Fig. 4).

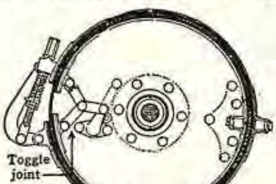


Fig. 4. An internal expanding brake where a brake band is expanded within the brake drum by a toggle joint. Note the external contracting brake (similar to Fig. 1) on the outside of the brake drum.

It will thus be observed that **the external brake is of the contracting band** type and is operated by a **lever or fulcrum action.**

The internal brake is either a **shoe** or a **band** of the **expanding** type, and can be operated by a **cam** action or a **toggle-joint** action.

With this in mind, the classification of almost any type of brake can be determined instantly.

Brake Drums

Brake drums can be divided into two classifications: (1) the **single**; (2) the **double** brake drum.

On most makes of cars the **brake drums are mounted** on the inner part of the hubs of the wheels, and are **single brake drums.**

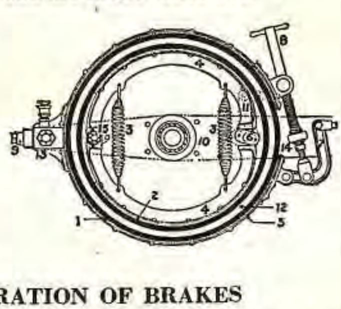


Fig. 5. The Locomobile, model "48," as an example, uses double brake drums for the rear brakes. Air space (12) between the drums keeps them comparatively cool. An external contracting brake band operates on the outside of drum (1); internal expanding brake shoes (4) operate inside of drum (2).

LOCATION AND OPERATION OF BRAKES

Brakes can be located in three places: (1) on the rear wheels, termed **two-wheel,** or **rear-wheel brakes;** (2) on the transmission shaft, termed **transmission or propeller-shaft brake;** (3) on all four wheels, termed **four-wheel brakes** (see also page 13).

(1) **Two-wheel brakes** usually have a single-brake drum on each rear wheel with an external brake on outside of drum and internal brake on the inside.

The external brake is usually operated by a foot **pedal,** and is called the **foot brake.**

The internal brake is usually operated by a hand lever, and is called the **hand brake**—formerly known as the emergency brake. See pages 12 and 13.

(2) **Sometimes a brake pulley** with a contracting type of band brake is mounted on the external part of the transmission shaft and operated by the **hand lever.** It is sometimes called the **transmission or propeller-shaft brake,** but the correct name is the **hand brake.**

(3) **The four-wheel brake** is discussed farther on, therefore we shall confine our attention here to a **two-wheel or rear-wheel type.**

Brake Connections

The foot-brake pedal and hand-brake lever are usually connected with the external and internal brakes in the rear-wheel brake drums by means of **brake rods** and sometimes by **flexible wire cables.**

Brake Rods

Examples of how connections are made with **brake rods on two-wheel brakes** are shown in Figs. 6, 7.

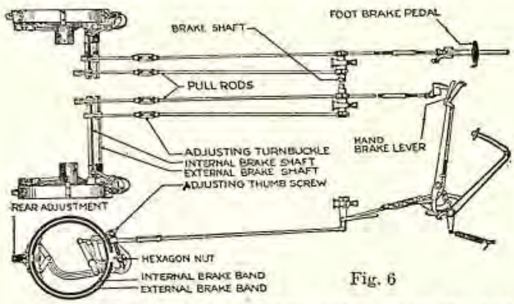


Fig. 6

Fig. 6. **Brake connections where rods connect the foot-brake pedal and hand-brake lever with external and internal bands.** The foot pedal operates the external brakes, and the hand lever operates the internal brakes. Note that an internal brake band with a toggle action is shown.

Fig. 7. **Brake connections where rods connect the foot-brake pedal and hand-brake lever with an external band and internal brake shoes.** The foot pedal operates the external brakes and the hand lever operates the internal brakes. Note that the clevises (14) are used for "distance" or "pedal and lever adjustments," whereas (7) and (16) are used for "brake-band clearance" adjustment. Note that the internal brake shoe has a **cam** action.

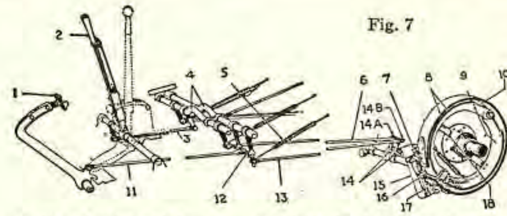


Fig. 7

(1) Foot-brake pedal
(2) Hand-brake lever
(3) Hand-brake forward rod
(4) Brake shafts
(5) Pull-back springs
(6) Hand-brake rear rod
(7) Foot-brake adjustment
(8) Brake linings
(9) Hand-brake shoes
(10) Brake drum
(11) Foot-brake forward rod
(12) Foot-brake equalizer
(13) Foot-brake rear rod
(14) Foot and hand-brake adjusting clevises
(15) Foot-brake band lever
(16) Foot-brake centering nut
(17) Hand-brake operating cam
(18) Anti-rattler springs

The adjustment of the external contracting brake (Fig. 7), which is the foot brake, is similar to the adjustment explained on page 889 (Fig. 10).

The adjustment of the hand brake (Fig. 7) can be tried by pulling the wheels by hand to determine that equal braking effort is applied to both rear wheels when the **hand-brake** lever is partly set, and that both lock at the same time with the wheels jacked up.

Adjustment is made at clevis (**14A**). The two clevises (14) are mounted on a tube within a tube. The clevis (**14A**) attaches to the inner tube and operates the cam (17); clevis (**14B**) is attached to the outer tube and operates the external brake lever (15). When the brake lever is released there should be no dragging of the brake shoes on the drum.

Brake Cables

Flexible cable is generally used in conjunction with rods and levers. The connection from the frame of the car to the wheel, however, consists of a specially designed flexible casing in which a flexible cable operates, thus transmitting brake-pedal pressure and taking care of the relative movement between wheels and frame.

FOUR-WHEEL BRAKE CONTROL

There are four methods of control: (1) mechanical; (2) hydraulic; (3) air; (4) vacuum.

Mechanical Method of Control

The mechanical operated method employs levers, rods, or cables for control.

The **foot-brake pedal** operates the four brakes simultaneously; the **hand-brake lever** operates either the rear-wheel brakes only, all four brakes, or a brake on the transmission shaft, termed the "transmission brake."

An example of a "mechanical" method of a four-wheel brake control system is shown in Fig. 7A.

Principle of operation:[1] The *foot-brake pedal* rod pushes directly against the left end of a rugged drop-forged *rotary equalizer* (Fig. 7B) which is pivoted under the center of the frame member.

The *four cables* connecting to the wheel brakes are attached to the rotary equalizer, each located at the same radial distance from the pivot pin. The angles at which the cables are attached to the equalizer are such that any rotary movement of the equalizer will produce the same distance of movement in each of the four cables. This holds true throughout their entire range of movement. Since the connections are close to the pivot and the section of the drop-forged rotary equalizer is large, any possibility of distortion, even under loads of several times that which it is possible to apply to the pedal, is eliminated.

The *hand brake* shown in Fig. 7A is employed on the Hudson and Terraplane cars, and is located to the left of the driver, with the mounting on the body dash panel. The lever extends downward from the pivot on the dash bracket, so that the hand grip is conveniently located just below the instrument panel. The hand-brake lever is connected to the right side of the rotary equalizer by a cable and *actuates all four wheel brakes.*

Adjustment of brake control system: The proper functioning of the brake control system is of vital importance. A freely operating brake control system permits its return to the stop provided, which is a return rest at the rotary equalizer on the chassis. With the brake control system returning to the maximum released position, a longer period of operation can be expected before readjustment is necessary. No backlash should be present at the foot-brake pedal or at the operating lever of each brake. Never adjust cable length except with shoes expanded tightly into the brake drums.

Adjustment of pedal rod: With the rotary equalizer against the frame bracket stop and the hand lever in the full "off" position, adjust the lock nuts on the lower end of the pedal

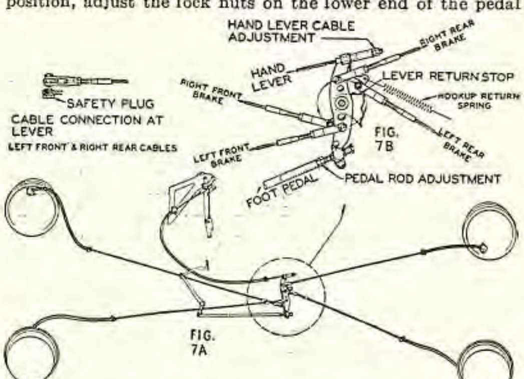


Fig. 7A. **Showing the fundamental operating principle of the cable control of the Bendix**[2] **mechanically operated braking system.** Fig. 7B. Close up view of the Bendix rotary equalizer which provides correct proportion of braking effort for each wheel and takes the place of the conventional cross-shaft.

[1] Compiled (1935) from Hudson Reference Sheet No. 5.

[2] See footnotes 1 and 2, next page.

push rod so that they are against the pedal push tube when the pedal shank is against the rubber bumper on the under side of the toe board bracket. Adjust the sleeve on the end of the hand-brake cable so that it is just against the rear face of the rotary equalizer. Be sure the rotary equalizer is still against the frame bracket stop after the above adjustments are made.

Lubrication: The foot-brake pedal and rotary equalizer bearings, clevis connections, and other frictional parts of the braking system should be lubricated every 1,000 miles of car service to insure their free return to the stops provided.

Lubrication of the cable and conduit control assemblies is as follows: Disconnect cable at rotary equalizer at brake operating lever, clean exposed portion of cable, and then pull cables through conduits from the brake end to expose that portion of cable which is sheathed by conduit. Clean this portion of cable, lubricate freely with Bendix[1] cable lubricant. Return cable into conduit and connect to brake operating lever, leaving rotary equalizer clevises disconnected until brake adjustment has been made. Conduit ends must always be firmly bottomed in abutment brackets.

Hydraulic Method of Control

By the term "hydraulic" is meant liquid pressure. It is best expressed in Pascal's law: "The pressure exerted upon any portion of a fluid inclosed in a vessel is transmitted undiminished equally to all surfaces." Since air can be compressed and liquid cannot, liquid is used for the transmission of pressure.[2]

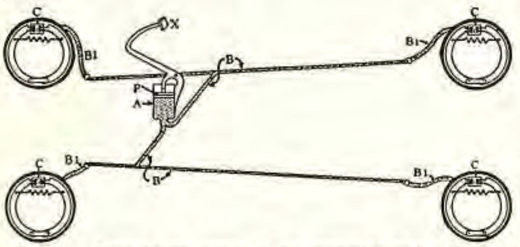


Fig. 8. **Showing the fundamental operating principle of the Lockheed four-wheel hydraulic brake system** by use of a master cylinder to originate pressure and the use of four wheel-cylinders to deliver the pressure to the brake shoes against the brake drums.

Principle of operation: The foot-brake pedal (X, Fig. 8) is connected to piston (P) in the master cylinder (A). When foot-brake pedal (X) is depressed, it forces piston (P) downward, thereby exerting pressure on the fluid in cylinder (A). Consequently, fluid is forced through copper pipes (B) and non-expansive flexible hose connections (B1) into the wheel-cylinders (C) on each of the four wheels.

Each wheel-cylinder contains two opposed pistons. The fluid enters the wheel-cylinders between the opposed pistons, forcing them outward. The pistons are in contact with the brake shoes; consequently the brake shoes are forced outward against the brake drums.

In accordance with Pascal's law, the pressure is equal in each of the wheel-cylinders and is equal to the pressure in the master cylinder. Increasing the force on the brake pedal (X) builds up greater hydraulic pressure within master cylinder (A) and therefore also builds up greater pressure within wheel-cylinders (C), thus causing a greater force to be exerted between brake shoes and drums.

Since the pressure is equal in each of the wheel cylinders, the forces are also equal, providing all wheel-cylinders are of the same size. The normal operating pressures are approximately 250 pounds per square inch.

When the foot pedal is released, the return springs on each of the brake shoes force the wheel-cylinder pistons inward, so that they return to their original "off" positions.

The wheel-cylinder pistons thereby force the liquid through the copper tubing, returning it to master cylinder (A). The fluid entering cylinder (A) forces piston (P) upward and thereby returns pedal (X) to its original or "off" position. The brakes are then ready for another application.

The entire system is filled with a special non-freezing fluid (known as "Lockheed hydraulic brake fluid"), and all air is expelled.

In systems using hydraulic foot brakes, the **hand-brake lever** is mechanically connected to either a brake on the propeller shaft or directly to the rear wheel brake shoes.

Air Pressure Method of Control

Air-pressure brakes: The air principle of operating four-wheel brakes is not as yet applied in general to pleasure cars. They are used on commercial trucks and trailer equipment, motorcoaches, and fire apparatus of large size. See also page 1081, 978.

Vacuum Method of Control

Vacuum power brake:[1] In this type, power is supplied by vacuum from the engine to a vacuum cylinder and piston. The piston actuates cables, master hydraulic cylinder, or brake rods as shown in Fig. 8A.

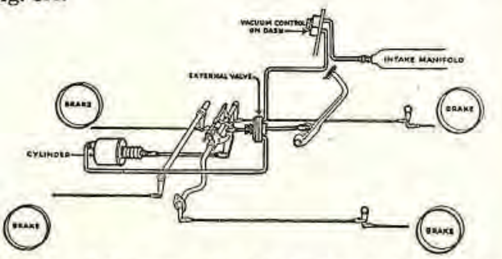


Fig. 8A. **B-K vacuum power brake system applied to brake rods.**

Vacuum power supplements the foot-pedal power on vehicles equipped with foot brakes. It increases the power applied to the brake system, thereby decreasing the pedal pressure required. On vehicles (such as trailers) that are not equipped with foot brake, the vacuum power brake can be installed as the *sole method of brake control.*

CARE AND ADJUSTMENT OF BRAKES[3]

As the safety of a car depends on its brakes, they must be kept in the best possible condition. They should bind tightly when pressure is applied to them, and be free and clear when the pedal or lever is released. A brake band or shoe that binds when the pressure is released produces friction, and makes the car hard-running.

A common brake trouble is slipping, generally the result of oil or grease working out of the rear axle. It is also caused by poor adjustment, or worn linings. Therefore the first and most important precaution is to stop any leak by putting in a washer. Poor adjustment may be cured by **readjustment.**

In the case of oil or grease working between the surface, **clean the brake drum and lining** by washing out the oil with gasoline, and then stop the leakage of grease out of the rear axle. This is usually done by the replacement of a felt washer or "grease retainer" washer (see Fig. 32, page 875, and Fig. 52, page 883) on the inside of the hub. The excess oil is generally due to too much oil in the differential casing, which works out into the brake drums.

Slipping caused by worn linings may be remedied to some extent by taking up the adjustment, but if too much worn for this, they must be replaced.

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[1] **See page 1088 for Bendix Duo-Servo brake operation and adjustments.**

[2] **See page 1083 for Hydraulic brake operation and adjustments; also, footnote giving information concerning *Servicing* and *Parts Catalogue*.**

[3] **This section deals with two-wheel brakes. The information in general is also applicable to four-wheel brakes (except Bendix, Lockheed hydraulic, and Steeldraulic).**

Replacing the worn lining is not difficult, as the brake lining is held to the steel band or shoe by brass tubular rivets.

Because the application of the brake generates heat, leather linings would be burned if kept in contact too long. For this reason, the brakes are usually lined with an asbestos friction lining.

If, when applying the brakes, the car has a tendency to skid to one side, this indicates that one wheel is free and the other dragging. In such a case the brakes are not equalized in adjustment. Therefore the brake resistance should be equalized.

The operator can save considerably by applying his brakes gradually. For instance, if a stop is to be made, instead of dashing up to the stop and applying the brakes with full force suddenly, simply coast to the stop and apply the brakes gradually, or even not at all. This, of course, requires practice.

If a brake squeaks, the lining may be dirty and dry, and needs cleaning with a stiff wire brush and gasoline. The dirt clogs the pores in the surface of the lining and glazes it over, which causes the squeak. Brake squeaks are also caused by improper clearance, exposed rivets, or high points between the brake drum and the brake band due to a rough, scored, or out-of-round drum. Where a one-piece application of brake lining is used, noise and squeak can often be eliminated by cutting out approximately 2″ of the lining opposite the rear adjusting screw or anchor bolt. In some cases noise can be eliminated by grinding or filing the corners of the lining at the ends. Oil anchor pins and all brake mechanism.

Chatter is usually caused by the brake grabbing and releasing. Can usually be corrected by adjustment. Look also for improper band or shoe support, loose parts, loose lining, worn linkage, eccentric drum, sticky lining, loose springs, loose wheel bearings, improper angle of bell crank lever which presses ends of lining into drum instead of pulling tangentially. Shoe brakes will occasionally chatter if the shoes are loose on supporting pins or if the springs supporting them are broken.

Brake drag is usually due to insufficient strength of the releasing mechanism, such as the springs; or the connections may be adjusted too tight; or there may be insufficient clearance at the bands, or rusty linkage, or out-of-round drum.

Lublication of brakes: Asbestos lining requires no lubrication because the oils tend to carbonize, owing to the high frictional heat, and eventually cause the linings to glaze. See that the hinges, cams, toggles, anchor pins, and lever bearings—in fact, all moving parts—are kept supplied with oil and free from rust.

Inspection of Brakes Before Adjustment

Points to consider when starting to make adjustments of the brake mechanisms are: Do the brakes merely need adjustment, or do they need an overhauling? If a car has been run for a long time, it is advisable to make an inspection as follows.

1. **Inspect the bearings in the rear wheel hubs,** to see if they are in good condition. If the bearings are loose or worn, this will make a difference in the adjustment of the brakes, especially when adjustment is made with the car jacked up and when it is made with the car on the ground under its weight. The adjustment can be tested by grasping the wheel on each side of the car, when jacked up, and "feeling" for looseness.
2. **Inspect the rear wheels to see if they are out of line.** If they are, it is probably the result of having skidded against the curb and having slightly bent the axle shaft or having thrown the wheel out of line. This will affect the brake adjustment. Test by spinning the wheel when the car is jacked up.
3. **Inspect the parts** of the brake mechanism to see if they are **loose**; if so, tighten. Anchor brackets should be firmly riveted as well as any other loose parts.
4. **Inspect the joints** and parts to see whether they are rusted or caked with dirt and grease; if so, clean and lubricate.
5. **Inspect anchor pins and lever pins** on the brakes for wear; also **clevis pins** (see Fig. 7, page 885). Replace pins if worn. Clean and lubricate if rusted or dirty. These parts are often overlooked.
6. **Inspect springs** (see S, Fig. 9, page 889) on the brakes. They should release properly and be kept free from rust and cleaned and lubricated, otherwise the brakes may drag and cause heat and wear and noise. When replacing springs, be sure they are of the same size and tension, especially on external brakes which separate the bands.
7. **Inspect the brake linings to see if they are coated with oil or grease;** if so, clean with gasoline after removing the wheels with the drums. Find the cause of the grease or oil being on the brakes, and remedy it.
8. **Inspect the brake linings to see if they are worn.** If slightly worn, "clearance adjustment" will take care of the difficulty. If **badly** worn, a new lining will be needed. Also see if the lining has worn down to such an extent that the rivets have cut the brake drum; if so, the wheel must be removed and the brake drum smoothed down with emery cloth, or, in bad cases, the brake drum must be turned or ground true.[1] If the band is not entirely worn down, the brake band can be adjusted for clearance.

Testing the Brake Action[2]

After the conditions enumerated above are attended to, and parts are cleaned, replace wheels and proceed to test the brake action as follows:

1. Jack up the rear axle, with the brakes in a complete "off" position. Note the **clearance of the internal bands** around the drum, which should be uniform and about 1/64″. On the external band, this will extend to within only about 3″ or 4″ of the end of the band, where the clearance will be greater.
2. To test the **internal brake band for clearance,** use a thin piece of metal or thickness gauge, inserting this between the drum and the band from the inner side of the brake support.

For a more elaborate and sure test, both for holding power and, what is equally important, the equal action (termed "equalizing action") of the right and left brake bands, proceed as follows:

1. Block the front wheels securely to prevent the car moving forward or back.
2. Jack up the rear wheels until they are entirely clear from floor.
3. Put all brakes on both sides in complete "off" position.
4. Start engine, run it slowly, and transmit power to the rear wheels, as when driving in low gear.
5. Engage the brakes carefully and lightly, and note the action of the wheels, which will show clearly any inequality between the right and left adjust-

[1] Special drum trueing machines are available for this work.

[2] The modern method is to test by means of brake-testers (see page 896).

ment. Both brakes should stop at the same time when the brakes are applied.

On some cars without equalizers the adjustment is made by lengthening or shortening the brake rods, by screwing off or on the yoke ends which connect to the brake cams or by varying the position of the brake-operating lever and slotted clevis on the brake cam shaft. Usually there is a hand adjustment on the contracting brake.

Sometimes all the overhauling the brakes need is a cleaning of the drums and brake lining with gasoline. If grease or oil works its way to the brakes, either too much is being carried in the differential or the felt washers in the axle need replacing.

Stopping Distances of Cars at Various Speeds

Minimum and maximum stopping distances from various speeds of a car with 4-wheel brakes in good adjustment and under the most favorable conditions, that may be regarded as reasonable distances allowed under motor vehicle regulations: 15 mph., 22′-28′; 20 mph., 35′-45′; 25 mph., 50′-65′; 30 mph., 67′-89′; 40 mph., 109′-149′; 45 mph., 134′-185′; 50 mph., 162′-224′; 60 mph., 224′-314′; 70 mph., 296′-419′; 80 mph., 379′-539′; 90 mph., 471′-674′; 100 mph., 573′-823′[1].

Average Brake Adjustments[2]

There are three adjustments to be considered when adjusting brakes: (1) brake-rod adjustment; (2) brake-pedal and lever adjustment; (3) brake-band clearance adjustment.

Brake-Rod Adjustment

The first adjustment of brakes should always be made in the brake rods rather than in the brake itself. Tighten up on these rods so as to get the proper travel in the brake pedal or hand lever. The adjustment of the brake pedal and hand lever is thus made through the rods, by seeing that the foot-brake pedal and hand-brake lever are in "off" position and the rods adjusted so that there is no binding. This can be tested by jacking up the wheels and observing if there is a drag. Adjustment can be made by a threaded adjustment at the front end of the rod, by screwing in one direction to lengthen and in the opposite direction to shorten the pull. The lever (see 15, Fig. 7) on the external brake should be in toward the band, in order to allow for full leverage.

Dragging of the brakes may be caused by too short an adjustment of the rods.

Before adjusting the brake bands, see that the **pull-back springs** are operating properly and lengthen the rods.

If the brakes will not hold, be certain that the brake lining has not become saturated with oil or grease; if so, wash with gasoline.

When the proper brake action cannot be obtained by further adjustment of the brake rods, then adjust the brakes themselves.

Brake-pedal adjustment should be made so that when the brakes are fully applied the distance from floor board is from about 1½″ to 2″.

Adjustments of External Brakes[3]

The foot brake usually connects with the external brakes and requires more adjustment, because it is used most. They are also exposed to dirt and water and require more frequent cleaning. The **hand brake** is mostly used for locking the wheels when standing and at intervals in conjunction with the foot brake on steep hills; therefore it requires less attention.

Usually, ordinary external brake adjustment for clearance is all that is required, and this can be done without removing the wheel.

Clearance adjustment of the external brakes is very important. If the band touches the brakes at different points of its circumference, the brake will drag at that point, which of course consumes extra power and causes wear on the lining. The purpose of adjusting this **clearance** is to relieve the drag, or to take up on an excess of clearance due to wear of the lining.

The proper clearance on most brakes is about 1/64″ to 1/16″ all round, more or less according to the kind and make of lining. Follow brake-lining manufacturer's instructions. Usually this clearance can be taken up as follows:

1. By adjusting the **lever,** as at (A) (Fig. 10).
2. By adjusting the **rear clearance** of the band, as at (D) (Fig. 10).
3. By adjusting the **lower half of the band** for clearance, as at (E) and (F) (Fig. 10).
4. By adjusting the **upper half of the band** for clearance, as at (G) (Fig. 10).

This is ordinarily sufficient. The drum, revolving in a forward direction, has a tendency to draw the top half of the band to the drum, therefore don't give it less clearance than the bottom, if anything, slightly more.

A thickness gauge is handy to place between the brake lining and the drum when adjusting clearance.

After adjusting the brakes, notice if the wheels turn freely when the foot-brake pedal and hand-brake lever are in the "off" position. If the wheels do not turn freely, or if they drag, the brakes are adjusted too tightly.

Many repairmen, with the wheels on the ground, and after making adjustment, move the car backward and forward to see if the band drags. If this is done, be sure that both brakes are adjusted equally, as sometimes the weight of the car on the wheels will alter the adjustment. (The modern method of testing is with brake-testing machines.)

In adjusting the brake bands, be sure to take up the same amount on both right and left-hand brakes. If care is not exercised in making the adjustment, one brake may set before the other, thus destroying the braking effect and causing one wheel to lock and slide over the ground, wearing off the tread of the tire very rapidly. Also be careful not to set the bands up so tightly that they drag and will not release when the foot is removed from the pedal.

Brake equalization test: Select a dry smooth road. Drive at 20 miles an hour. Throw out clutch and apply brakes so as to lock wheels. After the car has stopped, note where each wheel began to grip the surface of the road.

If the marks of each wheel begin at the same place, your brakes are equalized. If one mark is longer than the other, your brakes are not equal in action and an adjustment should immediately be made (Raybestos "Silver Edge").

If the brakes seem to be too tight after the car has just been washed, it is due to the fact that the brake lining, which is composed of a combination of closely woven wire and asbestos, has swelled slightly from the water. In a very short time this condition will disappear.

An example of an external brake band improperly adjusted and the points of adjustment are shown in Figs. 8D and 8E.

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[2] See footnote, p. 886, relative to adjustments of the **Bendix** and the Lockheed hydraulic brakes.

[3] The transmission brake is very similar to rear-wheel external brakes and are adjusted in somewhat similar manner. On the shoe type of external transmission brake, the adjustment is usually made at the top.

[1] Excerpts from NBS (National Bureau of Standards) *Letter Circular LC517*. The stopping distances shown, include the reaction time or distance traveled from the time that emergency is seen until brakes are fully applied. Applicable to private automobiles, buses and trucks.

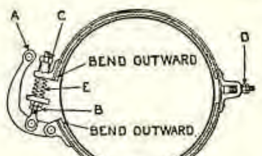


Fig. 8D. External brake band improperly adjusted.

Fig. 8E. Points of adjustment on external brake band. **A**, lever; should be close to band when in off position and should be in same relative position on each brake when adjustment is completed; **B** adjusts lower band; this adjustment should be made before making final adjustment of **C** (about 1/64" clearance); **C** adjusts upper band (about 1/64" clearance); **D**, anchor screw for adjusting clearance between lining and brake drum (about 1/64"); **E**, spring.

The band should now have equal clearance all around drum except for a short space near ends of the bands, which are bent slightly away from the drum as shown (Fig. 8E). The bands should grip drum evenly all around and at the same instant, or progressively from the anchorage on the upper band.

If brakes fail to hold in stopping car in forward motion of car, try brake in the reverse and if it is excellent, the trouble is that the pressure is too high on lower band. Bring upper one down by adjusting nuts **B** and **C** and try again. Spring **E** might be compressed fully and this would prevent the brake holding in forward direction. (Excerpts and illustrations from Johns-Manville *Brake Reliner's Manual.*)

Adjustments of Internal Brakes

The internal brakes are of the "toggle"-acting type or of the "cam"-actuated type, as previously explained.

As an example of adjusting clearance in the "toggle"-acting type of internal band brake, see Figs. 11 and 12, page 890. In order to make this adjustment, it is necessary to remove the rear wheels. Refer to page 890, and note the adjustments as there explained. See also, Fig. 18, p. 892.

As an example of adjusting clearance in the "cam"-acting type of internal brake, see Fig. 14, page 891, also Figs. 19 and 9, pages 892, 889.

Ordinarily, **the only adjustment required for the internal brake** is to adjust the pull rods or clevis, otherwise remove wheels and make adjustment on the brake itself.

AN EXAMPLE OF REAR WHEEL (TWO-WHEEL) BRAKE ADJUSTMENT

The foot brake, also termed the service brake, contracts on the brake drum. The **hand brake,** also termed the emergency brake, expands against inside of the brake drum. By studying Fig. 9, the functions of these brakes will be understood. Both brake bands are faced with brake linings.

The adjustment for clearance of the external brake band (B) is made at the nut (C) below the spring for clearance of the lower half of the brake band, and by nut (D) for the clearance of the upper half of the brake band.

The adjusting screws (E) and (F) are additional adjustments for procuring an even spacing or clearance all around the circumference of the drum. This clearance should be about 1/32", or not over 1/16".

The internal brake is operated by a cam (H) which expands a steel band lined with brake lining. The usual adjustment is made by shortening the brake rod at the turnbuckle.

The spring (S) serves two purposes: The adjustment nuts are locked by the spring and at the same time, it helps release the band when the pressure is taken off the brake lever.

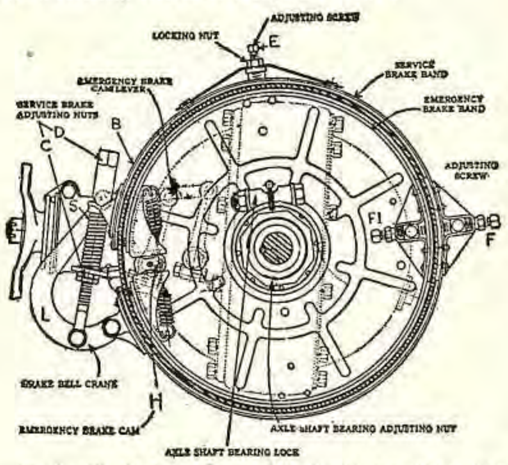


Fig. 9. The brake as used on the Studebaker "Light-Six" car. Note that a lever (L) termed a "brake-bell crank," connects with the external contracting band (B). This lever (L) is connected with the foot-brake pedal through the clevises and brake rods.

ADJUSTMENT OF BRAKES OF TIMKEN REAR AXLE

The adjustments described in what follows are of the brakes as used on the Timken semi-floating or fixed hub type of rear axles, and on the full-floating rear axle as shown on pages 865, 866.

The **external** brake (Fig. 10) is the type used on both, but the **internal** brake is of two types, shown in Figs. 11 and 12. The one shown in Fig. 11 is the type used on the semi-floating, or fixed-hub axles, and the one shown in Fig. 12 is the "toggle"-operated expanding band type of internal brake used on the full-floating axles.

The **internal** brake shown in Fig. 14 is the "cam"-operated expanding band type of internal brake formerly used. A later type of Timken brake is shown in Fig. 16.

External Brake Adjustments (Timken)

To adjust the external brakes, jack up both rear wheels, and put the brakes in the complete "off" position.

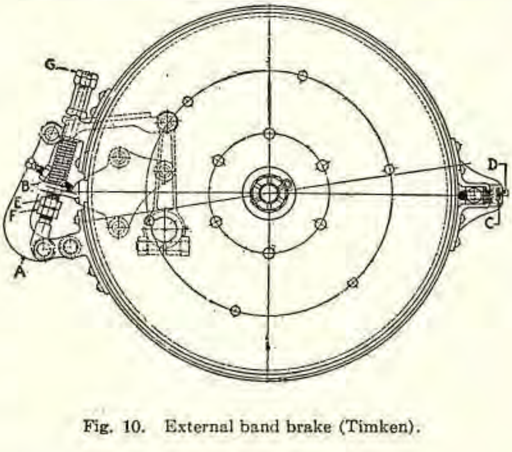


Fig. 10. External band brake (Timken).

Adjust the stop screw (B) (Fig. 10) so as to allow the **lever (A)** to come down as far as possible and still have a clearance of about 1/16″ with the operating mechanism.

Now remove the cotter pin **(C)** and turn the adjusting screw **(D)** until the clearance between the brake lining and the drum at this point (rear) is not more than 1/32″. Be sure that the brake drum clears at all points; if necessary turn the adjusting screw out slightly. Replace the cotter pin.

Now adjust the **lower half of the band** by turning nuts **(E)** and **(F)** until about 1/32″ clearance is obtained at this point also.

After locking these nuts firmly, make a similar adjustment of the **upper half** by turning nut **(G)**. Be sure that this nut is properly seated in the groove into which it fits, thus locking adjustment.

When these adjustments are complete, there should be a maximum clearance between the brake lining and the drum of about 1/32″ at all points, but they should not be in contact at any place. Readjust until this condition is obtained.

Internal Brake Adjustments: Timken Toggle Type

In order to adjust the internal brake, it is necessary to remove the rear wheel, carrying with it the brake drum. Jack up both rear wheels, put the brakes in complete "off" position; remove wheels.

To adjust the fixed-hub type of axle brake (see Fig. 11): First remove the cotter pin **(A)** and tighten up adjusting screw **(B)** until a maximum clearance of 1/32″ is obtained between the brake lining and the drum at this point. This clearance should be the least possible amount—only enough so drum will not rub at any point when revolved.

Having obtained the proper clearance, replace the cotter pin **(A)**. Next remove the head pin **(D)** and disengage screw **(E)**, freeing both ends of brake band.

Adjust the four set screws (F) to give the least possible clearance between the brake lining and the drum—1/32″ should be the maximum.

When this adjustment has been made, be certain that each set screw is firmly locked with lock nut.

Now adjust the screw (E) to give not over 1/32″ clearance between the lining and the drum at the two ends of the band and replace the pin **(D)**.

After making all these adjustments, there should be a maximum clearance all around the drum of 1/32″—if not, readjust until this result is obtained.

To adjust the internal brake on the full-floating type of axle, see Fig. 12.

Adjustment is made in a similar manner. Some of these axles are provided with a triangular plate in the brake drum which can be removed for adjusting the brake. In this case it is not necessary to take off the wheel.

Adjust the screw (B) to give the proper clearance at this point; obtain the correct clearance over the rest of the brake band by adjustment of screws **(D)** after loosening the clamp bolt **(C)**.

After making these adjustments, be sure that the cotter pin **(A)** has been replaced and that the clamp bolt **(C)** has been tightened up firmly.

Now loosen the clamp bolts **(E)** and **adjust screws (F)** until the forward edge of head-pin **(G)** is in line with the rear edges of pins **(HH)**. Tighten up bolts **(E)** and replace the wheel.

In replacing the wheel on the full-floating type of axle, be sure that you get a correct bearing adjustment described on page 864 under "Wheel bearings."

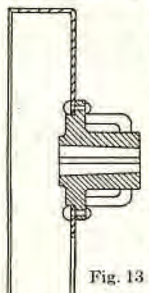


Fig. 13

Dummy Drum for Adjusting the Internal Brake

In garages or service stations when internal brake adjustments are frequently made, a dummy drum (Fig. 13) **can be used to advantage.** The same result can be obtained by a "cut-and-try" method, removing and replacing the wheel several times, but the use of a dummy will prove a great time saver.

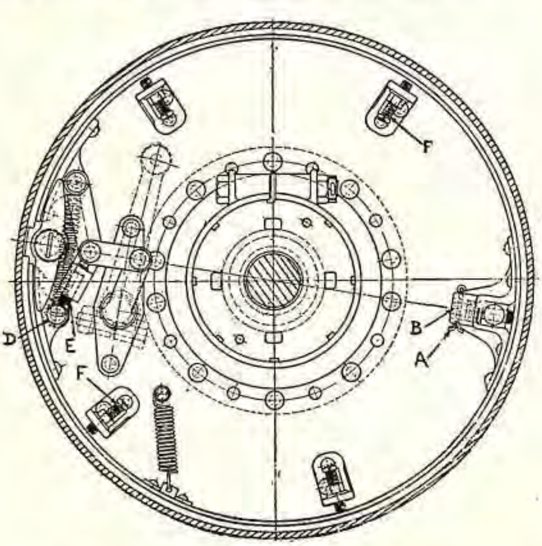


Fig. 11

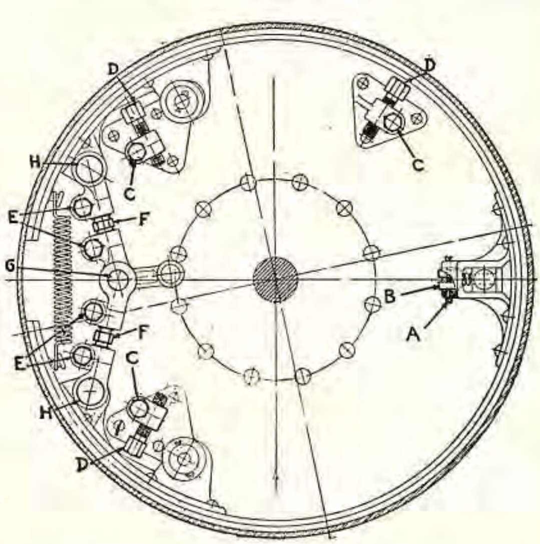


Fig. 12

Fig. 11. Internal toggle type of brake (Timken), as used on the fixed hub or semi-floating axle, as discussed on page 865.

Fig. 12. Internal toggle type of brake (Timken), as used on the full-floating type of axle, as discussed on page 865.

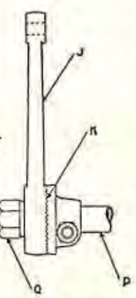
Internal Brake Adjustments: Timken Cam Type

Adjustment of the Timken-cam type of internal brake: A cam type of internal brake has been used on several axles formerly produced (see Fig. 14).

Fig. 14. Timken cam actuated internal brake.

To adjust this brake for slight wear of the brake-band lining, this can ordinarily be taken up satisfactorily without getting into the brake proper.

Fig. 15



This is done by loosening nut (Q) (Fig. 15) and moving lever (J) forward one notch in ratchet (K), and then tightening nut (Q). Perhaps two notches forward may be required.

For more band-lining wear than can be taken up by this method, put jacks under the rear axles, being careful to have them press up against the housing proper (or, on some Timken axles, against the pads made for this purpose), but never against the truss rods. Raise both rear wheels off the ground.

Next, put all the brakes on both sides of the axle in a complete "off" position.

Now, if the adjustment is merely to take up for wear of the brake lining in service, it is necessary only to (1) remove the wheel which also removes the brake drum; (2) remove the cotter pin (B), give screw (A) two turns to the right (i.e., in a clockwise direction), and replace pin (B); (3) loosen screws (C,C) give cam plates (D,D) one half-turn outward (i.e., to the left or counter-clockwise), and tighten screws (C,C).

Put the wheel back on and try the brake in the "off" position for a bare yet sure clearance, so that it will not drag. Try it in the "on" position for holding power.

If greater clearance is required, remove the wheel and partially reverse the adjustments detailed just above.

If still more holding power is desired and there is some clearance yet to spare in the "off" position, remove the wheel and repeat the adjustments to a partial extent.

Timken Types "5510" and "5710" of Brake

Both the external and internal brakes on the 1922 series axles are the same as those made on the corresponding axles of the former series, except on the new series "5510" and "5710" for heavy cars.

On these axles the **internal** brake is of a new type, as shown in Fig. 16, and requires no adjustment beyond that which can be obtained in the brake-pull rods. The adjustment of the **external** brake is similar to that explained on page 889, 890.

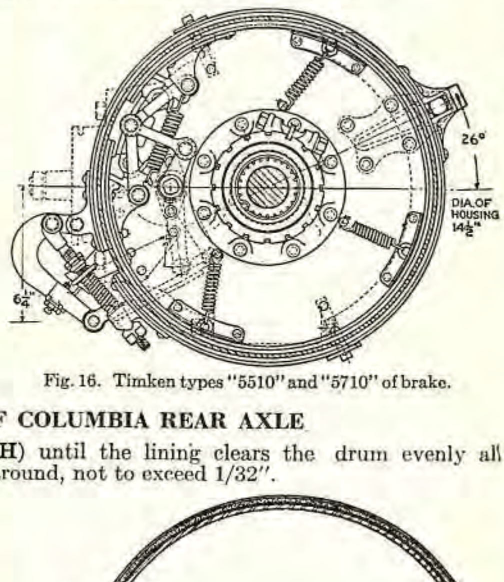


Fig. 16. Timken types "5510" and "5710" of brake.

ADJUSTMENT OF BRAKES OF COLUMBIA REAR AXLE

External Brake Adjustment on Models "10000," "30000," "50000" and "51000" Columbia Rear-Axle Brakes

To adjust the external brakes on these models, jack up both rear wheels, and put the brakes in the complete "off" position with lever (A) back against stop (B).

Lever adjustment: Lever (A) must set back against stop (B)—lengthen pull rods if necessary to get this condition.

Rear clearance adjustment: Remove cotter pin (C) and lock (E), and turn adjusting screw (D) until the clearance between the brake lining and the drum at this point does not exceed 1/32". Make sure that the drum clears at all points.

Lower half of band clearance adjustment: Replace lock (E) and cotter pin (C); next, adjust the lower half of the band by turning nuts (F) and (G) until the lining clears the drum evenly all around, not to exceed 1/32"; then lock nuts (F) and (G).

Adjust the upper half of the band by turning nut (H) until the lining clears the drum evenly all around, not to exceed 1/32".

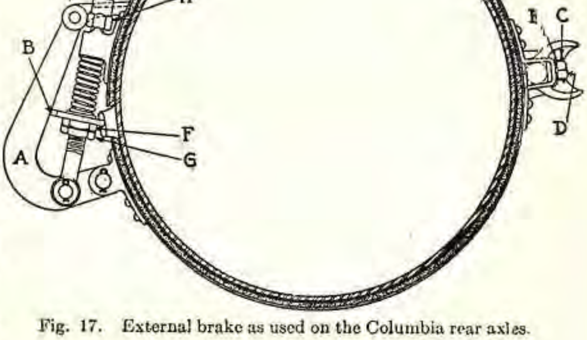


Fig. 17. External brake as used on the Columbia rear axles.

Be sure that nut (**H**) is properly seated in the groove into which it fits, as this locks the adjustment.

When these adjustments are made, there should be a maximum clearance of 1/32" between the brake lining and the drum at all points. The lining must not touch the drum at any place. Readjust until this condition is obtained, and test with a thickness gauge.

Internal Brake Adjustments on Models "50000," and "51000" Columbia Rear-Axle Brakes

To adjust the internal brakes on these models which are of the **"toggle-acting type,"** and are provided with adjustment at **four** points proceed as follows:

As a time saver, and to get the best results in adjusting this type of brake, a **dummy drum should be used.** The openings in the drum permit a view of the parts to be adjusted, insuring a much closer and more accurate adjustment than could be obtained without its use.

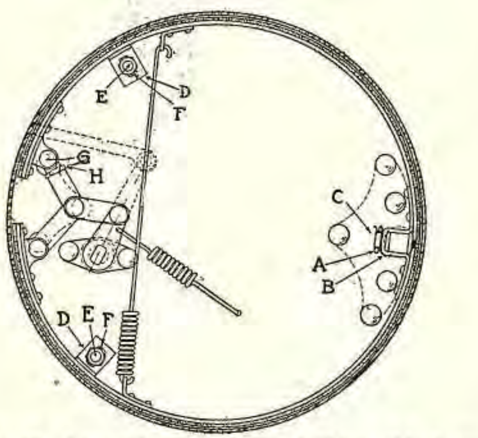


Fig. 18. Internal "toggle joint actuated" type of brake as used on the Columbia rear axles.

First, remove the rear wheels; then adjust the pull rods until the brake-shaft lever on the axle to which these rods connect is set back at same angle as external brake-tube levers when contracting lever (**A**) is back against stop (**B**) (see Fig. 17 and instructions for external brake adjustment above).

Next, remove cotter pin (**A**) and lock (**B**) (Fig. 18). Put on the dummy drum, bringing the opening in the drum directly over adjusting screw (**C**); turn adjusting screw (**C**) until the clearance between the brake lining and the drum at this point does not exceed 1/32", or the least possible amount obtainable, so that the drum will not rub at any point when revolved. Having obtained the proper clearance, replace lock (**B**) and cotter pin (**A**).

Next, bring the openings in the drum directly over the internal brake supports (**D**). These supports have a small projection that fits into slots in the brake band. Be sure these are in place. Loosen the nuts on bolts (**E**) just enough to allow supports (**D**) to move freely. Adjust supports (**D**) so that the clearance between the brake lining and the drum does not exceed 1/32", or the least possible amount that can be obtained, so that the drum will not rub the band at any point when the drum is revolved. In adjusting supports (**D**), use a bar as a lever for prying, working through the opening in the drum; with the bar resting on the drum-catch support, with the end of the bar at (**F**), move supports (**D**) up or down. This action moves the brake band until the proper clearance is obtained. Then hold the supports in place until the nuts on the outside of bolts (**E**) are drawn up tight, and remove the drum to see that it turns freely and that the clearance between the brake lining and the drum is the same all around. Clearance must not exceed 1/32".

To get the proper clearance at the points, remove pin (**G**) and adjust screw (**H**) until a maximum clearance of 1/32" is obtained; then replace pin (**G**).

After adjusting point (H), always check supports (D), making sure that this adjustment has not moved the band away from supports (D). If these supports do not set up tight to the band, readjust supports (**D**). After making all these adjustments there should be a maximum clearance all the way around the drum of 1/32"; if not, adjust until this result is obtained.

Important: Never adjust the pull rods without afterwards adjusting supports (**D**), as the adjusting of the pull rods pulls the band away from supports (**D**) causing rattles and also wear of the supports. To eliminate rattles, adjust supports (**D**) up tight to the band in release position.

In adjusting the brakes a thickness gauge should be used to measure the proper clearance between the brake lining and the drum. Dummy drums can be secured for models "10000," "30000," "50000," and "51000" from The Columbia Axle Co., Cleveland, Ohio. Asbestos brake lining 2½" in width is used.

Internal Brake Adjustment on Models "10000" and "30000" Columbia Rear-Axle Brakes

The internal brakes on these models are the **"cam-operated type,"** and only one adjustment for "clearance" is provided. See Fig. 19.

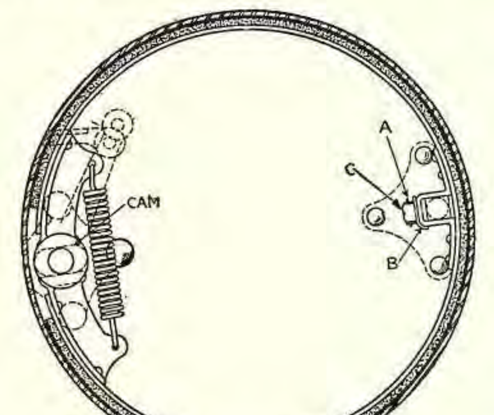


Fig. 19. Internal "cam-actuated" type brake, as used on Columbia rear axles.

To adjust, remove cotter pin (**A**) and lock (**B**), and turn the adjusting screw (**C**) until the clearance between the brake lining and the drum at this point does not exceed 1/32".

Adjustment for wear, which is the only adjustment usually required, is made by shortening the pull rods from the cam lever forward to the chassis.

OVERHAULING BRAKES

There are three things which must be particularly noticed in taking care of brakes and putting them in condition:

1. There must be no grease on the shoes.
2. The fabric must be in the best of condition.
3. The brake linkage must apply the brakes when the pedal is depressed.

The grease which penetrates to the brake lining usually works its way from the differential, and can be stopped by renewing the washer in the wheel hub.

To remove grease, first remove the wheel, then inspect the brake lining and see if it comes under the condition mentioned in No. 1 or No. 2 in the list above.

If a coating of grease is over the surface of the fabric, there will be two methods of procedure. The first method for removing grease is by the application of gasoline. This removes the grease from the outer surface very well, but not from below the surface of the fabric. A blow-pipe torch can be used in this instance, which can be gently applied as shown in Fig. 20, this page, care being taken not to char the fabric.[1]

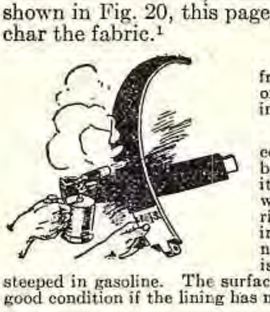


Fig. 20. Removing grease from under fabric brake lining on a two-piece internal expanding brake shoe.

After the heat has been directed against the surface of the brake for a short length of time, it will be noted that the grease will literally fry out of the fabric, leaving it upon the surface in the form of a black carbonaceous deposit. In this state it is readily removed by a cloth steeped in gasoline. The surface of the brake will now be in good condition if the lining has not been worn out.

Where oil or grease causes a glaze on the lining, wrap coarse emery paper around a half-round file and roughen the surface.

If the brake lining is badly worn down, so far that the fabric lining is too thin to be of service, or if the lining is excessively oil soaked, a new brake lining must be applied.

If the brake lining has worn down to the rivet heads, it should be renewed, unless the rivets can be sunk lower by a round-nosed punch, the other end of the rivet being placed over a small hole in a piece of metal on an anvil or vise. Then the rivets can be set up tighter.

Relining External Contracting Brake Bands

To reline the external brake: First, jack up the rear wheels. Disconnect the levers, etc., from the brake bands and remove the wheels and bands, being careful to keep all parts separate, so that they can be replaced with ease.

Second, wash all parts in gasoline or kerosene to remove the grease and dirt.

Third, remove the old brake lining,[2] by placing the band in a vise and cut the rivets with a chisel (Fig. 21); then open up the bench vise about ½", setting the bands so that the old rivets come over the opening one at a time. Drive them out with a nail set (Fig. 22). As the heads will most likely be worn off, it is easier to drive them from the lining side through to the band side. The old lining can then be easily removed from the band.

Fourth, measuring brake lining:[3] It is best to secure the lining from the automobile dealer or manufacturer ready to apply, but if this is not possible, then proceed as follows: Place it **inside** the band (Fig. 23), holding it firmly against the band and cut the lining from ¼" to ⅜" **longer** than the band, depending upon the diameter of the band.

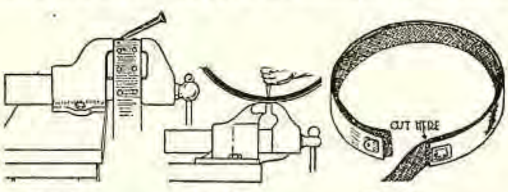


Fig. 21 Fig. 22 Fig. 23

Fig. 21. Method of cutting rivets on worn band.

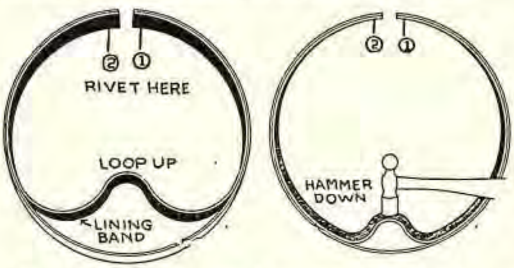
Fig. 22. Punch the cut rivets out.

Fig. 23. Method of determining length of lining for an external contracting band type of brake.

Fifth, rivet one end flush with band (Fig. 24–1), after having countersunk holes in the lining for the rivets. The position of rivet holes are located from holes in the brake band.

Sixth, place lining firmly in band all around, then draw out center portion of lining from band (which will make a loop as shown in Fig. 24), allowing the unriveted end of lining to slide along band toward the loop until it is just possible to force the lining back against the band with the loose end held from sliding.

Seventh, having found this position experimentally, locate other end rivet holes from holes in band. Insert rivets and head over on outside of band.



Figs. 24, 25. Lining external contracting brake band; one-piece application. This same method applies to attachment of external band lining where more than one strip of lining is used.

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[1] The practice of cleaning grease-soaked brake lining with gasoline or burning it out is not approved by brake-lining manufacturers because they state it is rarely a permanent remedy and should be resorted to only in case of emergency. One manufacturer states: "Grease increases the effectiveness of braking action when drum is cold, and greatly reduces braking power with warm drum. If presence of grease is discovered, almost immediately it may be washed off with gasoline, but otherwise it is advisable to reline, inasmuch as burning out the grease with a torch is rarely a permanent remedy and usually harms the lining." Another manufacturer states: "Once a lining of the woven or folded type becomes covered with grease it is difficult to obtain equalization of the brakes; however, if the leakage is noticed in time it can be washed from the lining with gasoline, after which a strong water solution of washing soda or lye should be used to remove the remaining oil from the gasoline. Some apply a heating torch and burn the grease out, but this generally carbonizes the oil and eventually causes a glaze. Moulded linings are more readily cleaned of grease."

[2] Brake-relining machines are now used extensively for this work.

[3] Most accessory dealers or jobbers possess data books of brake-lining measurements (also clutch facings) from early to late model cars. Brake-lining data books are supplied by almost all brake-lining manufacturers and will be forwarded upon request to the Brake Lining Manufacturers' Association, Inc., New York City, N.Y. When writing, be sure to state the name or brand of brake lining in which you are interested.

Eighth, force lining straight against band with hammer (Fig. 25). **Ninth,** place band over a block of wood or vise and use holes in band as a template. **Drill holes** for the rivets. It is important that the holes be in the correct **position. Tenth,** countersink[1] holes so that the rivet heads will be below surface of lining. Use a countersinking tool (Fig. 26).

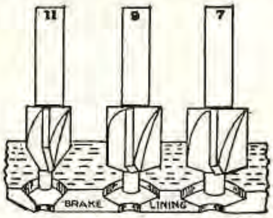


Fig. 26. A brake lining counter-sink.

Eleventh, place remainder of rivets through lining so head of rivet will rest in countersunk hole in lining and head over rivets on outside of band.

Twelfth, taper ends of lining by grinding on emery wheel, or file; round up with brake drum and reassemble. (NOTE: Fabric lining need not be tapered but all moulded lining should be.)

The foregoing procedure illustrates a one-piece brake-band-lining application. The same method applies to attachment of external brake-band lining where **more than one** strip of lining is used.

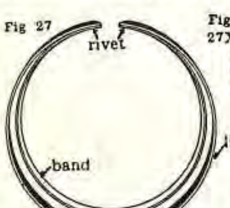
Fig. 26A. External brake band showing a one-piece application of brake lining.

Fig. 26B. External brake band showing a two-piece application of brake lining.

Relining Internal Expanding Brake Bands or Shoes

This method of procedure is applicable to internal brakes where one continuous strip of lining is used, termed, **one-piece** application.

Follow "First, Second, and Third" procedures under "Relining External Brake Bands." **Fourth,** place lining around band holding it firmly in place. **Fifth,** mark lining and cut it from $\frac{1}{4}''$ to $\frac{3}{8}''$ **shorter** than band (depending on the diameter of brake). **Sixth,** rivet ends of lining in place (ends flush[2]). To do this it is necessary to pull lining off the band at bottom, sideways (Fig. 27). **Seventh,** now force lining over band (Fig. 27X), thus insuring a tight fit. **Eighth,** now put in remainder of the rivets. **Ninth,** round band up with drum and reassemble.



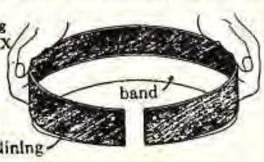


Fig. 27X. Replacing lining around band after riveting ends, insuring tight fit.

Fig. 27. Showing how lining is riveted (flush) at ends when raised from band at bottom; one-piece application.

A procedure applicable to internal brake shoes where one-piece lining is used is as follows:

Procedure: Use brake lining longer than necessary for complete job. Rivet one end flush with one end of brake shoe. Insert free end of lining in vise. Rest other end of brake shoe against vise and press down, thus stretching brake lining tight over shoe band. Drill holes, countersink, and rivet around the shoe, and cut off surplus brake lining.

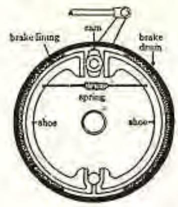


Fig. 27A. Internal brake shoe. Two-piece application of brake lining.

Fig. 27B. Internal brake band showing a two-piece application of brake lining.[3]

Another method, applicable to internal brake shoes or bands where two-piece or one-piece lining is used, is to locate, drill, and countersink the rivet holes in the **center** of the lining first and rivet the lining to the shoe at this point. After this, the lining is pulled tightly around shoe, and the remaining holes located and the rivets inserted, working from the center of the lining toward the end in each case.

Where moulded lining is attached to an internal brake shoe, it should be clamped or held firmly to the shoe and the center holes prepared first, spotting the holes from the holes in the shoe. Place rivets at center; then the remainder of holes and rivets can then be placed. Be careful to have the material fit closely to shoe. This can be done by working toward each end from the center rivets.

If the brake is of the metal-to-metal type, it is a matter of adjustment, no lining being used. This type is not used very much on pleasure cars but is found on some motorcoaches and some trucks of large size.

Burning-in is a method employed by some mechanics to seat a brake-band lining quickly, and consists of dragging brakes until they are very hot. This practice should be condemned. If the brake is properly adjusted or applied, the lining will quickly wear in with very few applications.

Riveting Brake-Band Lining[1]

Do not clinch the rivets against the brake drum. Drill and countersink the rivet head into the lining.

To place the rivets, see Fig. 27C. This shows a way of using a bolt held in a vise with the head of bolt resting on arm of vise to give a solid foundation.

Insert a rivet through the lining and band, as shown, the head of the rivet resting on the bolt.

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[1] Brake-drilling, countersinking, and riveting machines are now used extensively for this work. [2] On internal brakes, edges of lining should not project over ends of band or shoe. [3] Illustrations from Johns-Manville *Brake Re-Liner's Manual.*

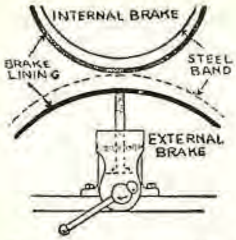

Fig. 27C. One method of riveting. Note that the illustration shows the internal brake curved up and the external brake curved down. The rivet head goes next to the fabric, and the riveting is always done on the band side.

Draw rivet snug with a rivet set, or a short piece of small gas pipe. Two or three blows with a hammer will be enough to draw the rivet head and the lining tight and in place. Too much pounding will tend to draw the rivet deeper in the lining and perhaps weaken it to the point of breaking through.

To rivet: Holding the band in the same position, the projecting end of the rivet is peened down with the ball peen of hammer till a good head is formed and the rivet draws tight.

Brake Lining[1]

Most of the brakes now in use are fitted externally and internally with steel bands or shoes faced with an asbestos friction brake lining.

There are four general kinds of brake lining, i.e., woven (from asbestos and brass wire yarn), folded and compressed, moulded, and heavy duty.

The advantages, features, and the use of each different kind of brake lining according to the claims made by the manufacturer, will not be generally discussed here. It is suggested that the repairman obtain literature from the brake-lining manufacturers which will explain the construction as well as the service their different kinds of brake linings are suitable for.

It might be well to point out that **heavy-duty brake lining,** which is generally woven but may be of any of the foregoing types, is suitable for high temperatures and heavy service. Should heavy-duty linings cut the brake drums, a standard lining must be used or the drums replaced with more suitable types. Drums for severe service are supplied by several manufacturers for many popular trucks and busses.

A later development is the **moulded brake lining.** It is suitable for internal brakes and severe service and its advantage is that the friction is very uniform, giving a smooth, quiet operation to the brake. It is usually made in segments to fit the particular brake for which it is designed, and must be correct in its width, thickness, and radius. It cannot be applied to all cars, as the brake may be unsuited to its use.

The sizes are usually measured in thickness and width, and are sold so much per foot.

The thicknesses run 1/8″, 5/32″, 3/16″, 1/4″, 5/16″, and 3/8″. The **widths** run from 1″, 1 1/8″, 1 1/4″, 1 1/2″, 1 3/4″, on up to 6″ wide.

The Ford model T used 1 1/8″×5/32″. The late model T used 1 3/4″×3/16″ on brake only and 1 3/16″×3/16″ on other two bands. The model A, 1 1/2″×3/16″.




Fig. 27C. Fabric brake lining. Fig. 28 Fig. 29 Fig.30

Brake Lining Rivets

Rivets most in use are flat head made of **solid aluminum** (Fig. 28), without burrs, or are made of **tubular brass** (Fig. 29), the tubular brass rivet having the preference.

The Ford Model T used **split or clinch** rivets (Fig. 30).

Rivets—How Used

When solid or tubular rivets are used, the head of the rivet is placed next to the brake-lining fabric and is countersunk into it, and the rivet is bradded on the steel lining of the brake, as shown in Fig. 31. Countersinking the rivet head beneath the brake-lining surface reduces the tendency to cut or score the drum.

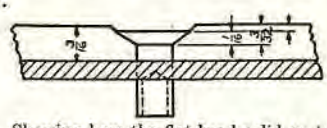

Fig. 31. Showing how the flat-head solid or tubular rivet is used with the head countersunk into the lining.

When split rivets are used, the head of the rivet is placed next to the steel band and the projecting ends of the rivets are turned into the brake lining or fabric as in Fig. 31A.

Many mechanics do not punch holes in the lining, but drive the split rivets through the lining. Place the lining and the band over a wooden block clamped in a vise, and **drive** the rivets through a hole in band and through the lining into the wood. Then put the rivet head on the bolt clamped in a vise, and turn over the projecting ends of the rivet into the lining, as shown in Fig. 31A.

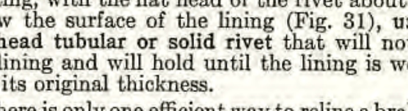

Fig. 31A. Showing how the split rivet is used with the head next to the steel band.

The Raybestos Co., in its publication, *Silver Edge*, advises **not to use split rivets,** the proper method being that of drilling, countersinking, and riveting, with the flat head of the rivet about 1/32″ below the surface of the lining (Fig. 31), **using a flat-head tubular or solid rivet** that will not split the lining and will hold until the lining is worn to half its original thickness.

There is only one efficient way to reline a brake and that is to **remove the band** so that you may be sure of what you are doing. The questionable practice of attempting **to reline the brakes with split rivets without removing them from the drum** is a rather poor gamble, because about every third rivet does not split. Both prongs turn the same way, enlarge the hole through the lining, and have no binding effect.

The **general condemnation of split rivets** arises from the fact that, as usually applied to a band that has been removed from the drum, the prongs are turned lengthwise of the lining, so that they parallel the warp threads. When the prongs are jammed into the lining they cut the cross-threads, or filling, which hold the warp threads together.

Experience has proved that split rivets, except for **Ford Model T cars, can never be substituted for** tubular or solid rivets properly applied.

The Johns-Manville *Brake Re-Liner's Manual* gives the following information concerning rivets: "The most satisfactory rivet for attaching friction lining is a **flat head, brass, tubular rivet.**

[1] See Index under "Brake-lining sizes," as used on various cars. See also footnote 3, page 893.

"Tubular rivets are divided into two types, i.e., **full tubular** or **semitubular.** "Full tubular" means that the entire shank is drilled to the head. Generally speaking, full-tubular rivets are used for clutch facings. Semitubular rivets are better for brake-relining work as they are considerably stronger than the full-tubular rivets. With semitubular rivets, however, it is necessary that the rivets be reasonably correct as to length.

"To arrive at the correct **length** of rivet, take the combined thickness of the brake lining and brake band or shoe and to this add the diameter of the rivet body. (Only the net thickness of the lining after counterboring is considered.) This is the minimum length to be used and it is also possible to use the next longer length.

"All rivets up to 7/16" long the 3/8" **heads** are satisfactory; and on rivets 8/16" or longer, we recommend that the 7/16" or 1/2" heads be specified.

"**Depths of countersinking.** On lining up to and including 3/16" in thickness, the lining should be countersunk 1/2 of the total thickness; on lining thicker than 3/16" and moulded lining, the lining can be countersunk two-thirds of the lining thickness, leaving one-third for the holding.

"Not all **aluminum rivets** are satisfactory, as some are quite hard and will tend to cut the brake drums if permitted to come in contact with them.

"Where end lining rivets are used to hold band clips or fittings, use **solid rivets** at these points instead of tubular."

BRAKE SERVICE SHOP EQUIPMENT AND INFORMATION

The essential equipment for a modern brake-service shop would consist of the items following. The more equipment a shop has, the better the service to the customer.

Brake-tester

Brake-drum trueing machine

Brake relining machine

Special tools

Stock of rivets and brake lining

Brake-testers: The old method of testing the adjustment and equalization of brakes was by sliding the wheels on the pavement. The modern and scientific method is by means of brake-testers with which brakes can readily be checked for defects, then adjusted and equalized, and again rechecked while the car is on the testing machine. Other more simple types of brake-testers test each individual brake.

There are several brake-testers on the market, all of which have some means of indicating the resistance to rotation of the wheels when the brake is applied, all of which are more dependable and speedy than the old method. A road test, however, is usually made as a final check.

Brake-drum refacing and trueing machines: Brake drums which are scored, concave and out-of-round cause grabbing, squeaking, and undue wear of the brake lining. Machines are made in the form of lathes for turning the drums true without removing the drums from the wheels. In addition to turning, some of the machines have attachments for honing to a polish after turning, and others grind.

Quoting from Thermoid *Reference Book on Brakes:* "It is not advisable to true up drums if an excessive amount of material must be taken off. Drums are generally made to a minimum of thickness and any excessive lightening of the wall of the drum will be followed by trouble with the drum going out of round again after very short service.

"After trueing up brake drums, it is necessary to use **over-size lining** on the brake bands or shoes to take up the space formerly occupied by the removed metal. In practice it is found that lining 1/32" heavier than original equipment lining may be used. Using the fullest size lining possible on a job will give the car owner maximum service from the brake, and allow the maximum number of readjustments before relining."

Some types of brake testers will detect out-of-round drums. A dial tester reading in thousandths and equipped with a magnet to hold it in any convenient position can be used. Ring gauges and feelers or thickness gauges can also be used. A device known as the Wadell true-vision brake and drum gauge is especially designed for this work; made by Wadell Engineering Co., Newark, N.J.

Brake relining machines: Machines which will locate and punch out the old rivets from the lining and band, drill and countersink the new lining, and head over or clinch the new rivets are available, either as individual machines operated by foot power for these different operations or in the form of a combination motor-driven machine.

Special tools for handling the minor brake service work consist of rear and front axle jacks, or a combination roller jack, wheel-pullers with adapters, dummy brake drums, ring gauges, brake and drum gauge, brake-shoe bench anvils, vise (about 4" swivel base), brake-lining cutter, brake-lining stretcher, bolt-cutter, wire cleaning brushes, hand drill, pliers, putty knives, paint (black), paint brush, sledge hammer (10 or 12 lbs.), files, and a good assortment of wrenches, including socket wrenches, Stillson wrenches, large monkey wrench, and open end wrenches. An air line is handy for blowing out and cleaning. Special tools are also required for servicing Bendix brakes and the Lockheed hydraulic brake (see footnote, page 886, relative to these).

Stock of brake lining: The various sizes of brake **lining** in popular demand to be carried in stock as suggested by Multibestos Company are as follows: 1 1/2"×5/32"; 1 1/2"×3/16"; 1 3/4"×3/16"; 2"×3/16"; 2 1/4"×3/16"; 2 1/2"×3/16". These sizes are for passenger cars mostly, although the 2", 2 1/4" and 2 1/2" sizes can be used on some of the smaller trucks.

Popular sizes for motorcoaches, trucks and taxicabs as suggested by the Multibestos Company are 2 1/4"×1/4", 2 1/2"×1/4", 3"×1/4", 3 1/2"×1/4", 4"×1/4". It is not always advisable to carry lining for this service as most of these are controlled by fleet owners who operate their own repair shops. If, however, a service station can secure this type of business, then a sufficient assortment of sizes should be carried to take care of the particular needs.

The kind of brake lining to carry in stock depends upon the kind of cars in the community which will need brake servicing and also conditions of service to which they are subjected. The brake lining manufacturer's recommendation should be followed.

Rivet cabinet provides a single receptacle subdivided for each rivet number, and is a necessity. Such a cabinet with a complete assortment of various sizes of rivets can be obtained from the brake lining manufacturers.

General Information

Repairmen who contemplate entering the brake-servicing business, or those already in business who wish **information** concerning complete equipment and modern servicing methods for brake-service stations, should get in touch with concerns who supply brake-lining and brake testing equipment (see *Supplementary Index* for latter). Some of the brake-lining manufacturers supply instructive brake-service bulletins or manuals to those who use their product.

For brake-lining and clutch-facing sizes for various makes and models of cars such as data books, see footnote 3, page 893.

For service information on Bendix brakes and Lockheed hydraulic brakes, see pages 1083–1090.

Literature which will give brake-lining (also clutch-facing) information can be obtained by writing to the following brake-lining companies: American Brakeblok Corp., Detroit, Mich.; Asbestos Mfg. Co., Huntington, Ind.; Firestone Tire and Rubber Co., Brake Lining Division, Akron, Ohio; Gatke Corp., Chicago, Ill.; Johns-Mansville, New York, N.Y.; Keasbey & Mattison Co., Ambler, Pa.; Marshall Asbestos Corp., Subsidiary of Bendix Aviation Corp., Troy, N.Y. (no clutch facing); Thermoid, Trenton, N.J. (send 50 cents in stamps for large *Thermoid Recommendation Chart*); United States Asbestos Division of Raybestos-Manhattan, Inc., Manheim, Pa.; Wagner Electric Corp., Automotive Parts Division, St. Louis, Mo.; World Bestos Corp., Patterson, N.J.

In giving the few names of manufacturers above, it is not the writer's intention to imply that these are the only manufacturers, or that they are selected in preference to others, as there are many other concerns who are making high-grade products; see automobile trade magazines or inquire of your jobber.

Wheel Alignment

Wheel alignment is necessary and is a profitable line of work, especially when added to the brake service shop.

Correct wheel alighment not only insures safe and easy steering but prevents undue tire wear.

Misalignment of any one factor, or any factors collectively, namely, *camber* (wheel slant), *kingpin inclination* (inward tilt of kingpin), *caster* (backward tilt of kingpin), *turning radius* (proper relation of wheels on a curve), *toe-in* (wheel gather), *tracking* (relation between front and rear wheels and frame), causes the wheels to roll improperly, so that either difficult steering, erratic steering, excessive tire wear, or a combination of these results will be produced.

None of these problems are new; yet they have assumed a new importance and a different method for correction with the advent of the present-day balloon tires, four-wheel brakes, high speeds, and knee-action units. The car manufacturers design their front-axle assembly to meet the conditions and deliver new cars in perfect alignment; but accidents, bumping curbs too hard, improperly mated tires, etc., may cause misalignment.

The importance of these factors and methods of correcting misalignment is explained under the subjects of *Wheel Alignment Principles* and *Correcting Misalignment of Wheels* (see Supplementary Index).

PRINCIPLES OF THE EARLY ELECTRIC AND VACUUM BRAKES

Although the construction of electric and vacuum brakes has undergone considerable improvement, the following information describes the **early principles.**

The electric brake is seldom used at present. The vacuum brake is used to a considerable extent on large passenger cars, motorcoaches, trucks, and trailers. See also pages 1081 and 886.

The Electric Brake

Construction: The Hartford braking motor (Fig. 32) is shown with reduction gearing. The armature shaft carries a worm gear which drives at a reduction of 100 to 1.

This worm gear in turn operates a drum through an internal gear at a reduction of 4 to 1, giving a total reduction of 400 to 1.

A steel brake pulling cable, which is wound on the drum, transmits the pull of the motor to the brake mechanism.

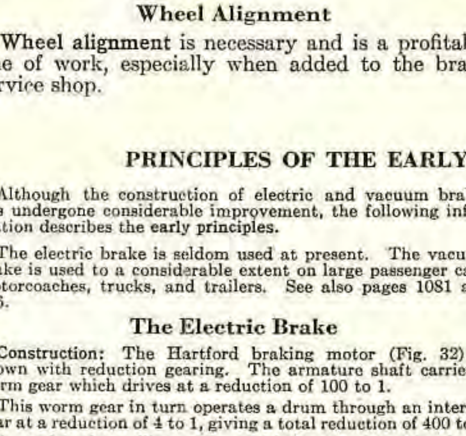

Fig. 32. **The Hartford electric brake,** consisting of a braking motor operated from a storage battery and controlled by a lever controller on the steering column.

The controller is moved by degrees, which applies the brake gradually; or suddenly, if moved to the extreme limit.

The point of decreased speed before coming to a full stop is illustrated by the fact that a car, moving at the rate of 50 miles an hour, or 73 1/3 feet a second, can within 35 feet, or in one half-second's time, be slowed down to 15 miles an hour or 22 feet a second, and can be brought to a dead stop within the next 10 feet. The current required is 40 amperes for two-fifths of a second, at a pressure of 6 volts.

The Vacuum Brake

This brake is known as the Prest-O-Vacuum brake, and is shown connected with the rear brakes in Fig. 33.

Principle: By utilizing the suction in the intake manifold to exhaust the air from a cylinder (B) carrying a piston, the piston is forced to move, and in its motion applies the brakes through the usual braking system. The extent to which the brakes are applied depends, of course, upon the suction of the cylinder, and this is controlled by the driver through a throttle valve operated either by a pedal or a hand lever.

The general layout of the system when installed on a car is shown in Fig. 33. It will be noted that the forward end of the

Fig. 33. The vacuum brake.

suction tube is attached to the intake manifold at its junction (I) with the carburetor pipe, this being the point of most constant suction. From here it leads to the throttle valve (C), located convenient to the driver's foot.

The construction and principle involved is similar to the air-brake cylinder used on railway trains, having a pressed-steel shell, a cast-steel head, and carrying a pressed-steel piston with leather packing. This piston has a diameter of 7″, an area of 38½ sq. in., and a stroke of 4″, the entire braking cylinder assembly weighing about 10 lbs.

The suction in the manifold (I) varies from 8 to 12 lbs. per sq. in. When the throttle valve (C) is opened wide, at least 10 lbs. per sq. in. suction is applied to the piston in the braking cylinder. Hence the area of the piston being 38½ sq. in., a suction, or, to be more exact, a pressure, of 10 times 38½ or 385 lbs., is applied to the piston.

The piston, therefore, is moved under a direct pull of 385 lbs., and this in turn is compounded through the toggle-joint connections to give a pull of 4,000 lbs. on the brake rods. This is an extreme example of what the system can do, as a pull of 4,000 lbs. is seldom required, unless on large trucks. It is evident that the pull applied to the brakes may be graded from 0 to 4,000 lbs. at the option of the driver, the pull depending only upon the opening of the throttle valve.