Dyke's Automobile

and Gasoline Engine

Encyclopedia

The
Elementary Principles, Construction, Operation *and* Repair *of* Automobiles, Gasoline Engines *and* Automobile Electric Systems; including Trucks, Tractors, Motorcoaches, Automotive Diesel Engines *and* Motorcycles

Simple, Thorough *and* Practical

By

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St. Louis, Mo., U.S.A.

Nineteenth Edition

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BOOKS

By the same Author

Dyke's Diseases of a Gasoline Automobile (1903)

Dyke's Anatomy of the Automobile (1904)

Dyke's Motor Manual (1915)

Dyke's Carburetor Supplement (1927)

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A series of remarkably practical and successful books.

"Dyke's Automobile and Gasoline Engine Encyclopedia" has passed through 19 editions and many impressions, and is recognized as an authority throughout the English-speaking world.

PREFACE TO THE NINETEENTH EDITION

This book has been compiled with three general classes of readers in mind, i.e., the **student,** the **repairman,** and the **car owner.**

To make the book as **practical** as possible, the **underlying principles** involved in each subject are first discussed. When once the **student** has mastered the **fundamental principles** of the main parts of an automobile he will understand all makes of cars. Although the construction may vary, the principle of operation remains practically the same.

If the book is used by the **repairman** as it should be used, he will have it always available for immediate **reference,** at the bench as well as at home. If he will use the book intelligently, he will find practical suggestion and advice covering many questions that he will encounter in the shop, in the garage, or on the road.

The average **car owner** is in much the same situation as the student, in his need of the necessary knowledge to enable him to meet emergencies with intelligence, and to maintain his car without relying on advice from others.

The scientific principles embodied in the highly developed cars of today are merely improvements on the early designs, now discarded. Hence many of the old designs are illustrated and discussed, in order that the modern type may be thoroughly understood. Moreover, the thousands of **illustrations** have been assembled with a view to showing graphically every point discussed. Many of these are not drawn to scale; the exaggerations that they show are intentional, in order to bring out clearly the point discussed and the principle involved.

The **truck and tractor** are each **related to the automobile,** and hence they are given full space in the general scheme of the book.

The **plan of the book** is to present this information in the form of **Instructions,** in place of the conventional chapters. If the student will proceed systematically through the book, digesting each Instruction before passing to the next, and if, in addition, he can have a car available for practical demonstration and experiment, he should emerge at the end with a mind stored with all the necessary facts and principles.

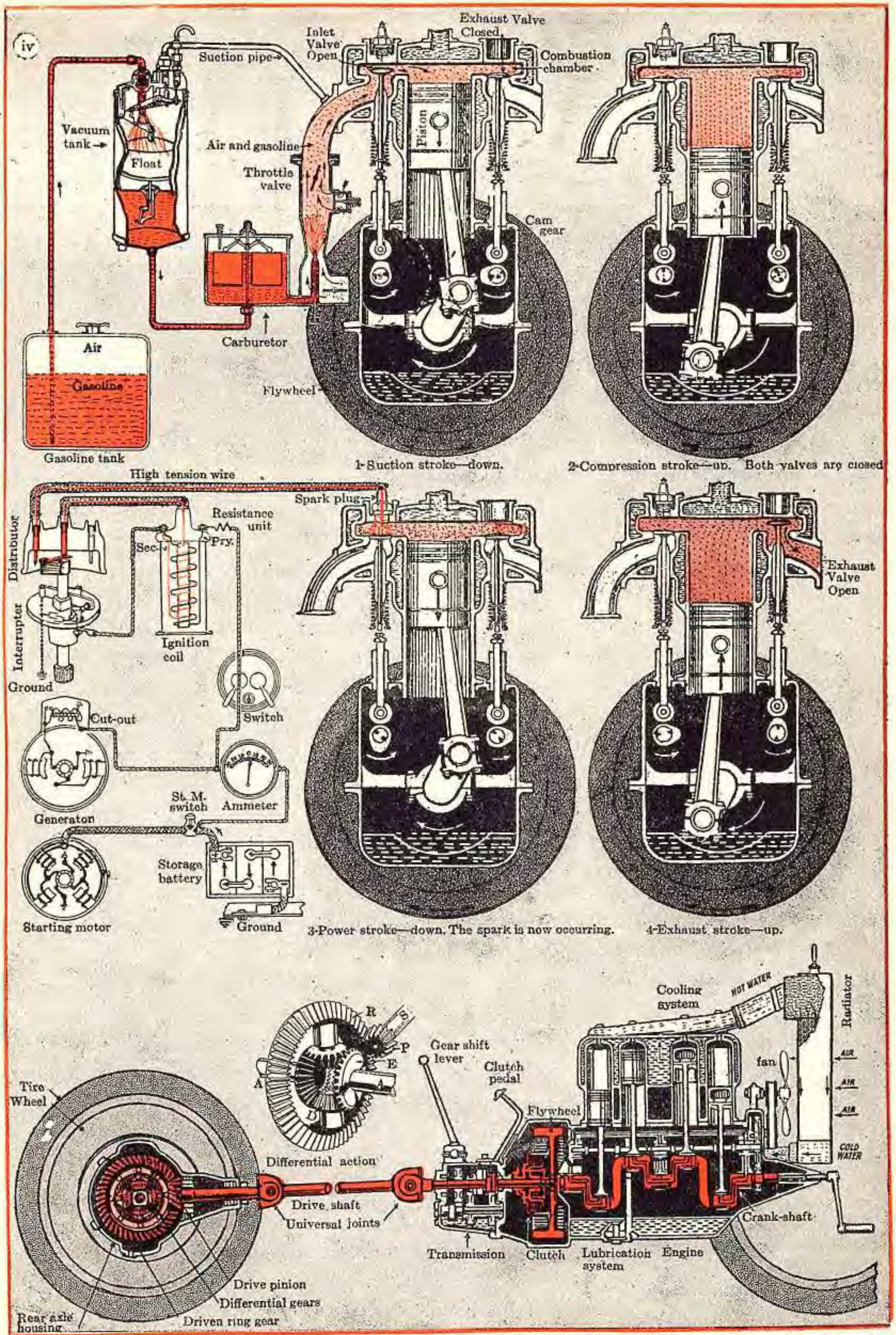
The **Table of Contents and the Index,** used intelligently, will quickly lead the reader to any subject on which information is sought. The book embodies sixteen principal sections. If the reader will now turn to pages v and vi, the sixteen sections with the eighty-six instructions will be noted. Also, turn to page 1153 and notice the arrangement of the **Index.**

The thirteenth edition was completely re-written; the fourteenth, fifteenth, sixteenth, seventeenth, and eighteenth editions were partly revised; and in this **nineteenth edition,** further revisions and additions have been made.

The author is under obligations to many of the engineers and the several trade journals of the automotive industry. While credit is given in the following pages wherever it is due, it is a pleasure to the writer to express his gratitude in a comprehensive manner. The writer is also indebted to Mr. Warren A. Taussig (assistant editor) for valuable services rendered.

A. L. Dyke

St. Louis, Mo., 1940



THE WORKING PRINCIPLES OF THE GASOLINE AUTOMOBILE: The principle of the gasoline engine, illustrating the *four-stroke cycle*, are shown in the four upper illustrations. The essential *systems* which cause the engine to operate are included, namely, the *fuel-feed and carburetion* system and the *electrical* system. Transmission of power from engine to road wheels is shown in the lower illustration. The parts shown in red constitute the *drive system.*

Although appearance and construction may vary in different makes of cars, *the principle of operation is fundamentally the same.* The purpose of this book is to explain the *principle* of all parts, to point out the *differences in construction and design*, and to instruct in *testing, adjusting and repairing* each unit of the automobile.

See "Note," page 462-H pertaining to fuel pumps.

TABLE OF CONTENTS*

Instructions How to Find Subjects, as well as other pointers, are given on page **1153** of the **Index**. We advise that the reader turn first to this page and read it carefully, and follow the instructions given.

Attention is called to the **Specifications of Passenger Cars** on page 1055 and **Trouble-Shooting Charts** on pages **462A** to **462P**.

(* Please read footnote page vi, also inside of front cover of this book.)

Note: Although the subjects in the Table of Contents remain substantially the same, a number of additions have been made in this nineteenth edition.

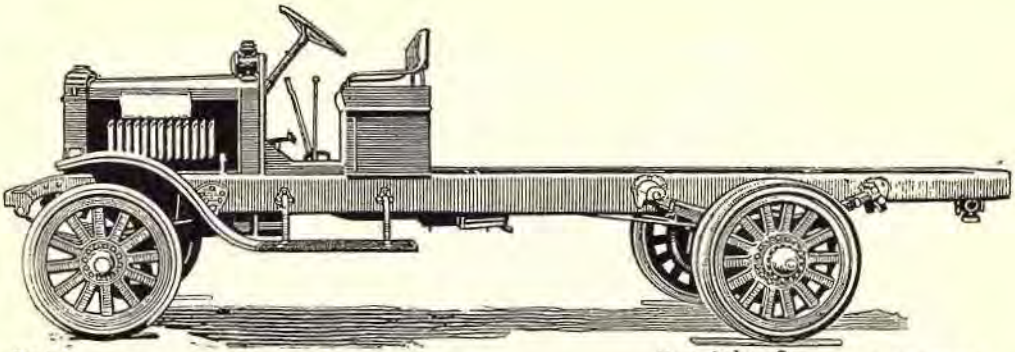


Fig. 1

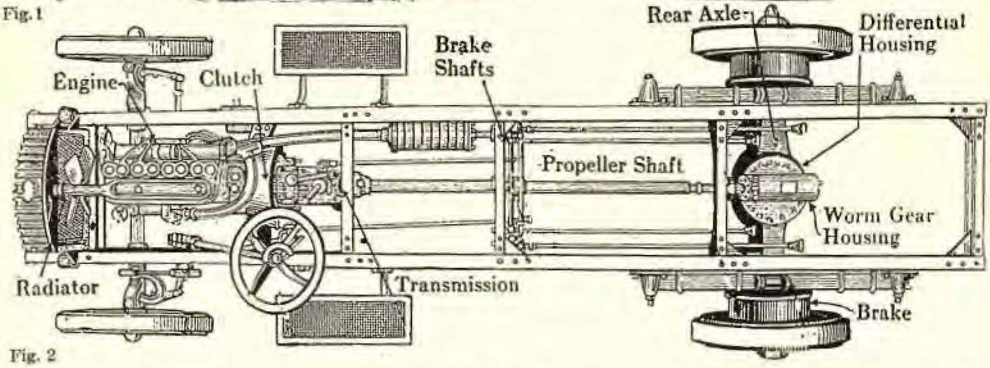


Fig. 2

A Truck

The principle of the truck is similar to the principle of a passenger car type of automobile.

The engine is usually a four-cylinder type of engine, for reasons explained under the Truck Instruction. (See Index.) The truck engine is a slower-speed engine than the automobile engine. The average maximum speed of a truck engine is 900 to 1,000 r.p.m. The engine speed is controlled by a hand throttle and foot accelerator, as in the case of the automobile engine, but **a governor is employed,** for reasons stated under the Truck Instruction, which is to prevent undue "racing" of the engine when changing gears or releasing the clutch.

By governing the engine speed, the car speed is also limited. For instance, the governor can be set to govern the engine speed at 950 r.p.m., which gives a maximum car speed of 14 m.p.h., which is the average speed of a heavy-duty truck.

The speed of a passenger type of automobile varies from $1\frac{1}{2}$ m.p.h. to 50 or 60 m.p.h., and a governor is not employed. The engine speed of a passenger type of automobile varies from 150 r.p.m. to as high as 2,500 to 3,000 r.p.m. The truck, however, being designed for commercial use, must necessarily be more efficient; hence the employment of a governor.

All complicated devices are eliminated on a truck, for the sake of efficiency. For instance, the electric starting motor is seldom used. Instead, the engine is cranked by hand in connection with an "impulse starter." (See Index.) Instead of a coil, battery, generator, cut-out, timer, and distributor being used for **ignition,** a high-tension magneto is usually employed. The gravity fuel-feed system is used instead of a vacuum or pressure feed. The tubular type of radiator for **cooling** is used instead of the cellular type. The cellular type, as generally used on automobiles, is more artistic in appearance, but the tubular type has larger openings, is less liable to clog, and is easier to repair.

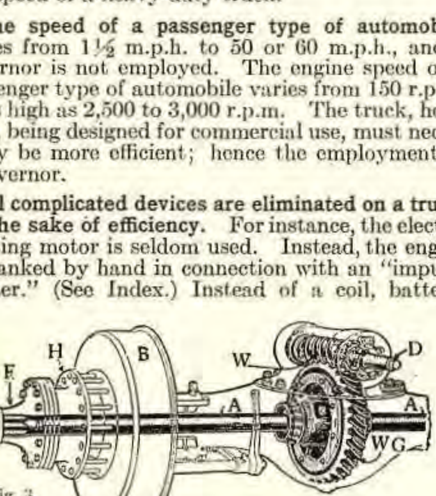


Fig. 3

The drive method usually depends on a propeller shaft connected with (**D**) to a worm gear (**W**) to a worm-driven gear (**WG**) on the differential. The worm gear gives a greater reduction and is silent and possesses enormous strength. The double-reduction internal gear drive is also used. The four-wheel drive is another type. (See Index.)

The rear axle is usually a full-floating "live" axle. Axle shafts (**A**) are split and the inner ends are connected to differential gears and the outer ends to the hub flange (**F**).

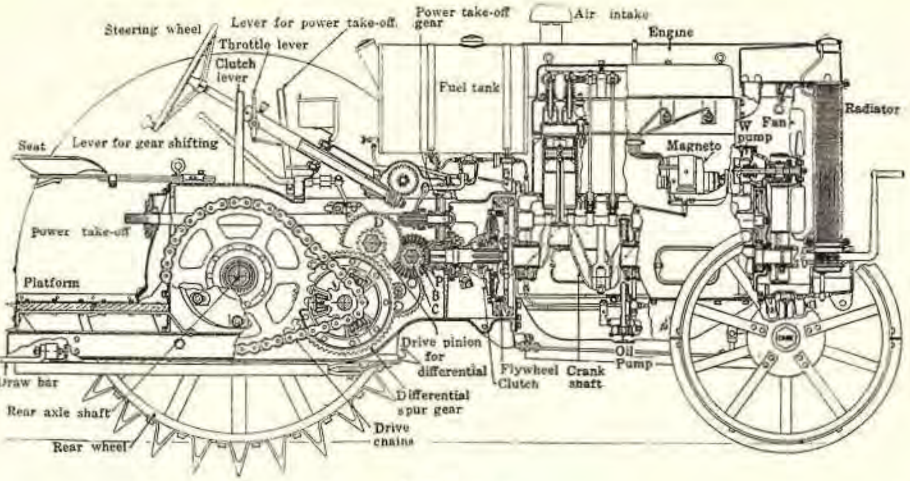
The transmission is usually a three-speed forward and reverse, and is similar to an automobile transmission, but of heavier construction. **Gear ratios:** On the truck shown above: **on first speed,** rear wheels make 1 revolution to every 24 of the crank shaft of the engine; **on second speed,** 1 to 13.6; **on high speed,** 1 to 8.

The clutch used on the truck shown above is a dry-plate multiple-disk type. The disk type of clutch is extensively used, also the cone clutch.

The tires on the truck illustrated are solid 34" x 4" single, in front; 36" x 7" in rear. The "dual" solid tire, also the "pneumatic cord" truck tire is also extensively used.

The steering gear used on the truck shown above is of the conventional type.

From the foregoing specifications of a truck and after a study of this book, it will be noted that a truck differs only in a few details from the principle of the passenger-car type of automobile.



A Tractor

The purpose of a tractor is explained in the Tractor instruction. Note that in addition to doing **tractor work,** such as pulling plows or other drawbar work, it will do belt work, such as operating a thresher, etc., and will also do **power take-off work,** such as driving power binders and corn pickers.

The illustration above is that of a four-cylinder engine tractor. Most all tractor engines are four-cylinder, for reasons explained under the Tractor Instruction.

The construction of a tractor differs considerably from that of an automobile or truck, but the same underlying principles of the engine and drive system are employed.

The engine used on a tractor is a slow-speed engine, and has usually a long stroke. This particular tractor engine has a bore of 4 5/8″ and a 6″ stroke. **A governor** is employed for the purpose explained under the subject of "Governors." The speed of the engine is governed to 1,100 r.p.m.

The ignition is usually a high-tension magneto, with an "impulse starter." (See Index for explanation of an impulse starter.) Most tractor engines use magneto ignition for reasons stated in the Tractor Instruction.

The tractor engine operates for long periods of time at full power. Therefore it must be built heavier and more substantial than the automobile engine, as, for instance, in the bearings, etc.

The fuel is usually either gasoline or kerosene. When using kerosene or low-grade fuels, the tractor must be started and warmed up on gasoline. Then turn on to the low-grade fuel. A combination manifold with adjustable heat-controlled damper enables the tractor to operate efficiently on any one of the different grades of fuel.

Drive system: The engine on the tractor shown above is a four-cylinder, vertical type, with valves-in-the-head. The power from the crankshaft is transmitted to the spur-gear transmission by means of a clutch. The power drive is from crankshaft to bevel pinion P, to bevel gear B, to spur-gear C, to spur-gear D, to drive pinion, to differential spur-gear, to drive chains, to rear axle shafts and to drive wheels. From the transmission, power is transmitted to both rear wheels by means of two steel roller chains driven by sprockets on differential shaft. Rear wheels are 48″ in diameter and have a 12″ face.

The speed of the average tractor is $2\frac{1}{2}$ miles per hour on low gear, 3 to $3\frac{1}{2}$ miles on intermediate gear, and 4 to $4\frac{1}{2}$ miles per hour on high gear. (See also Index under "Tractors.")

The transmission on the tractor shown above has three speeds forward and one reverse. The road speeds at normal engine speed of 1,100 r.p.m. and with the standard gears are. low gear $2\frac{1}{2}$ m.p.h.; intermediate $3\frac{1}{4}$ m.p.h.; high gear 4 m.p.h.; reverse $2\frac{3}{4}$ m p.h. A higher road speed on high-gear for industrial tractors or other special uses is obtained by the use of special gears.

The belt power is obtained from a 13″ pulley mounted on the first reduction shaft which runs at a speed of 780 r.p.m. Belt speed is 2,600 r.p.m.

The tractor illustrated (the Case model "L') has a wheel base of 79″, and its overall dimensions are: length $128\frac{1}{2}$″; width 67″; height (to top of hood), 57″. This tractor **pulls** three 14″ plows in tough sod, or four plows under usua conditions. It is also adapted for other drawbar work, requiring a similar amount of power, and it will operate a 28 x 46″ thresher (belt work) fully equipped

It will be observed that the tractor, while it differs widely in construction, from that of the truck or passenger car automobile, is, in many respects, similar in principle, the main difference being in the drive system and fuel used by the engine.

The Motorcoach and Taxicab

The purpose of a motorcoach is to transport public passengers. Motorcoaches are made with single deck or double deck.

The **engine** is similar to the types used in passenger cars and trucks. The **drive systems** used are similar to those employed by trucks, namely, worm, double reduction, spiral-bevel, or internal gear.

The principle of construction is similar to that of a modern truck and passenger car type of automobile. See specifications, page 998.

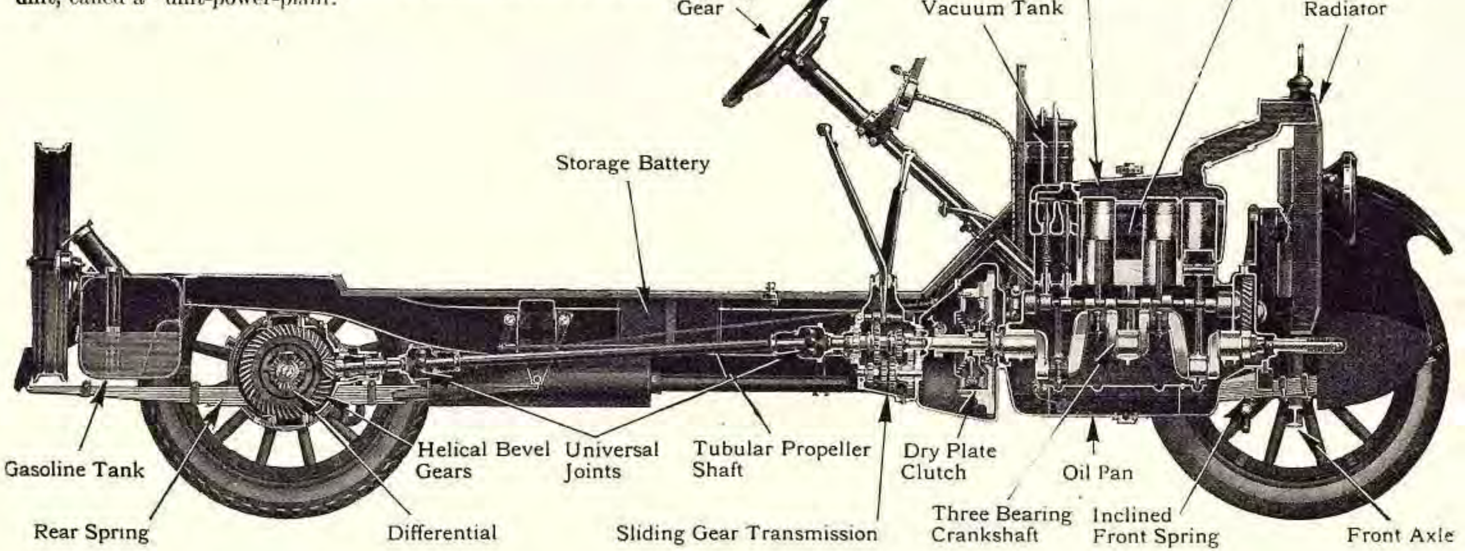
The purpose of a taxicab is to provide the public with a motor vehicle for hire by the trip or hour. The **engine** and **drive system** are similar to those used in passenger cars.

The principle of construction is similar to that of a modern passenger car type of automobile.

TYPES OF AUTOMOBILE CHASSIS

The following pages exemplify types of automobile chassis. The modern automobile employs either a four, six, eight, twelve or sixteen-cylinder engine. The cylinders may be arranged "in-line," or two banks in "V" formation.

The engine, clutch and transmission are usually housed in one **unit**, called a "unit-power-plant."



A Four-Cylinder Automobile Chassis: Side Sectional View; Cylinders Four-In-Line

The illustration above shows a side sectional **view of** an automobile powered with a four-cylinder in-line engine.

The drive system on the car shown above is a propeller shaft with a helical (spiral) bevel gear drive-pinion which meshes with a helical bevel gear on the differential of the rear axle. Other types of drive gears are straight tooth bevel gears and the hypoid gear design. Other types of propeller shaft drive systems are the front-wheel drive and the worm and worm-gear drive.

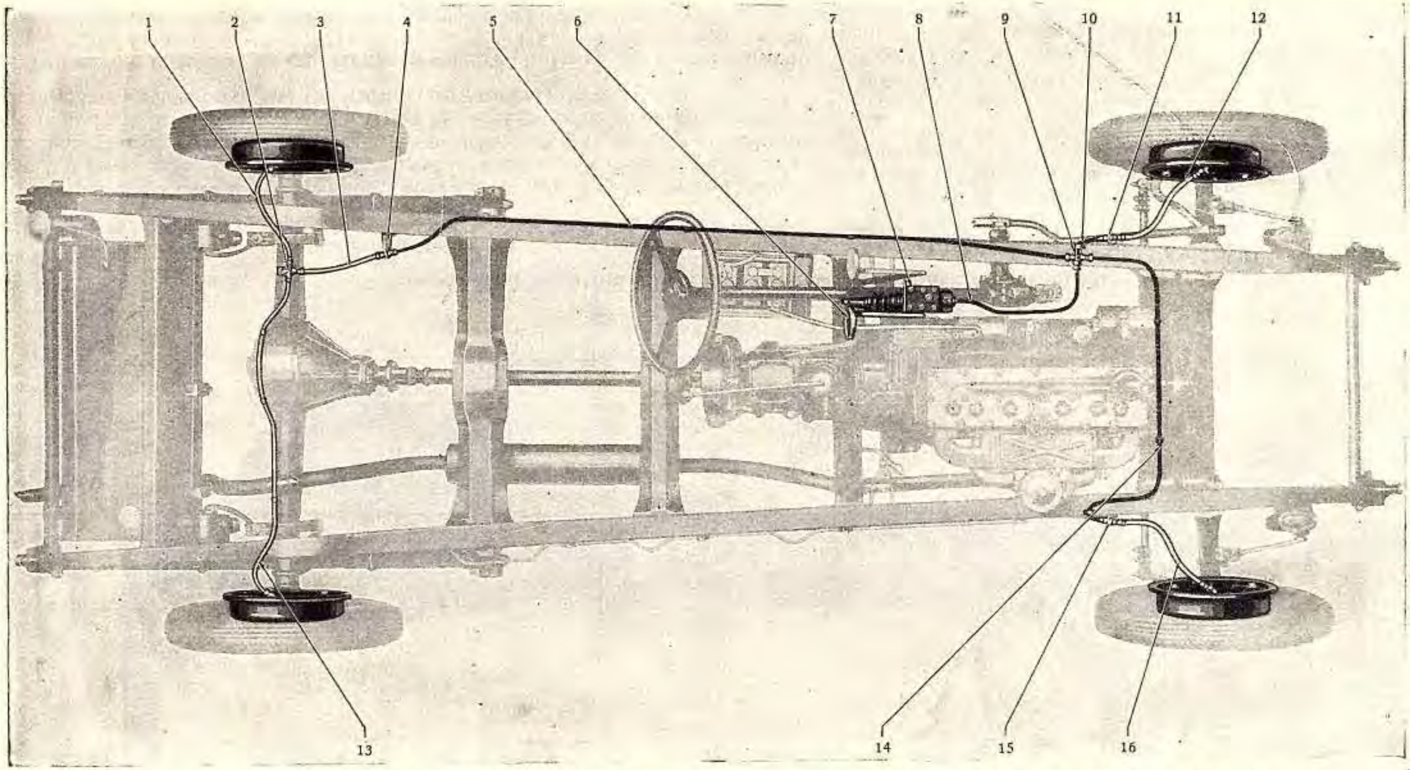
The engine is started by an electric motor, which derives its electric current supply from a storage battery. The storage battery is kept charged by a generator (dynamo) driven from the engine.

The gasoline feed is from the gasoline tank in the rear of the car to a vacuum tank, thence to carburetor. Many cars use a gasoline pump instead of a vacuum tank.

The speed of the engine is controlled by a foot accelerator and hand throttle. Owing to the great variations of speed, the governor is not employed on passenger-car automobiles. The speed of automobile engines varies from 150 to 3,600 r.p.m., and is sometimes as high as 4,200 r.p.m., or more.

The ignition, in most instances, and in car shown, is of the coil, battery, and timer-distributor type.

Cooling system on car shown is a "thermo-syphon" circulation system, explained in the discussion on the subject of "Cooling." The cellular type of radiator is used.



1—Rear axle brake tube—left
2—Rear axle brake tube tee
3—Brake flexible hose
4—Rear brake flexible hose frame bracket
5—Brake tube, frame tee to rear flexible hose
6—Brake pedal
7—Brake master cylinder and reservoir
8—Brake tube, master cylinder to frame tee
9—Brake tube frame tee
10—Brake tube, frame tee to front flexible hose—left
11—Front brake flexible hose frame bracket
12—Brake flexible hose
13—Rear axle brake tube—right
14—Brake tube, frame tee to front flexible hose—right
15—Brake tube to flexible hose union
16—Brake flexible hose

A Six-Cylinder Automobile Chassis: Cylinders Six-In-Line and Hydraulic Four-Wheel Brakes

The illustration above shows the Chrysler "70" (1930) chassis with a unit-power-plant. The engine has six cylinders in-line.

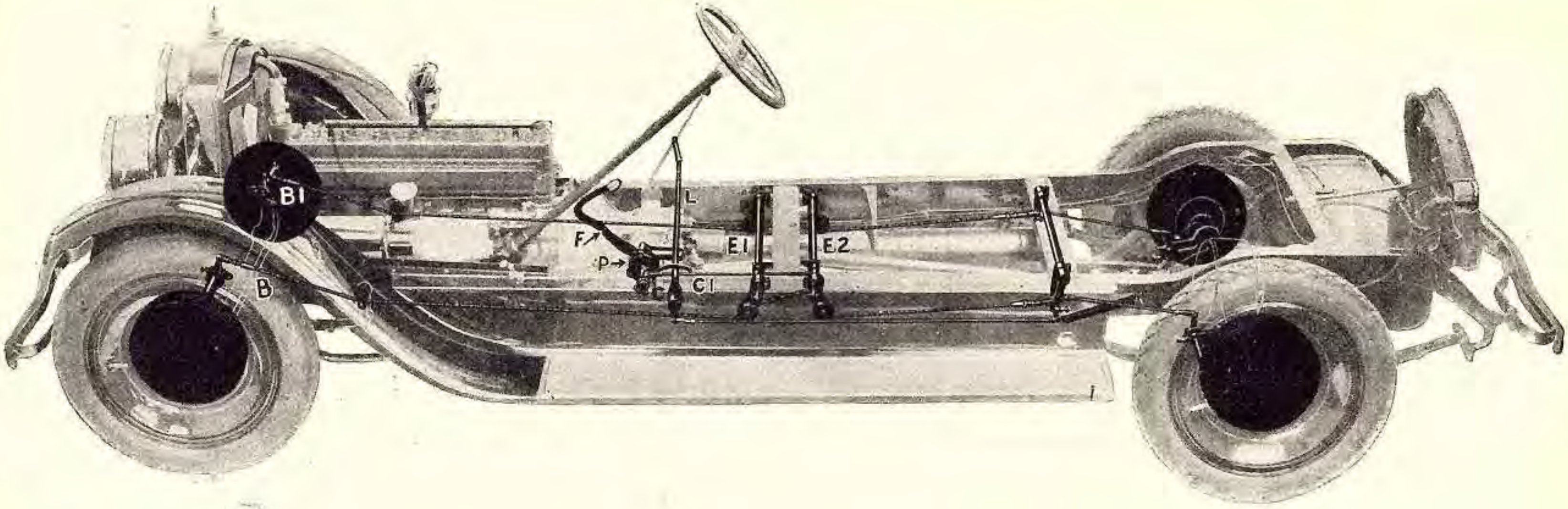
Four-wheel brake system: The internal expanding brakes in all four wheels are operated by **hydraulic action** by movement of the foot-brake pedal. The external contracting brake on the drum mounted at the rear of the transmission is operated by the hand-brake lever.

Operation: Connected to the foot-brake pedal (6) is a piston which operates in a master cylinder (7), bolted to the left-hand side of the flywheel housing. Leading from this master cylinder to cylinders at each of the four brake supports are metal tubes and heavy non-expanding hose. In each wheel cylinder are two pistons, each of which presses against the upper ends of the brake shoes. The whole system (that is, all cylinders and lines) is full of liquid, all air having been expelled in the process of filling. There is no pressure in the system when the brakes are not in operation and the brake shoe facings are held clear of the drums by the brake return springs.

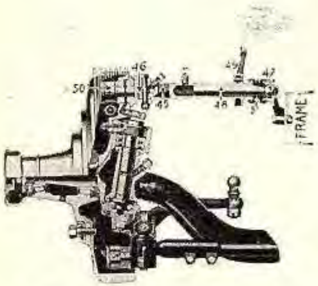
When the foot-brake pedal is depressed, the piston in master cylinder moves forward, expelling into the lines sufficient liquid to force out the pistons in each of the brake wheel cylinders until the brake shoe facings come in contact with the drums.

When the foot-brake pedal is released, the pistons in the wheel cylinders are returned to their stops by the brake shoe return springs, forcing the liquid, used in displacing the pistons, through the lines back into the master cylinder.

For **specifications** of the Chrysler and other cars see pages 1055–1062.



An Eight-Cylinder Automobile Chassis: Cylinders Eight-In-Line; Four-Wheel Mechanically Operated Brakes



View showing front wheel brake operating cam shaft (45) on front-wheel brake with universal joint (46) at outer end and ball joint (47) on inner end. Note support to frame. Note that the shaft (48) is free to slide in (45) and to turn in socket (47) which takes care of movements of front wheels when steering. When pressure is applied to cables connected with (49) the cam (50) expands the internal brake shoes.

The illustration above shows the Packard model "136" chassis with a unit power-plant. The engine has eight cylinders in-line.

Cooling of engine is termed "forced circulation," by means of a water pump. The cellular type of radiator is used.

Thermostatically controlled shutters are built into the radiator assembly which automatically control the water temperature on the later "eighth" series cars.

The driving torque is transmitted to the spiral bevel driving gears in the rear axle through a propeller shaft with a universal joint at each end. The final drive is through the differential and axle shafts to which the rear wheels are keyed.

On the later "eighth' series cars the hypoid gear design is used for the driving pinion and differential gear which produces silence of running superior to the spiral bevel gear. Driving forces and the torque of the rear axle are transmitted through the rear axle springs.

Chassis lubrication: By pulling handle of a lubricator hand pump one stroke oil is distributed to 43 points.

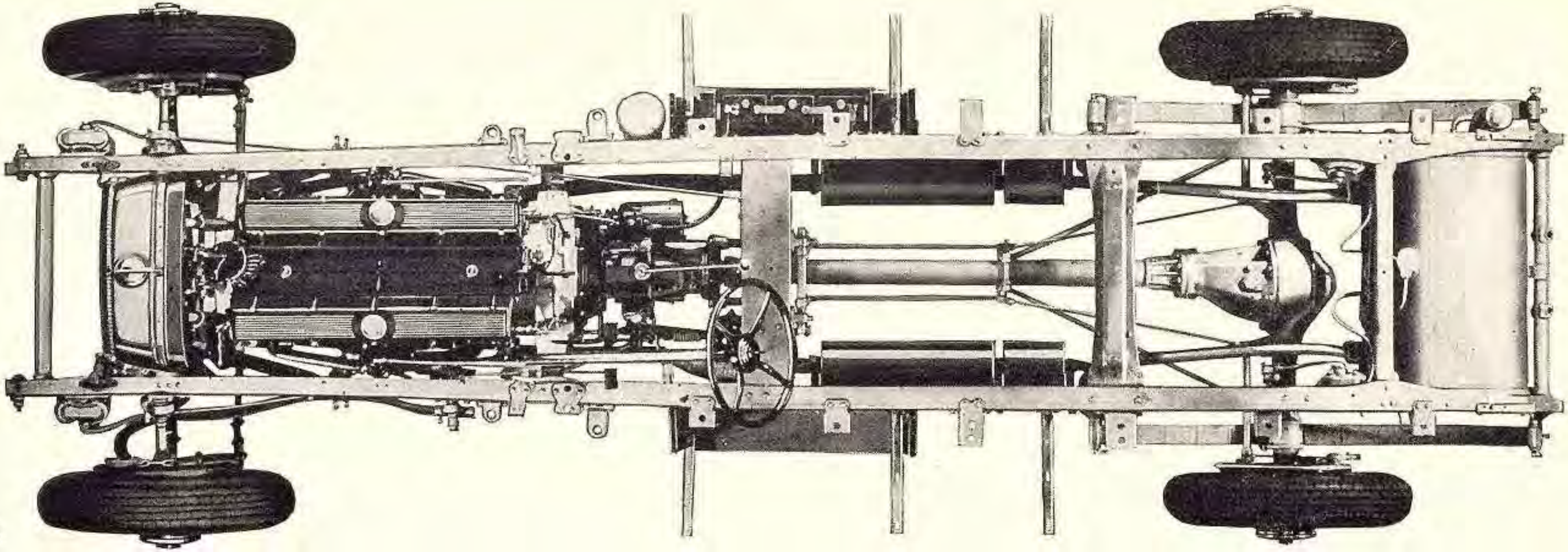
On the later "eighth" series cars the system works automatically through engine vacuum.

Four-wheel brake system: The internal expanding shoe type brakes in all four wheels are **mechanically operated.** When foot-brake pedal (F) is depressed, both front (E1) and rear equalizer shafts (E2) are rotated, equalizing the pull on all four brakes. One end of the front brake cable (B) is attached to the left front wheel brake camshaft lever (49), and the other end (B1) to the right front-wheel brake camshaft lever. When foot-brake pedal is depressed, owing to planetary gears in base of foot pedal at (P), a 26° movement of the pedal transmits a 90° movement to the crank (C) connecting with (C1). The hand-brake lever (L) can operate the two brakes on the rear wheels independently of the foot-brake pedal so as to provide a parking brake.

The rear brakes receive about 60 per cent of the braking effort, and the front 40 per cent. This prevents locking of front wheels which would otherwise affect the steering of the car.

Note: Since above illustration was made, Packard has discontinued the use of planetary gears in base of foot pedal and has made many other changes and improvements throughout the chassis.

For **specifications** of Packard and other cars see pages 1055–1062.



A Sixteen-Cylinder Automobile Chassis: Cylinders Sixteen V-Type

The illustration above shows the top view of the Cadillac "V-16" chassis,[1] series 452, with a V-type of engine. Engine, clutch and transmission are housed in one unit, called a "unit-power-plant" installation. The power-plant mounting is of the five-point type.

Drive: Power is transmitted from the engine crankshaft through a two-plate clutch and three-speed transmission, thence to the three-quarter floating rear axle by a steel propeller shaft enclosed in a torque tube. Only one universal joint is used which is automatically lubricated from the transmission case.

Transmission: Known as the Syncro-Mesh transmission. Its purpose is to secure noiseless shifting of the control mechanism by automatically synchronizing (or equalizing) the speeds of the two members which are to be coupled together, before this shift is made; brought about by a pair of simple cone-type friction clutches, which are actuated by the control lever through a cam mechanism. (Applies to second and high, but not to low and reverse, which are of the conventional type.)

Brakes: Four-wheel **mechanically operated** type with the addition of a vacuum assister or booster. The **assister** is connected to the two intake manifolds which furnish the necessary vacuum. It is connected at the rear end to the center cross member of the frame, and at the front end, to a lever on the pedal shaft. The force thus developed is applied to a lever on the pedal shaft and is added to the force applied by the driver to the pedal. The brake assister does not interfere with the pedal action. The foot brakes may be applied when the engine is not running.

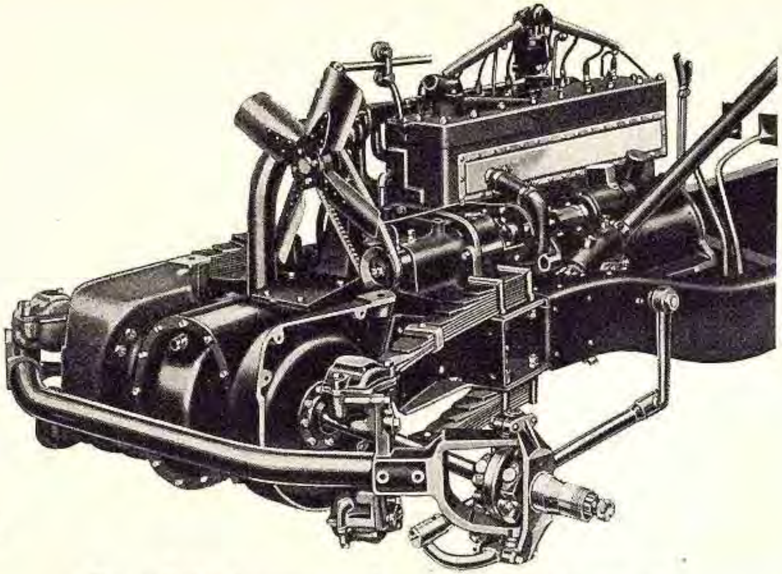
Fuel system: Except for the fuel tank at the rear of the car, there are two separate gasoline systems. Each of these systems has its own fuel line, vacuum tank, strainers and carburetor. The vacuum fuel feed is taken care of by a vacuum piston type pump operated by an eccentric on the camshaft at the rear of the engine. There is no connection from the inlet manifolds to the vacuum tanks.

Cooling: Forced circulation accomplished by a single water pump with a double-outlet or dual delivery driven from the generator by an extension shaft with flexible couplings. Water reaches the left cylinder block through a copper pipe cast in the rear of the crankcase. It returns, from both blocks, to the cellular radiator. A condenser tank reduces the amount of cooling liquid lost through evaporation.

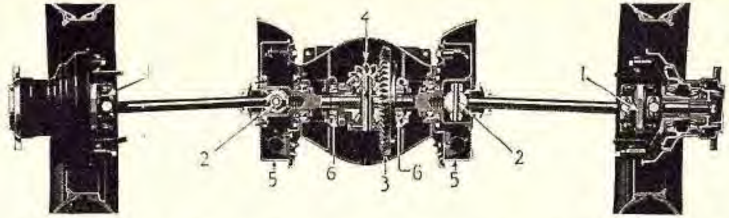
Chassis lubrication: A **chassis lubricant** is used for the high pressure Alemite system for chassis points, such as spring bolts, shock absorbers, steering connections, front and rear brake shafts, spring shackles, clutch pedal. **Engine oil** for generator oil cups, timer cam, distributor, starter pedal shaft, door hinges, starter motor. **Cup grease** on water pump and in wheel bearings. **Gear lubricant** in steering gear box, transmission and rear axle.

For **specifications** of Cadillac and other cars see pages 1055–1062.

[1] The Cadillac V-12, series "370," chassis is very similar in general appearance to the V-16 chassis, but has a twelve-cylinder engine and shorter wheelbase—140″–143″ instead of 148″ as on the V-16.



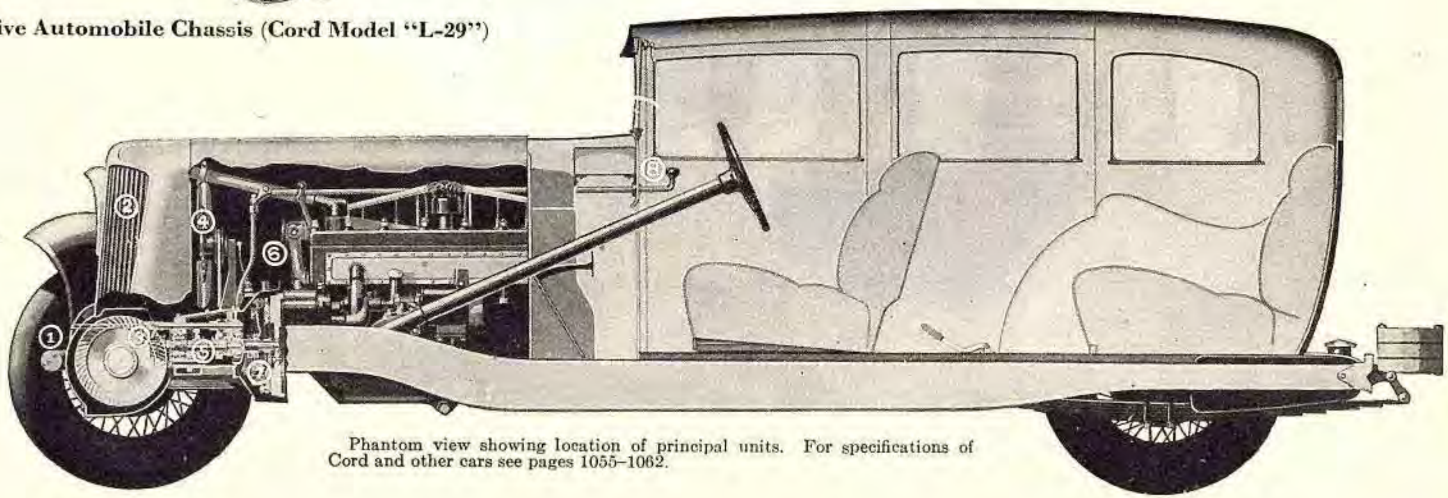
Front Drive Automobile Chassis (Cord Model "L-29")



The dead tubular front axle is cut away to show the differential, universal joints and brakes. The differential is of the conventional construction and the reduction is obtained with hypoid bevel gears. Names of parts: 1, outer universal joint; 2, inner universal joint; 3, ring gear; 4, drive pinion; 5, brake drum; 6, differential bearings.

Engine, clutch, transmission, differential and driveshafts all together form a unit power and drive plant; shown in illustration to the left. The quarter elliptic front springs are attached to the tubular front axle with rubber shackles. The drum-shaped housings enclose the brakes and the differential is at the center. Note the construction of the frame, the tubular dead axle and the drive to the wheel spindles.

1—Front axle
2—Automatic radiator shutters
3—Differential
4—Four-blade fan
5—Transmission
6—Battery
7—Single plate clutch
8—Gear-shift lever

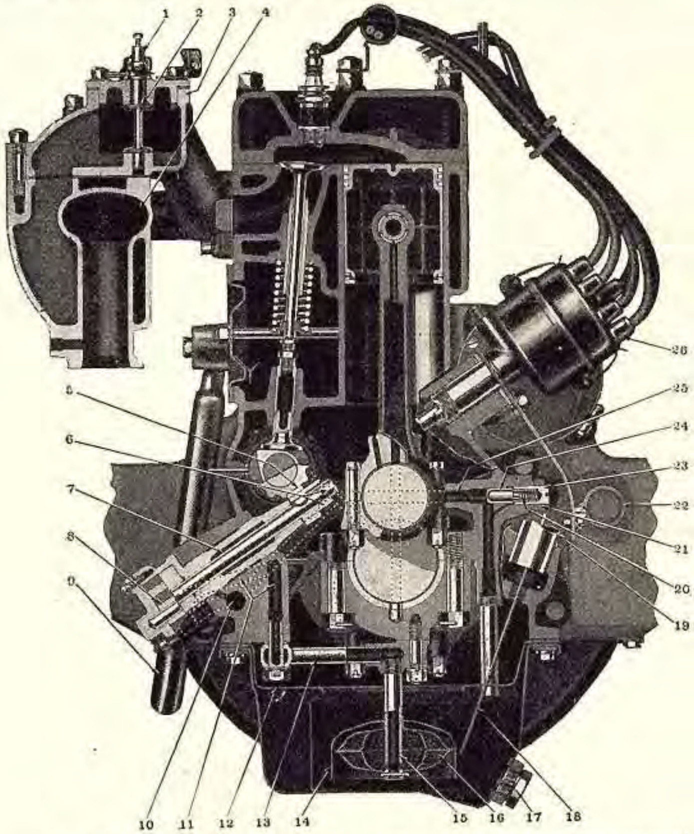


Phantom view showing location of principal units. For specifications of Cord and other cars see pages 1055–1062.

The following pages exemplify types of automobile gasoline engines in general use. The modern engine employs either four, six, eight, twelve or sixteen cylinders. All engines discussed operate on the four-stroke cycle principle.

The cylinders may be arranged **"in-line,"** or two blocks in **"V"** formation.

The valves may be arranged **vertically**, or at an angle, and all on one side of cylinder, which would designate the cylinders as the **L-head** type. They may be arranged vertically, or at an angle and on opposite sides of cylinder, which would designate the cylinders as the **T-head** type. They may also be arranged vertically, or at an angle and in cylinder-head (overhead), which would designate the cylinders as the **I-head** type. Another arrangement of the valves is to place them horizontally.

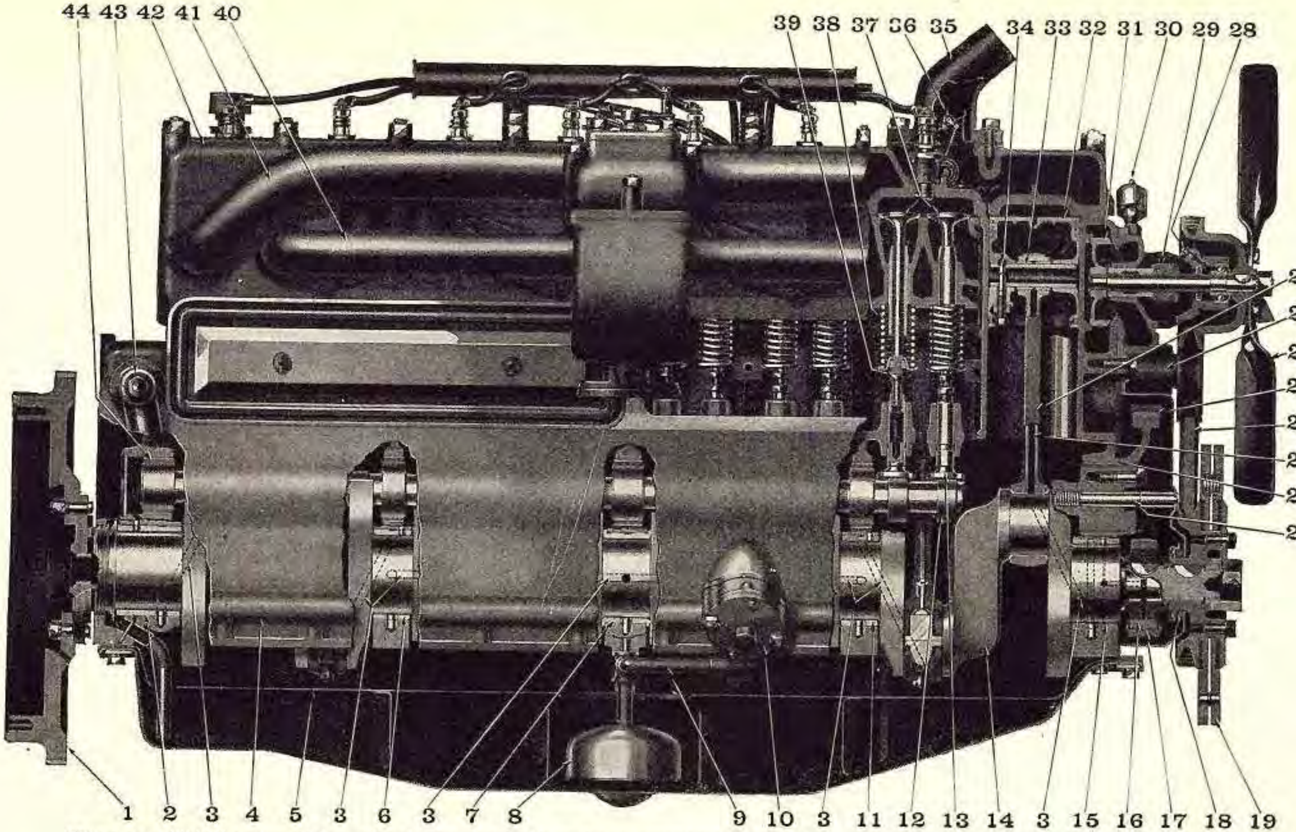


Willys eight "8-80" engine with eight in-line, L-head type of cylinders and valves on the side of cylinders, operated by one camshaft on the side. End sectional view.

Cylinder arrangement: vertical, eight-in-line, L-head, cast in one block, water cooled; detachable head. **Valve arrangement:** poppet type valves on one side of cylinder with valves set at an angle. **Valve operation:** by one camshaft on the side of engine. **Camshaft drive:** from crankshaft by means of sprocket and silent timing chain. **Names of parts follow.**

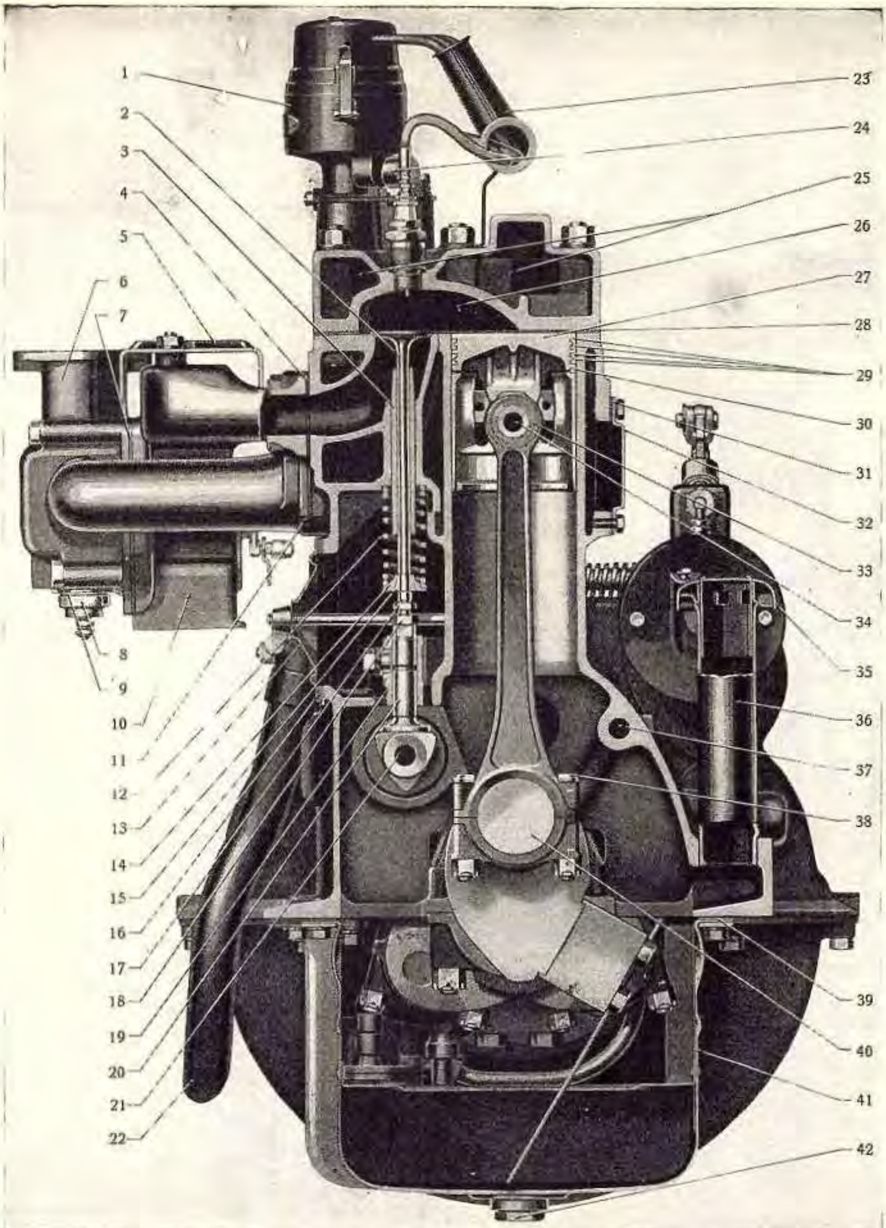
1—Manifold heat control lever
2—Manifold heat control valve
3—Exhaust manifold
4—Intake manifold
5—Oil pump driven gear
6—Oil passage to main and camshaft bearings
7—Oil pump shaft assembly
8—Oil pump pinion
9—Ventilator
10—Main oil distributing passage
11—Oil pump suction passage
12—Oil pan tray
13—Oil pump suction pipe
14—Oil suction bell
15—Oil suction pipe
16—Oil strainer
17—Oil drain plug
18—Oil measuring rod
19—Oil filler pipe
20—Oil relief valve spring
21—Oil relief valve spring retainer lock nut
22—Timing hole cover
23—Oil relief valve spring retainer
24—Oil relief valve plunger
25—Passage to oil relief valve
26—Ignition distributor

For specifications of the Willys and other engines see pages 1055–1062.



Willys eight "8-80" engine. Side sectional view showing how the one camshaft on the side operates valves on the side. Names of parts follow.

1—Flywheel
2—Crankshaft main bearing—rear
3—Oil passages to connecting rod bearings
4—Main oil distributing passage
5—Oil pan tray
6—Crankshaft main bearing—rear intermediate
7—Crankshaft main bearing—center
8—Oil suction bell
9—Oil pump suction pipe
10—Oi pump assembly
11—Crankshaft main bearing—front intermediate
12—Camshaft
13—Valve tappet
14—Crankshaft
15—Crankshaft main bearing—front
16—Crankshaft sprocket
17—Timing chain
18—Chain cover oil seal
19—Crankshaft damper assembly
20—Camshaft thrust plunger
21—Camshaft bushing—front
22—Oil passage to piston pin
23—Fan and generator drive belt
24—Camshaft sprocket
25—Fan
26—Generator
27—Connecting rod
28—Fan bearing oiler
29—Water pump packing gland
30—Water pump bearing grease cup
31—Water pump
32—Piston
33—Piston pin
34—Piston pin lock screw
35—Water outlet
36—Thermostat
37—Valves
38—Valve spring
39—Valve tappet adjusting screw
40—Intake manifold
41—Exhaust manifold
42—Cylinder head
43—Ventilator
44—Camshaft bushing—rear

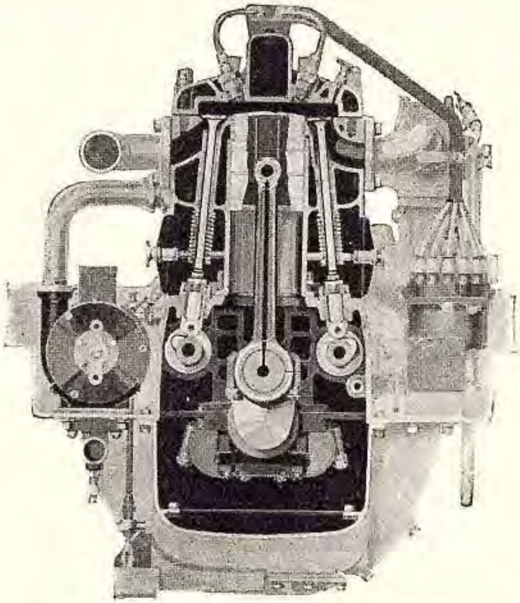


Chrysler "70" (1930) engine with six in-line, L-head type of cylinders and valves on the side of cylinders, operated by one camshaft on the side. Front sectional view.

Cylinder arrangement: vertical, six-in-line, L-head, cast in one block, water cooled, detachable head. **Valve arrangement:** poppet type valves on one side of cylinder with valves set vertical. **Valve operation:** by one camshaft on the side of engine. **Camshaft drive:** from crankshaft by means of sprocket and silent timing chain. **Names of parts follow.**

1—Distributor; 2—Exhaust valve
3—Valve guide
4—Exhaust manifold gasket
5—Manifold heat shield
6—Intake manifold. (The down-draft carburetor is placed on top of manifold instead of underneath.)
7—Intake to exhaust manifold gasket
8—Gasoline fuemer
9—Gasoline fuemer gasket
10—Exhaust manifold
11—Intake manifold cover plate
12—Valve spring; 13—Valve chamber cover plate
14—Valve spring retainer; 15—Valve spring retainer lock
16—Valve chamber cover plate gasket
17—Valve tappet adjusting screw
18—Valve tappet adjusting screw nut
19—Valve tappet guide
20—Valve tappet; 21—Oil passage
22—Crankcase ventilator outlet pipe
23—Ignition cable tube and bracket
24—Distributor grease cup
25—Water passages
26—Combustion chamber; 27—Piston
28—Cylinder head gasket
29—Piston ring Nos. 1, 2, 3, 4
30—Piston ring No. 5
31—Cylinder water jacket cover gasket
32—Cylinder water jacket cover
33—Piston pin bushing; 34—Piston pin
35—Crankcase oil filler or breather pipe cover
36—Crankcase oil filler or breather pipe
37—Oil passage
38—Connecting rod cap bolt
39—Oil pan gasket
40—Crankshaft
41—Oil pan; 42—Oil pan drain plug

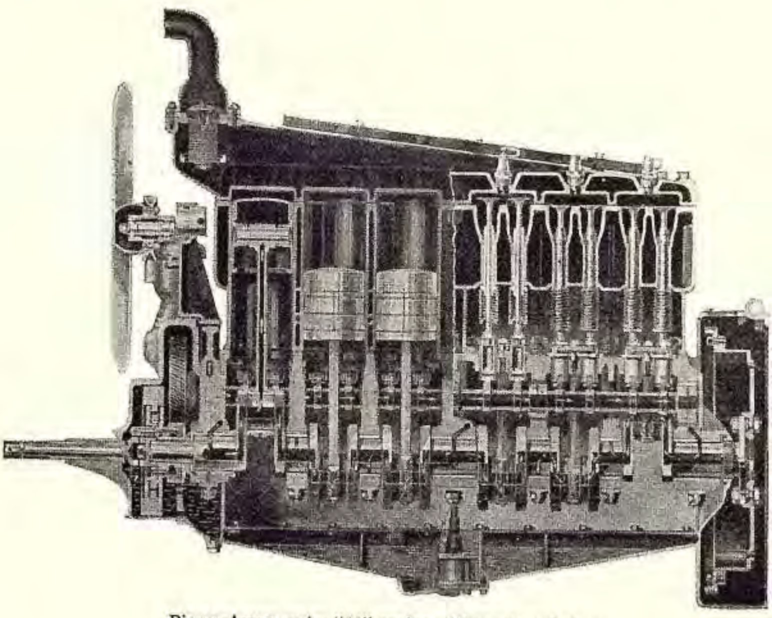
For **specifications** of the Chrysler and other engines see pages 1055-1062.



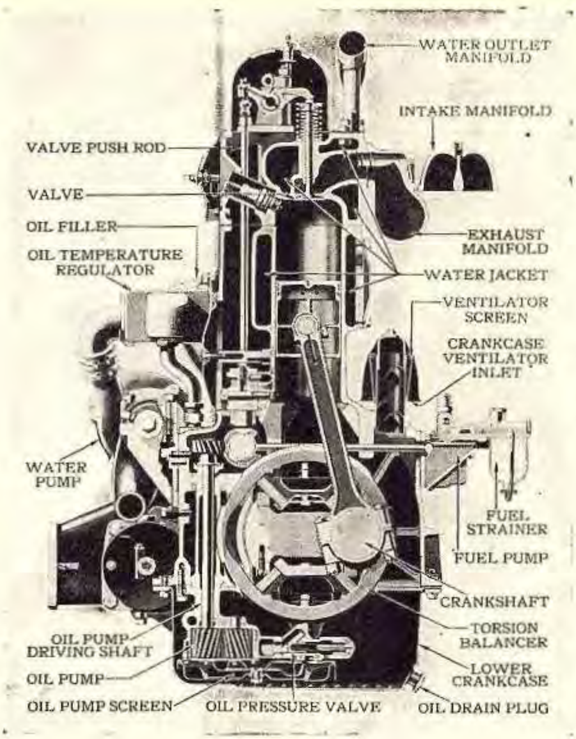
Pierce-Arrow series "36" engine, with six cylinders **in-line,** represents an example of an engine with **T-head type of cylinders** and **valves on both sides** of cylinders, operated by a **camshaft on each side.** End sectional view.

Cylinder arrangement: vertical, six-in-line, T-head, cast in one block, water-cooled, detachable head. **Valve arrangement:** poppet type valves on opposite sides of cylinders. Valves are set at an angle. Two inlet and two exhaust valves per cylinder, termed "dual valves." **Valve operation:** by two camshafts. One camshaft operates the inlet valves on one side of the engine and the other camshaft operates the exhaust valves on the other side of engine. **Camshaft drive:** from crankshaft by means of helical timing gears.

Note: The Pierce-Arrow T-head engine is no longer in production. The L-head, eight-in-line engine is now used on all Pierce-Arrow cars. For **specifications** of the Pierce-Arrow and other engines see pages 1055–1062.

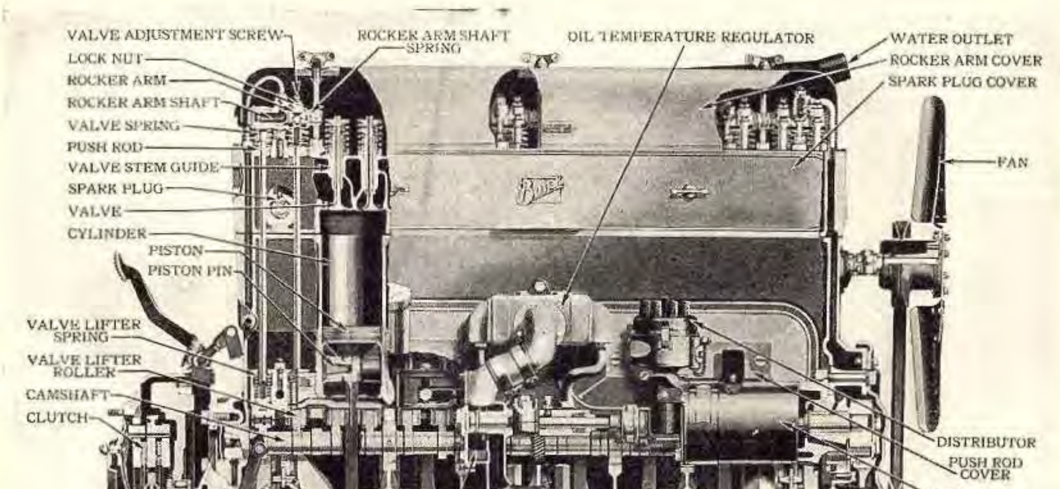


Pierce-Arrow series "36" engine. Side sectional view.



Buick series "8-80" and "8-90" engine with eight **in-line, I-head type of cylinders and valves overhead** in cylinder-head, operated **by one camshaft on the side.** Front sectional view.

Cylinder arrangement: vertical, eight-in-line, I-head, cast in one block, water-cooled, detachable head. **Valve arrangement:** poppet type valves in cylinder-head (overhead). **Valve operation:** operated off the cams on the one camshaft on the side of engine, by means of valve-lifters, push-rods and valve-rockers. **Camshaft drive:** from crankshaft by means of helical timing gears.



Buick series "8-80" and "8-90" engine. Side sectional view showing how the one camshaft-on-the-side operates the **valves-in-the-head** by means of valve push-rods and rocker-arms. For **specifications** of Buick and other engines see pages 1055–1062.

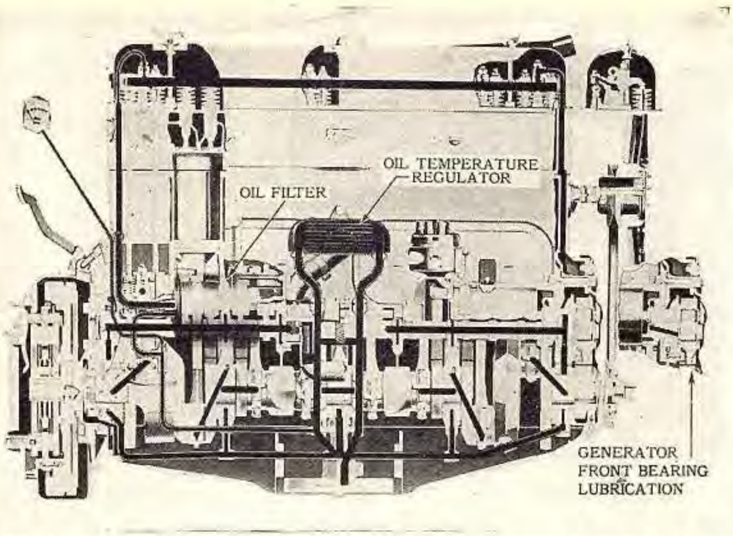


Fig. 3. **Pressure feed oiling system with oil filter and temperature regulator** of the Buick series "50, 60, 80 and 90" engines. Oil is supplied under pressure from the oil pump to all main, connecting rod and camshaft bearings. A secondary line from the oil pump delivers oil to the oil filter and thence to the hollow rocker-arm shaft. Timing gears and generator shaft front bearings are lubricated by the overflow of oil from the rocker-arm shaft. Cylinder walls, pistons and piston pins are lubricated by oil forced through a small hole drilled through the lower end of each connecting rod which meters with the hole in crankshaft once each revolution. This is termed a **force-feed** engine lubrication system.

The **oil filter** removes from the crankcase oil, all particles of dirt and carbon not already eliminated from circulation by the oil pump screen.

Fig. 4 (lower left illust.). **Oil temperature regulator:** Acts as a cooler for the oil by preventing a rise in temperature, under continued high-speed driving, to a point where the lubricating quality of the oil would be reduced. It also acts as an oil heater when engine is started cold, since the temperature of the water in the cooling system, under control of the radiator shutter, is raised more quickly than the temperature of the oil in the sump would be raised without the aid of the temperature regulator.

This regulator, in its dual capacity, tends to equalize temperatures of the engine oil and cooling water, thereby providing a more uniform temperature of engine parts with a consequent uniformity of heat expansion throughout the engine.

It consists of a radiating core through whose passages the oil is circulated and which is water jacketed by a shell flanged to the cylinder block and connected to the water pump by a hose. All water from the pump is forced through this shell and contacts with the surfaces of the radiating core.

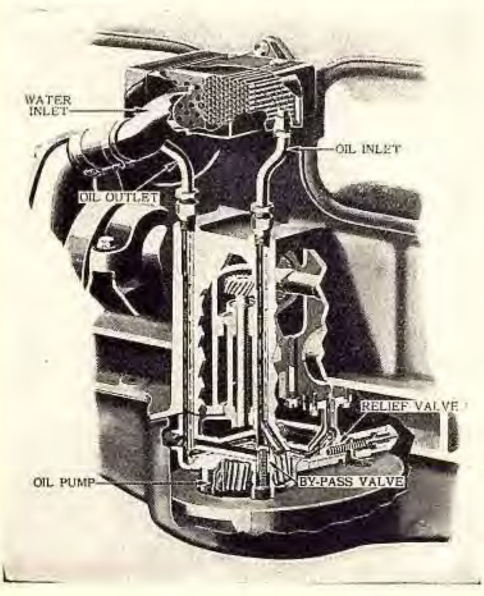
The operation of the temperature regulator is as follows: When the engine is started cold, the high viscosity of the oil builds up a resistance in the core passages of the regulator sufficient to cause a by-pass valve in the oil pump to open and permit direct passage of the oil to the bearings without circulation through the regulator. To shorten the period necessary to warm the oil sufficient to allow circulation through the temperature regulator, the pressure relief valve discharges the excess oil back into the pump body instead of the oil sump.

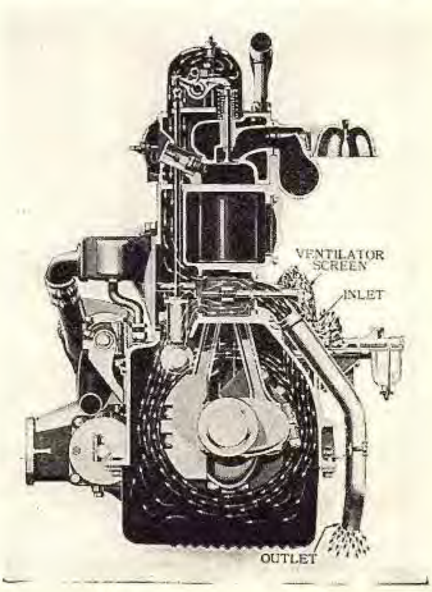
When the temperature of the engine oil is raised sufficiently to reduce its viscosity to a point where the resistance to flow in the core passages of the regulator is less than that required to hold the by-pass valve open, this valve will close and all the oil supplied by the pump passes through the core of the temperature regulator, where it is still further warmed by the water surrounding the core.

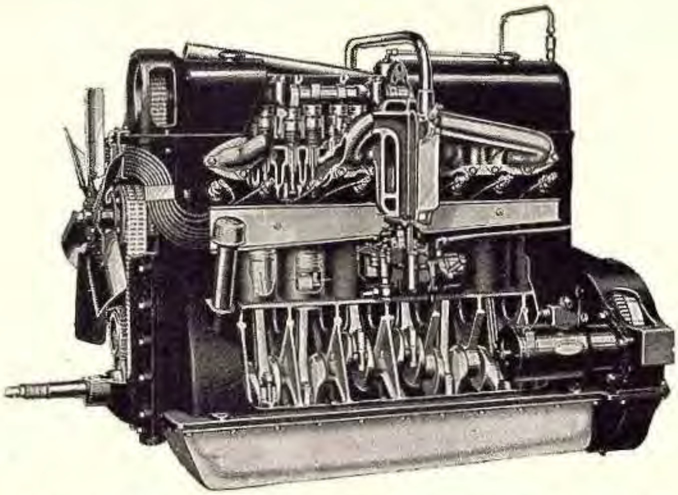
If the car is then driven at high speed for any considerable length of time, the temperature regulator then assumes its function as an oil cooler.

Fig. 5 (lower right). **Crankcase ventilator:** Prevents harmful dilution of the engine oil by water and fuel. This system utilizes the crankshaft with its counterweights and torsion balancer as a blower to force the vapors consisting of fuel and water, from the crankcase into the valve-lifter compartment. A vent at the rear of the rocker-arm cover permits air to be forced into the cover and this air is forced also into the valve-lifter compartment, carrying with it vapor from within the rocker-arm cover. An opening from valve-lifter compartment is connected to an outlet pipe between Nos. 4 and 5 cylinders for expelling vapors below the engine side pan.

This system does not remove all fuel dilution, but a small amount is not harmful and is really necessary in cold weather. It does, however, remove all of the water dilution under average driving conditions. The car owner may assist in preventing harmful dilution by avoiding the use of "choke" longer than necessary, by not idling engine at extremely slow speeds for long periods, by not flushing engine with kerosene, by seeing that compression is good, ignition system functions properly and that carburetor is correctly adjusted.

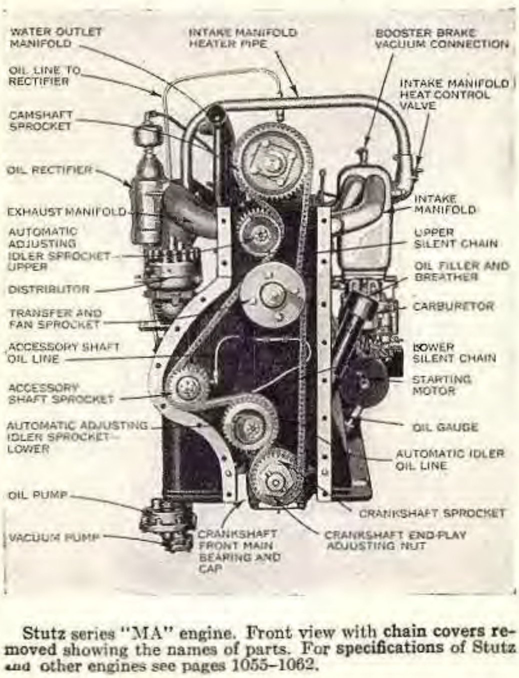




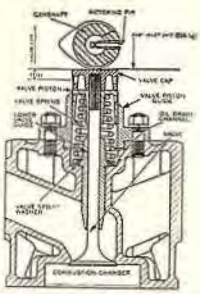


Stutz series "MA" engine with eight in-line, I-head type of cylinders and valves overhead in cylinder-head, operated by one overhead camshaft. Three-quarter and part sectional view

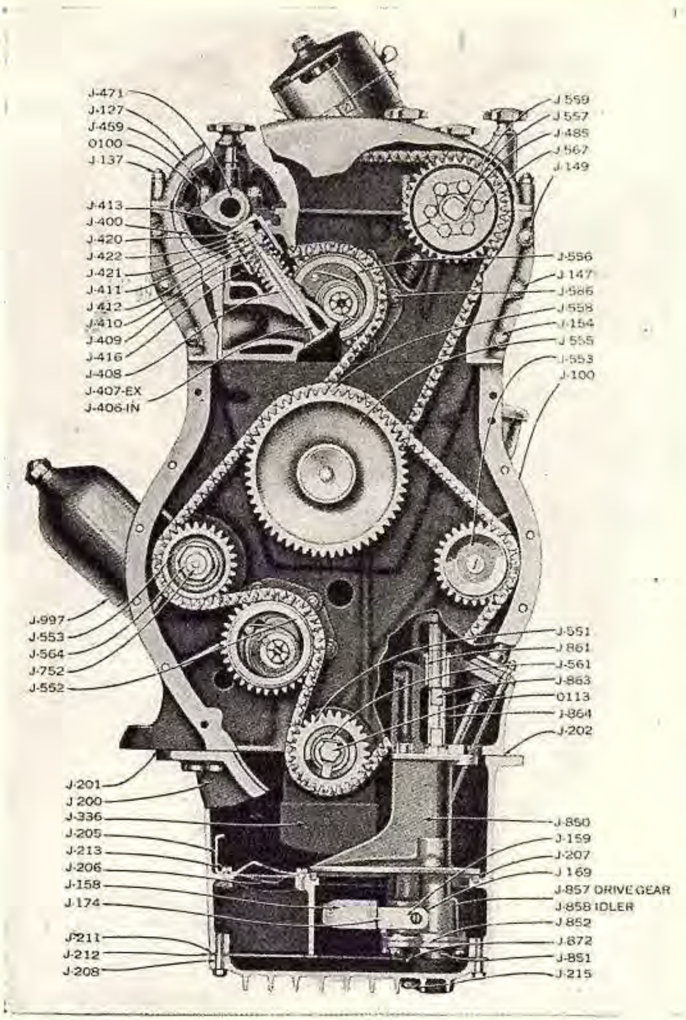
Cylinder arrangement: vertical eight-in-line, I-head, cast in one block, water-cooled, detachable head. **Valve arrangement:** poppet type valves in cylinder-head (overhead). **Valve operation:** operated off of one overhead camshaft. The cams wipe directly on the valve caps screwed on the ends of the valve stems. **Camshaft drive:** from crankshaft by two silent chains and sprockets. The lower chain drives the accessory shaft at 1.2 times the crankshaft speed and the transfer sprocket at 5/6 times the crankshaft speed. **Lubrication** is full-force-feed with oil circulated through engine under pressure by a gear oil pump located at the right front of engine somewhat above the oil base to prevent any possibility of freezing. The oil pressure regulator is located at the right side of crank-case.



Stutz series "MA" engine. Front view with chain covers removed showing the names of parts. For specifications of Stutz and other engines see pages 1055–1062.



Cross-section through valve

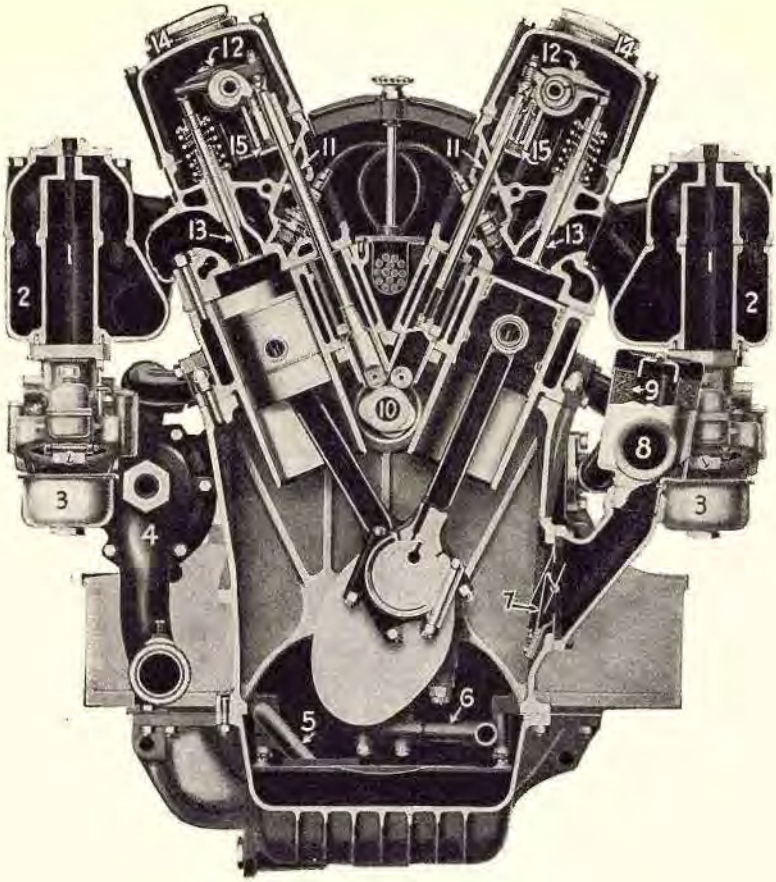


Duesenberg model "J" engine with eight **in-line, I-head type of cylinders** and **valves overhead** in cylinder-head mounted at an angle, operated by **two overhead camshafts.** Cross sectional front view.

Cylinder arrangement: vertical, eight-in-line, I-head; the eight cylinders are cast in one block, water-cooled, detachable cylinder-head. **Valve arrangement:** dual, poppet-type valves in cylinder-head (overhead), mounted at 35° angle to vertical center line of cylinder-head. **Valve operation:** the inlet valves on the left side are operated by one camshaft and the exhaust valves on the right side are operated by another camshaft. **Camshaft drive:** two endless silent timing chains with automatic adjustment drive camshafts and accessory shafts. The lower chain (J-558) drives the generator shaft, water pump shaft, and transfer sprocket for upper chain. The automatic idler sprocket (J-552) automatically adjusts the chain for wear. The upper chain (J-559) drives the two camshafts from driven transfer sprocket of lower chain. An automatic idler (J-556) maintains the correct tension which automatically compensates for wear. **Lubrication:** full-force-feed system. **Names of some of the parts follow.**

J-100—Cylinder block
J-158—Oil gauge float
J-159—Oil gauge float bracket
J-174—Oil gauge float assembly
J-200—Oil pan
J-201—Oil pan R.H. gasket; J-202—L.H. gasket
J-205—Oil pan baffle plate; J-206—Screen
J-336—Crankshaft small counterweight
J-400—Cylinder head
J-406—Valve; J-408—Valve guide
J-409—Inner valve spring; J-410—Outer spring
J-411—Valve spring retainer
J-412—Retainer wedge
J-413—Valve tappet; J-416—Tappet guide
J-418—Valve tappet guide clamp stud
J-420—Valve tappet adjusting nut
J-421—Valve tappet adjusting sleeve
J-422—Valve tappet adjusting shim
J-459—Camshaft bearing stud
J-471—Exhaust camshaft
J-485—Camshaft plug
J-551—Crankshaft sprocket
J-552—Lower adjusting sprocket assembly
J-553—Accessory shaft sprocket
J-555—Transfer sprocket assembly
J-556—Upper adjusting sprocket assembly
J-557—Camshaft sprocket
J-558—Lower chain; J-559—Upper chain
J-752—Water pump drive shaft
J-850—Oil pump body; J-857—Oil pump gear
J-858—Oil pump idler gear
J-863—Oil pump drive shaft

For **specifications** of the Duesenberg and other engines see pages 1055–1062.



Cadillac V-16, series "452," **sixteen-cylinder V-type** engine with **I-head type of cylinders** mounted at a 45° angle and **valves overhead** in cylinder-heads, operated by **one camshaft.** Sectional end view. **Names of parts:** 1, inlet header; 2, exhaust head; 3, carburetor (except for the gasoline tank at rear of car, there are two separate gasoline systems; each has its own feed line, vacuum tank, strainers and carburetor. See fuel pump, piston type, page 116A); 4, water pump; 5, oil suction pipe; 6, oil feed line; 7, crankcase ventilator thermostat; 8, crankcase ventilator; 9, air filter; 10, camshaft; 11, push rod; 12, valve rocker-arm; 13, valve; 14, oil filler; 15, valve silencer plunger in dash-pot.

Cylinder arrangement: V-type. Two banks of eight I-head cylinders at an angle of 45°, thus giving a power impulse every 1/8 turn of crankshaft. Cylinders are staggered, permitting side-by-side straight connecting rods. Water cooled. Compactness is secured by following aircraft practice in projecting the nickel iron cylinder barrels into the crankcase. Detachable cylinder head on each block. **Valve arrangement**: poppet type valves in cylinder-head (overhead). **Valve operation:** operated off the cams on one camshaft by means of valve-lifters, push rods and valve rockers. Double valve-springs are used to prevent clatter even at the highest speeds. **Camshaft drive:** from crankshaft by means of one timing chain, as the use of automatic adjuster makes it possible to drive the generator and water pump as well as the camshaft with the same chain.

The lubrication system is a full-force-feed system and supplies oil under pressure to all engine bearings, including the camshaft bearings, and piston pins and hollow rocker-shafts, through which oil is distributed to the rocker-arms, valve stems and push rods. The overflow from the rocker-arms keeps the dash-pots of the automatic valve silencers full. Baffles in the sump are provided to prevent oil surge. Lubrication to the lower connecting rod bearings is provided through metered holes in the crankshaft throws for oil supply from the main bearings. Each connecting rod is rifle-bored from lower to upper bearing so that oil can reach the piston pin which is locked in piston. There are two oil filler holes 14, one in the center of each valve cover. The oil thus added flows down through the tubes around the valve push rods 11, and into the crankcase.

The air inlet passage of the crankcase ventilating system is fitted with a **thermostatic valve** 7, which is set to open below 170° and closes above 180°, permitting **the** entry of air only during warming-up period.

Fig. 2 (left). **Timing-chain:** One timing chain drives from crankshaft timing-sprocket to the camshaft timing-sprocket and generator. An idler gear with an automatic adjuster takes up chain wear.

Fig. 3 (right). **Crankshaft** has eight throws and five main bearings. Bearings are steel-backed. The end thrust is taken by the center main bearing. Cylinders are staggered, permitting side-by-side straight connecting rods.

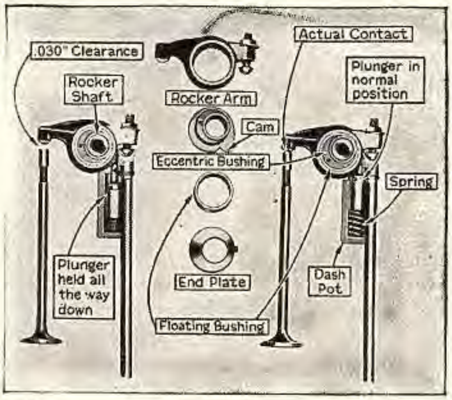


Fig. 4. **Valve silencer:** The overhead valve mechanism is provided with hydraulic automatic valve silencers that automatically maintain practically zero valve clearance and effectively prevent tappet noise. The valve rocker-arm is operated in the usual way from the camshaft by a push-rod.

Each rocker-arm, however, operates on a flanged eccentric bushing. A dash-pot and plunger are located directly below the flange of this eccentric bushing, the plunger bearing against a cam on the flange. Upward pressure of a spring under the plunger, which operates in oil, keeps the eccentric always in such a position that the rocker-arm touches both the valve stem and the push rod. This pressure is not great enough, however, to hold the valve open.

The dash-pot cylinder below the plunger is kept full of constantly filtered oil and this oil prevents the plunger from being forced down as the valve opens and closes. The clearance between the plunger and the cylinder is just enough to let the plunger move downward slowly to compensate for wear and expansion as the engine heats up.

Valve adjustment: As the clearance is automatically held at zero, no valve adjustment in the usual sense of the word is necessary. The automatic silencers take care of all variations due to wear or to valve grinding operations.

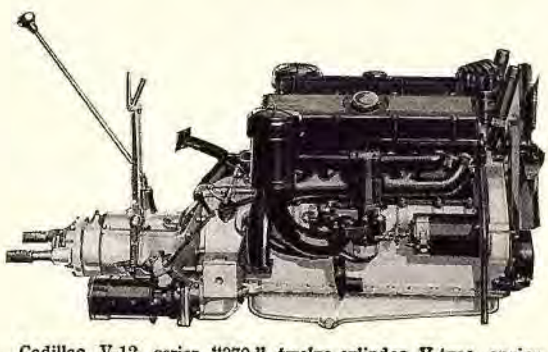
There is, however, provision for an **initial adjustment** to secure the proper position of the eccentric cam, and if this adjustment is disturbed, it must be corrected to the proper standard. To make this adjustment, the silencer plunger must be held down as far as it will go. This can be done by using a special tool in the upper hole of the plunger to release the poppet valve inside the plunger. The eccentric must then be turned so that the cam rests on the plunger while it is thus held down. With the cam and plunger in this position, the adjusting screw in the rocker-arm should be set to allow .030" clearance between the rocker-arm and the valve stem. **Important:** The plunger must be held all the way down with the cam resting on it when making this adjustment.

This adjustment can be made either with the engine running or with the engine stationary. If the engine is not running, the piston must be at the firing point for each cylinder, while the adjustment for that cylinder is made. If the engine is running, it is simply necessary to hold the plunger down and check the clearance with the feeler, making adjustments as necessary.

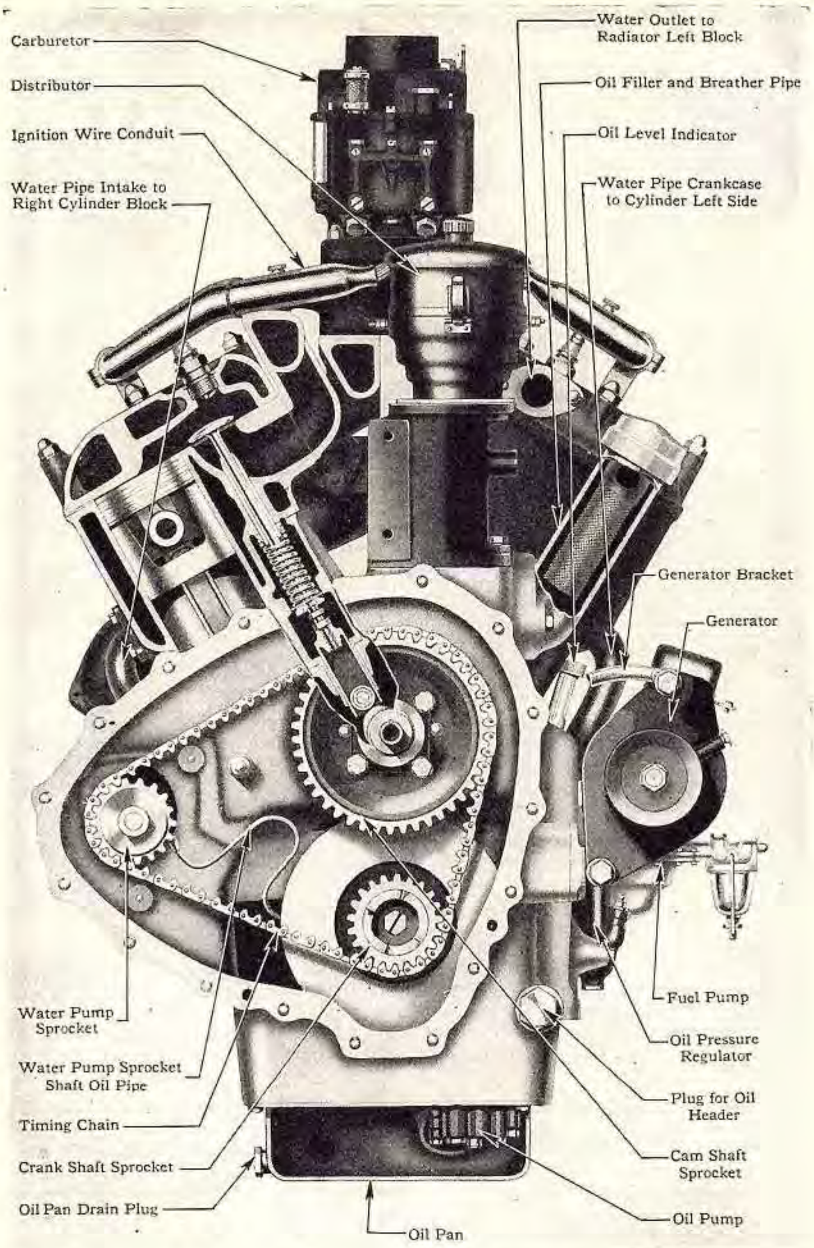
Cadillac V-12, series "370," twelve-cylinder "V" type engine is of the same design and principle as the larger V-16, but has twelve cylinders. The cross sectional view of the V-16 engine would in fact pass for the V-12 engine with minor differences, for example, the type of carburetor intake muffler attached to each carburetor (see illustration below). This device is used to neutralize the sound waves which silence air roar noises in the carburetor intake. The piston displacement of the V-16 is 452 cubic inches and the V-12, 368 cubic inches.

The V-12 engine cylinder blocks are mounted at 45° angle, allowing the use of the same type of overhead valve mechanism as on the V-16. This 45° angle permits mounting the carburetors and manifolds on the outside of each block as on the V-16 without making the hood as bulky as it would be if the cylinders were at 60°, which is the theoretically correct angle. With the greater number of cylinders on this engine overlapping far more than on any 8-cylinder engine, the difference in the intervals between the power impulses is not noticeable. For firing impulse or intervals, see page 424C.

For the **electrical system,** firing order, ignition timing, etc., see pages 424C–424E. For specifications of Cadillac ngines and others, see pages 1055–1062.



Cadillac V-12, series "370," twelve-cylinder V-type engine. Right-side view. Similar to the V-16, and many of the parts **are** interchangeable.



Lincoln eight-cylinder V-type engine (1931). Sectional front end view. Names of parts are shown on illustration.

Cylinder arrangement: V-type. Two banks of four L-head cylinder blocks, each cast in one block with detachable cylinder-heads. Cylinder blocks are mounted at an included angle of 60°. Cylinders are not staggered, therefore connecting rods are of the forked and plain type. **Valve arrangement:** poppet type valves on the side of each cylinder block. **Valve operation:** operated off cams on one camshaft by means of valve-lifters. **Camshaft drive:** the camshaft and water pump are driven from crankshaft by means of sprockets and one silent timing chain.

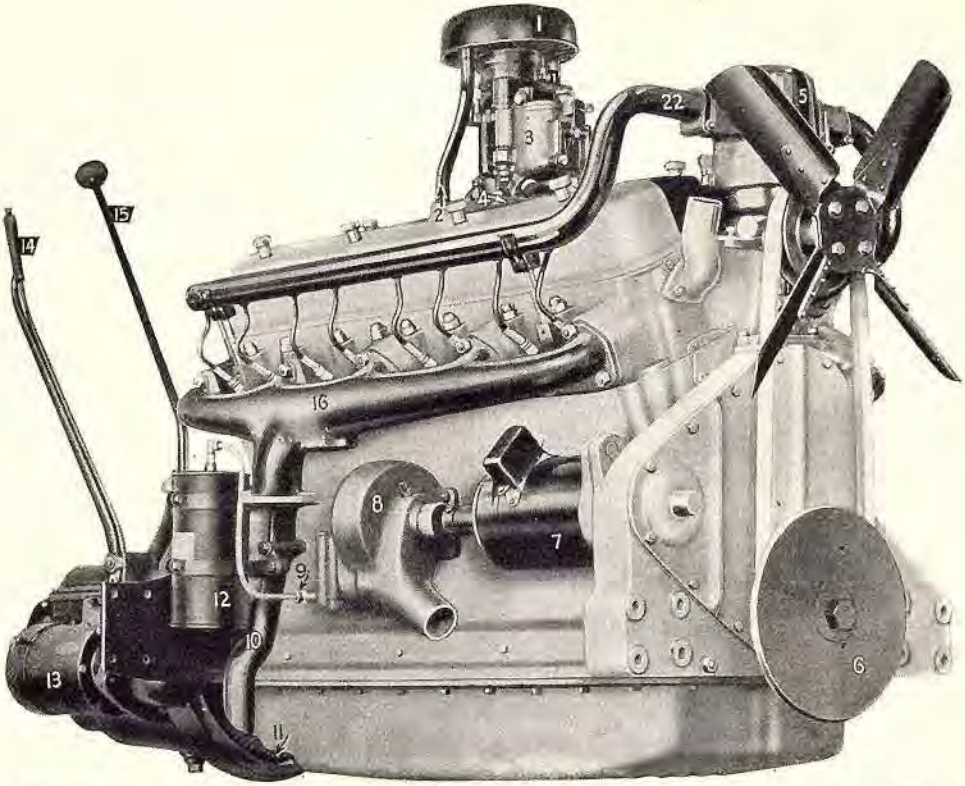
Carburetor: Stromberg type "DD." Plain tube down-draft type with fixed orifices. A hydraulic throttle return check acts in conjunction with the free-wheeling feature of the car to prevent engine from stalling immediately after the foot accelerator is released and the car coasts along without any drag on the engine.

Cooling is by a forced water circulation system consisting of the centrifugal water pump, radiator, 6-blade fan, condenser tank and thermostatically controlled radiator shutters.

Clutch is a double disc, dry plate type. **Transmission** is of the **free-wheeling** type incorporating the over-running clutch principle with the standard three-speed gear shift.

Engine lubrication is of the force-feed type.

For specifications of the Lincoln and other engines see pages 1055–1062.



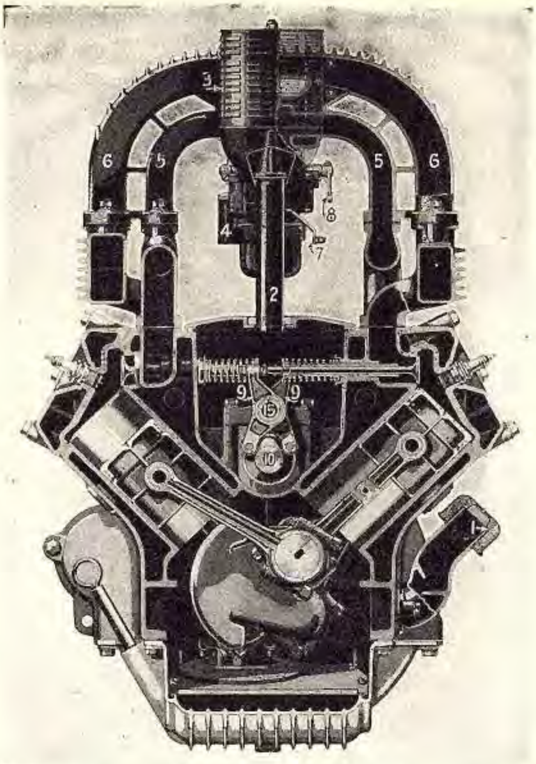
Marmon (1931) sixteen-cylinder, V-type engine with I-head type of cylinders at an angle of 45° and valves overhead in cylinder heads, operated by one camshaft. Right-side view. Names of parts: 1, air cleaner; 2, breathing tubes; 3, carburetor; 4, duplex down-draft intake manifold; 5, timer-distributor; 6, modulator to relieve torsional vibration on the crankshaft; 7, generator; 8, water pump; 9, oil purifier inlet; 10, crankcase breather; 11, flywheel; 12, oil purifier; 13, starter. No crank is provided, it being impractical to crank engine by hand. Means for rotating the engine to make timing adjustments are provided on the flywheel of engine; 14, hand-brake lever; 15, gear-shift lever; 16, exhaust manifold; 17, carburetor control arm; 18, rocker-arm tension spring; 19, push rod; 20, rocker-arm; 21, spark plug; 22, wiring manifold.

Cylinder arrangement: V-type. Two banks of eight I-head cylinders at an angle of 45°, or inclined $22\frac{1}{2}$° off the vertical, thus giving a power impulse every 1/8 turn of crankshaft. The firing order is 1L, 3R, 6L, 7R, 2L, 4R, 5L, 1R, 8L, 6R, 3L, 2R, 7L, 5R, 4L, 8R. Cylinders are not staggered as connecting rods are forked. Cylinder block is aluminum alloy with steel cylinders pressed into place. Cylinder walls are case hardened. Crankcase and cylinder block one piece. Water-cooled. Valve-seats, spark plugs and combustion space completely surrounded by water. Cylinder-head is detachable and made of aluminum silicon copper alloy and valve seats are aluminum bronze. Combustion chamber is machined. **Valve arrangement:** poppet type valves in cylinder-head (overhead). **Valve operation:** operated off the cams on one camshaft by means of valve-lifters, push-rods and valve-rockers. Valve springs are double variable pitch. **Camshaft drive:** from crankshaft by means of tripple roller chain.

Lubrication: Force-feed lubrication is provided by a gear type oil pump for every rotating bearing in the engine—the rocker-arms by means of a hollow rocker-arm shaft and the valve mechanism by means of drilled holes in the rocker-arms. The main bearings are lubricated by means of oil lines to each main bearing, which, in turn, lubricate adjacent connecting rod bearings by means of drilled oil leads in the crankshaft. Camshaft bearings are lubricated by pressure from the corresponding main bearings. Cylinder walls lubricated by oil stream spray from hole in connecting rods.

Miscellaneous specifications: Cylinders: 16; bore and stroke: 3 1/8"x4"; piston displacement: 490.8 cu. in.; horsepower: S.A.E. 62.5; brake horsepower: 200 @ 3,400 r.p.m.; displacement horsepower ratio: 2.454 cu. in. per horsepower; compression ratio: 6 to 1; horsepower engine weight ratio: one horsepower for each 4.65 pounds weight; engine weight: 930 pounds, including equipment; engine equipment: oil filter, air cleaner, gas filter, heat indicator, down-draft carburetor, modulator, Delco Remy electrical system, clutch, clutch and brake pedals; spark plugs: metric, one per cylinder; intake manifold: duplex down-draft type cast in a single piece for both cylinder blocks; carburetor: duplex type; exhaust manifold: for each cylinder block with separate muffler and tail pipe; pistons: trunk type, slotted skirt, aluminum alloy, heat treated with two compression rings and one oil ring above piston pin.

Cover removed showing the accessible overhead valve mechanism of the Marmon sixteen-cylinder engine.



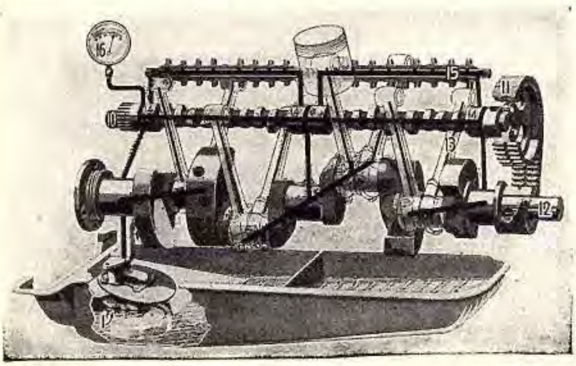
Viking V-30, eight-cylinder **V-type** engine with cylinders at an angle of 90° and **horizontal valves** operated by **one camshaft.** End sectional view.

Cylinder arrangement: V-type. Two banks of four staggered cylinders cast integral with crankcase are placed at an angle of 90°. Cylinders water-cooled. Cylinder-heads detachable. Connecting rods side-by-side. **Valve arrangement:** poppet type valves placed horizontally. **Valve operation:** operated off the cams on one camshaft 10, by means of valve-rockers 9. **Camshaft drive:** by one silent chain 11, from crankshaft timing sprocket to camshaft timing sprocket. The camshaft 10 is chain driven, while the fan, water pump and the generator are driven by separate V belts.

Crankcase ventilation: Approximately one-third of the carburetor air supply is drawn from the crankcase, entering at the breather port 1, and sweeping through the crankcase to a duct 2, into carburetor 4. The air intake of carburetor is provided with air cleaner 3.

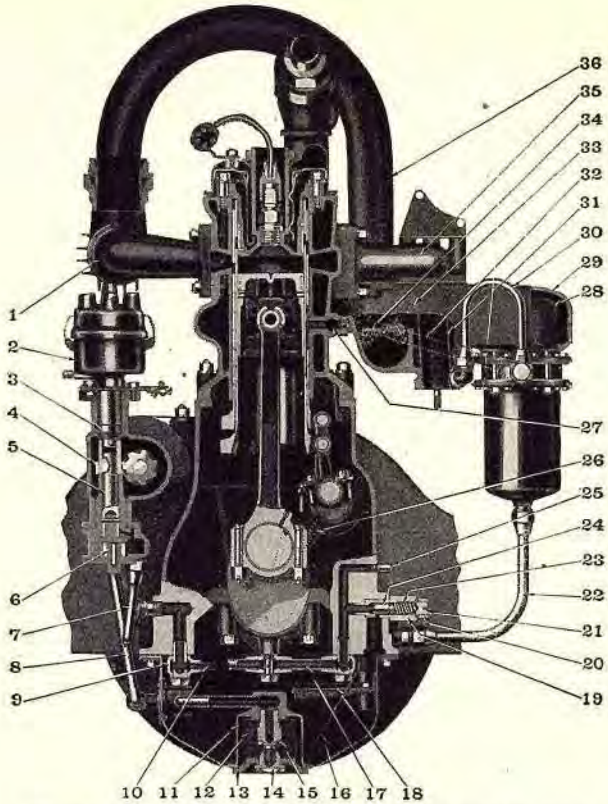
Manifolds: The exhaust manifold 6 carries the hot gases outside and above the intake system 5. Hot gases from the left block rise and arch over the engine and pass to the front, where they join those from the right-hand bank to pass downward and backward to the muffler. A manually controlled valve is provided to divert exhaust gases from the arch to pass about the intake passage and hasten the warming up period.

Carburetor: The carburetor 4 is mounted above the engine adjacent to and surrounded by the inlet ports. From it the fuel travels with a down-draft and divides into the two blocks, all of whose inlet valves are equidistant from the carburetor, and thence into the combustion chambers. Gravity assists the flow of gases to the combustion chambers. Diaphragm type fuel-pump feed to carburetor is employed. The throttle lever is shown at 8 and choke lever at 7.



Viking engine lubrication is a full-force-feed system. Oil from the oil pump 1, submerged in the crankcase, is carried through leads in the engine walls and the crankshaft 12, to all crankshaft and connecting rod bearings. From the main bearings it is carried on to the camshaft 10, which is drilled for its entire length as an oil lead. The connecting rods 13 are rifle drilled to carry oil under pressure to the piston pins. From the camshaft bearings 14, the oil travels upward, still under pressure, to the rocker-arm supporting shaft 15, and to the rocker-arm bearings. The lead to the oil gauge 16 is taken from the rear camshaft bearing 14.

For **specifications** of the Viking and other engines see pages 1055–1062.



Willys-Knight, model "87," six-cylinder, **in-line, sleeve-valve engine.**
End sectional view.

Cylinder arrangement: vertical, six-in-line, I-head, water-cooled.

Valves: sleeve type. Two sleeves, one within the other, travel up and down between the piston and the cylinder wall in such a manner that when the openings in the upper ends of sleeves, and also in the cylinder wall, come into register with each other, an opening into the cylinder is created.

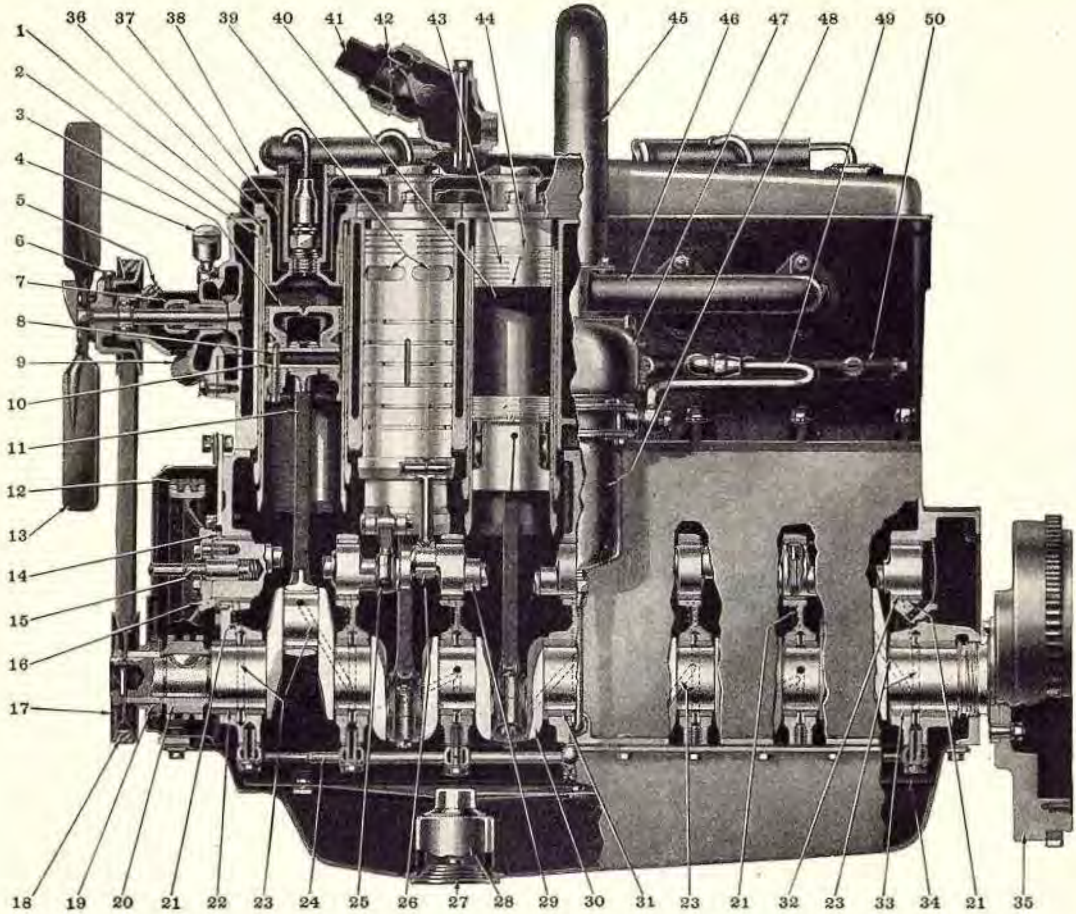
The intake openings for fresh gas are on one side of the cylinder; on the opposite side are the exhaust openings through which burned gases are expelled.

These sleeves are moved up and down by short rods connected to an eccentric shaft, taking the place of the camshaft in the poppet type engine. This movement of the sleeves is very similar to the operation of the valves on a steam engine.

Eccentric shaft drive. The eccentric shaft takes the place of the conventional camshaft (see next page). It is driven from crankshaft by means of sprockets and one timing chain.

Lubrication is of the force-feed type with oil circulated through engine by an internal gear pump located on the right side forward end of engine below ignition distributor.

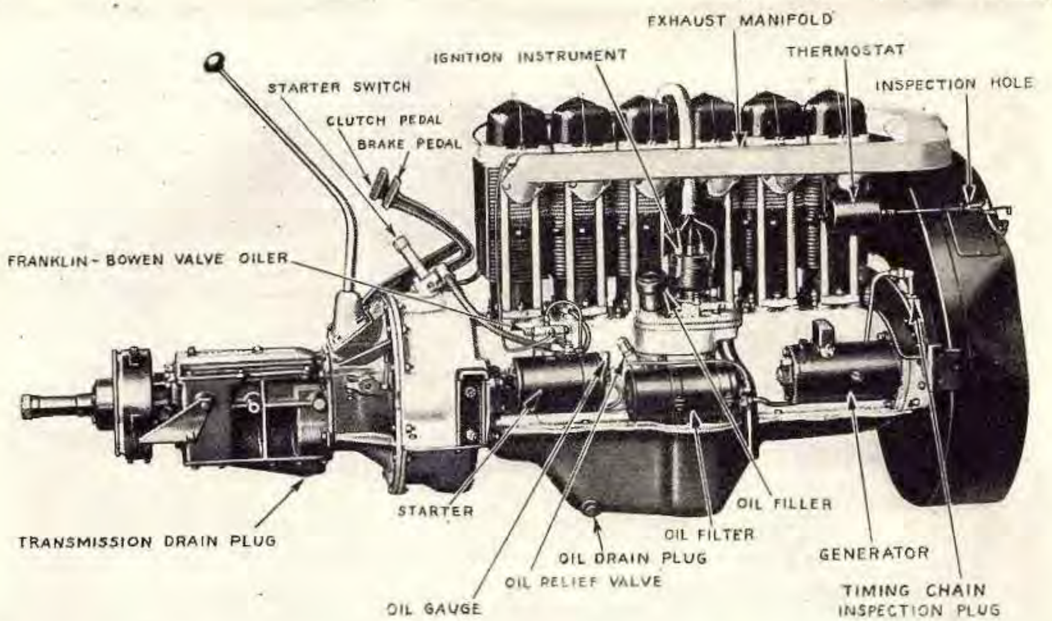
1—Exhaust manifold
2—Ignition distributor
3—Timer shaft driving collar
4—Pump and timer driven gear
5—Oil pump shaft assembly
6—Oil pump pinion
7—Oil pump discharge pipe
8—Oil pump suction pipe
9—Oil distributor pipe
10—Oil lead to center main bearing
11—Oil suction bell
12—Oil strainer
13—Oil strainer cover
14—Oil strainer cover nut
15—Oil strainer suction pipe
16—Oil measuring rod
17—Lead to oil relief valve
18—Oil pan tray
19—Oil relief valve case
20—Oil relief valve spring retainer lock nut
21—Oil relief valve spring retainer
22—Rectifier to crankcase oil return tube
23—Oil relief valve spring
24—Oil relief valve plunger
25—Lead to oil pressure gauge
26—Oil passage to eccentric shaft bearing
27—Oil rectifier cylinder suction passage
28—Oil rectifier
29—Intake header
30—Rectifier to intake header suction pipe
31—Intake header tube
32—Cylinder to rectifier suction pipe
33—Manifold heat control lever
34—Manifold heat control valve
35—Intake manifold
36—Intake heater pipe



Willys-Knight "87" sleeve-valve engine. Side sectional view showing **how the eccentric shaft 29 operates the inner sleeve connecting rod 25, outer sleeve connecting rod 26, and the inner and outer sleeves.** The eccentric shaft 29 is driven from crankshaft sprocket 20 by a silent timing chain 12 to eccentric shaft sprocket 16. **Names of parts follow.**

1—Inner sleeve
2—Outer sleeve
3—Piston
4—Water pump bearing grease cup
5—Fan bearing oiler
6—Fan pulley adjusting screw
7—Water pump packing gland
8—Piston pin lock screw
9—Water pump
10—Piston pin
11—Piston connecting rod
12—Timing chain
13—Fan
14—Eccentric shaft bushing—front
15—Eccentric shaft thrust plunger
16—Eccentric shaft sprocket
17—Fan driving pulley
18—Fan belt
19—Chain cover oil seal
20—Crankshaft sprocket
21—Oil leads to eccentric shaft bushings
22—Crankshaft main bearing—front
23—Oil passages in crankshaft
24—Oil distributor pipe
25—Inner sleeve connecting rod
26—Outer sleeve connecting rod
27—Oil strainer cover
28—Oil suction bell
29—Eccentric shaft
30—Crankshaft
31—Crankshaft main bearing—center
32—Eccentric shaft bushing—rear
33—Crankshaft main bearing—rear
34—Oil pan tray
35—Flywheel
36—Cylinder-head
37—Cylinder cover baffle thimble
38—Cylinder cover
39—Intake port in sleeve
40—Exhaust port in sleeve
41—Water outlet
42—Thermostat
43—Cylinder-head sealing ring
44—Oil ring
45—Intake heater pipe
46—Intake manifold
47—Intake header
48—Oil rectifier
49—Cylinder to rectifier suction pipe
50—Oil rectifier cylinder suction passage

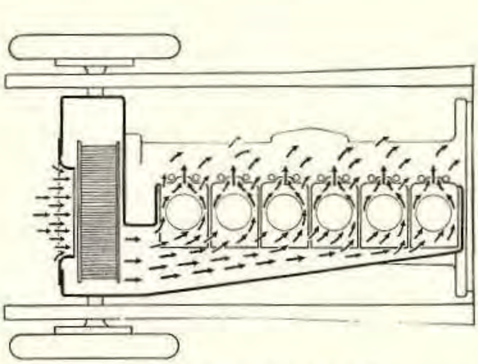
For specifications of Willys-Knight and other engines see pages 1055–1062.



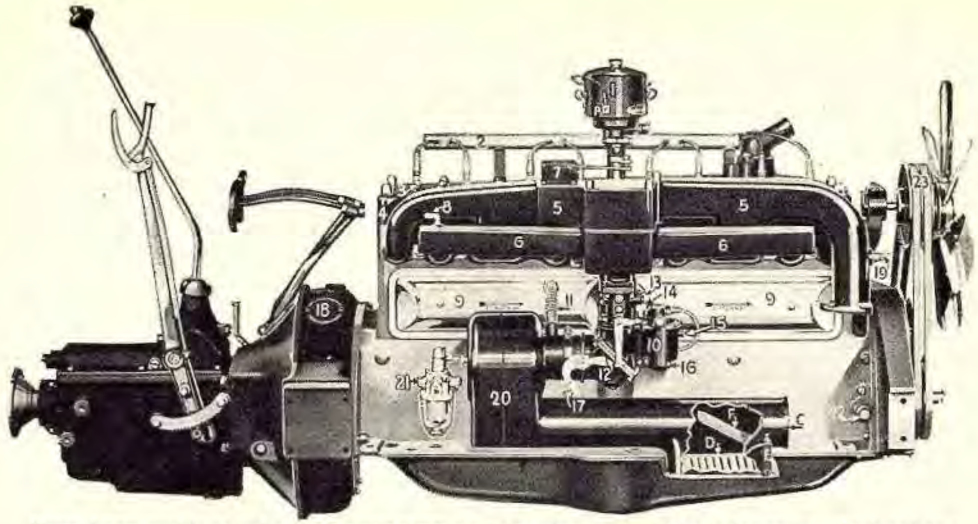
Franklin series "15" **air-cooled engine** with six **in-line I-head type** of cylinders and **valves overhead** in cylinder-heads operated by **one camshaft** on the side. Right-side view of the unit-power-plant.

Cylinder arrangement: vertical, six-in-line, I-head, air-cooled. Cylinders are cast individually of nickel iron. **Valve arrangement:** poppet type valves overhead, in individual detachable aluminum alloy cylinder-heads with bronze insert valve-seats. Rocker-arms are mounted in a cast-iron case mounted on top of cylinder-head. **Valve operation:** operated off the cams on one camshaft on the side of engine by means of valve-lifters, valve push-rods and valve-rockers. **Camshaft drive:** from crankshaft by means of one silent timing chain. **Cooling:** individual aluminum alloy detachable cylinder-heads are provided with large horizontal cooling fins. The cylinders have similar horizontal cooling fins of cast metal. The cooling blast of air from the front-mounted blower (15″ turbine fan) is passed over the cylinders and head horizontally as shown in illustration below. Flow of air is regulated by thermostatically controlled shutter mounted in the hood front. **Lubrication:** pressure or force-feed from gear pump to header supplying main and connecting rod bearings, valve oiler and timing chain. Cylinders and pistons receive a stream of oil from a metered outlet in the connecting rods. Oil pump relief valve set to read 40 to 45 pounds at 32 m.p.h. with oil at room temperature. Pressure taken at end of valve oiler intake pipe. Valves are lubricated by an automatic valve oiler. Engine oil is fed to the valve oiler from the oil pump. The oiler filters the oil and distributes it to the valves and mechanism. Capacity of oil reservoir is 6 quarts.

For **specifications** of the Franklin and other engines see pages 1055–1062.



View showing how the **cooling blast of air** is passed over the cylinders and head horizontally.



Pierce-Arrow, models 41 and 42, unit-power plant[1] consisting of an eight-cylinder in-line engine, clutch and transmission, showing the right-side view. **Horsepower of engine** is 132 with a bore of 3½", stroke 5" and piston displacement of 385 cu. in. **Transmission** is the **free-wheeling**, constant mesh, helical gear type with standard three-speed gear shift. **Clutch** is double plate with spring loaded torsional damper incorporated in the hub of clutch.

Cylinder arrangement: vertical, eight-in-line, L-head, cast in one block and integral with crankcase, water-cooled, detachable head. **Valve arrangement:** poppet type valves on right side of cylinders with valves set at an angle. **Valve operation:** by one camshaft on right side of engine. **Camshaft drive:** from crankshaft by means of sprockets and one non-adjustable short silent timing chain. **Names of parts follow.**

1—Timer-distributor; semi-automatic. Two individual coils, condensers and dual contact-breakers are used; one set for each four cylinders. The distributor rotor has two high-tension electrodes, one is a brush in contact with a ring or race in distributor cap, the source of supply, the other is the gap lead to spark plug segments. One contact-breaker fires four cylinders and the other contact-breaker fires four cylinders. The firing intervals are 45° apart.

2—High-tension wiring conduit or manifold

3—Spark plugs, one per cylinder; 7/8"

4—Detachable cylinder-head

5—Exhaust manifold

6—Duplex exhaust heated intake manifold

7—Thermostat unit which automatically governs the heating of intake manifold.

8—Vacuum connection to intake manifold for windshield wiper; 9—Valve housing covers

10—Carburetor, duplex type with two mixing chambers, each serving four cylinders independently. Outside mixing chamber feeds 1, 2, 7 and 8 and the inside 3, 4, 5 and 6.

11—Crankcase ventilating tube to carburetor air intake horn; draws moisture and water vapor from crankcase; prevents crankcase dilution and back pressure in crankcase

12—Carburetor connection for closing choke and lifting auxiliary needle for starting when engine is cold. The choke butterfly valve itself is fitted with a small spring-loaded poppet valve to prevent overchoking.

The carburetor throttle valve (left side of engine) is interconnected with starter pedal to open throttle valves in carburetor to facilitate starting.

13—Carburetor idle adjusting screws; approximately 1¼ to 1 3/4 turns after screws are seated provides adjustment.

14—Carburetor accelerating pump needle adjustment; approximately 1 turn to left after screw is seated provides adjustment.

15—Carburetor float level inspection plug; adjust so gasoline level is 1/16" below bottom of inspection hole.

16—Carburetor high-speed jets; non-adjustable

17—Carburetor choke tube support connection

18—Inspection cover to read flywheel markings for ignition and valve timing

19—Pipe plug which can be removed to listen to explosions when adjusting carburetor. Adjustment should be made with four cylinders running. Four cylinders can be cut out by disconnecting high-tension wire at coil, or at primary connection P on distributor.

20—Carburetor combination air intake silencer and cleaner. During cold weather F is down, closing louvers D, and air is drawn through C, taking hot air off exhaust pipe. In warm weather F is up and louvers are open and air is drawn in at D. These louvers are arranged in such a manner that the normal air flow from front to rear below the car is reversed, thus causing the louvers to act as an inertia air cleaner. A wire mesh air cleaner is also provided in the unit. The pipe is not insulated with sound absorbing material, yet the system is highly effective as an air intake silencer for carburetor hiss. Adjustment for opening and closing louvers is at E.

21—Fuel pump. The fuel line is completely insulated against heat to prevent vapor lock (overheating of gasoline).

22—Oil pressure adjustment: 30 lbs. at 40 m.p.h. with oil hot, (using No. 30 S.A.E. oil). Turn adjusting plug to right to increase pressure.

23—Dual fan belt. Drives fan, generator and water pump. Adjust very tight, or so that a total deflection of belt will be 1 inch with 20-lb. scale pull. When renewing belt, always replace both.

Engine lubrication is of the force-feed type. Oil is forced by pressure from a positive gear-driven gear type pump through cored passage in crankcase to hollow crankshaft, to all main and connecting rod bearings, and through a rifle drilled camshaft to the six camshaft bearings. Oil is also distributed from main bearings through cored passages direct to each individual valve-lifter, also, to timing chain sprocket. Cylinder walls and piston pins are lubricated by a spray from metered hole in the top of lower part of connecting rod. Oil is filtered through a replaceable oil filter.

Valve clearance: .006" exhaust valves and .004" intake valves; engine hot. Temperature approximately 160°.

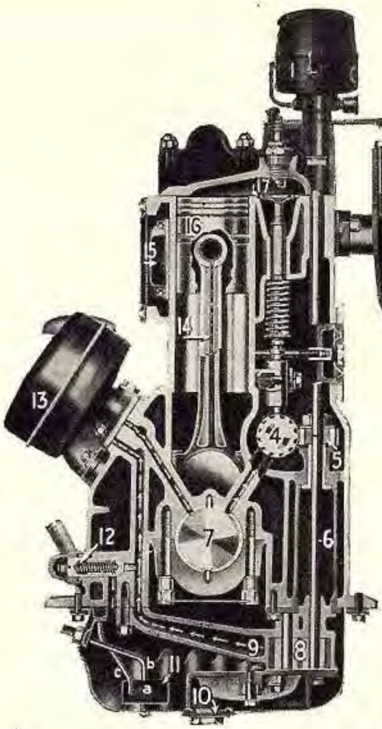
Valve timing: exhaust opens 40° BBC; closes 12° ATC. Intake opens 5° ATC; closes 45° ABC. Total intake period 220°; total exhaust period 232°.

To time valves: Adjust No. 1 intake to .010" clearance with piston on top dead center of compression stroke (this clearance necessary due to special cam design.) When engine is cranked, clearance will be taken up between valve-lifter and valve stem when line of marking on flywheel $\frac{\text{INTAKE OP}}{\text{1–8}}$ is directly under pointer when looking through inspection hole 18 in flywheel housing. Adjustment to be made when engine is cold. After this operation and after installing timing chain, adjust valve clearance as specified under valve clearance above.

To install timing chain: Remove hood, radiator and timing chain cover; remove cap screws in camshaft sprocket. Special tool used to center chain cover with crankshaft when replaced

Ignition timing: With distributor fully advanced, spark should occur when flywheel marking $\frac{\text{IGN}}{\text{4–5}}$ is directly under pointer. Then synchronize on $\frac{\text{ING}}{\text{1–8}}$. Time with stationary contact-breaker and synchronize with movable contact-breaker. Spark should occur 7° before top dead center. Points break every 45°.

[1] Model 43 power plant is similar, except it develops 125 h.p. with a 4 3/4" stroke and has a piston displacement of 366 cu. in.; helical timing gears are employed for camshaft drive instead of a silent timing chain, thus reversing the direction of the camshaft; a single ignition coil and other minor differences



Reo models "30–35" engine with eight **in-line, L-head type of cylinders and valves on the side** of cylinders, operated by **one camshaft on the side.** View shows the **full-force-feed oil circulation** system. The Reo is an example of one of the engines which use **cored** and gun-drilled passages to carry the oil to the bearings. A **hydrostatic oil-level gauge** on the instrument board registers the amount of oil in the oil pan by quarts.

Cylinder arrangement: vertical, eight-in-line, L-head, cast in one block and integral with crankcase, water-cooled, detachable head. **Valve arrangement:** poppet type valves on one side of cylinder with valves set vertical. **Camshaft drive:** from crankshaft by means of sprockets and silent timing chain; one camshaft on the side. **Names of parts follow.**

1—Timer-distributor

2—Exhaust manifold

3—Duplex intake manifold

4—Camshaft

5—Gear driven from camshaft

6—Timer-distributor and oil pump drive shaft

7—Crankshaft

8—Oil pump, gear type

9—Oil lead to oil filter and then to bearings through cored passages

10—Oil drain

11—Dash oil level indicator pan unit showing air chamber a, air tube b and air delivery tube c. (This is the KS oil level Telegage; see index.)

12—Oil relief valve

13—Oil filter

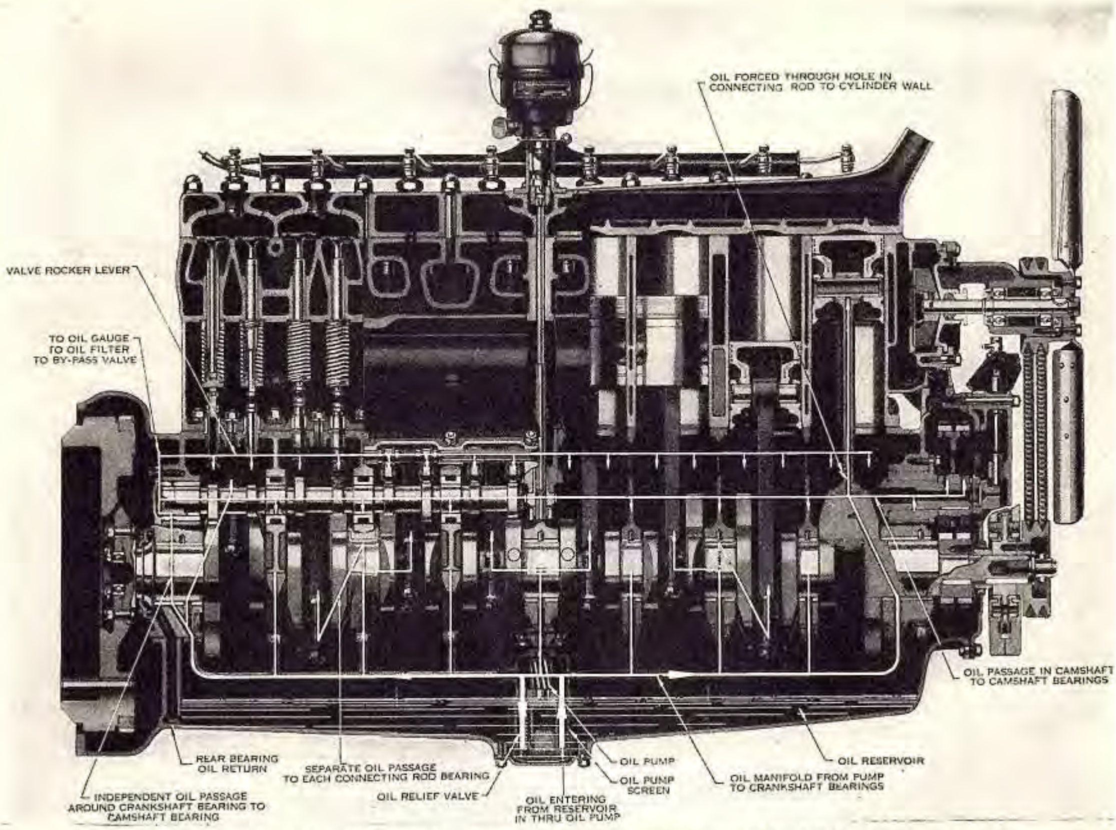
14—Oil passage up connecting rod (thus identifying the lubrication system as a full-force-feed system.)

15—Water distributor manifold

16—Piston

17—Valve head and seat

For **specifications** of Reo and other engines see pages 1055–1062.



Packard "eighth" series, eight-cylinder **in-line engine,** showing side sectional view of the **full-force-feed** oiling system.

Cylinder arrangement: eight-in-line, L-head, cast in one block, water-cooled; detachable head. **Valve arrangement:** poppet type valves on one side of cylinders. **Valve operation:** by one camshaft on the side. **Camshaft drive:** from crankshaft by means of sprockets and silent timing chain. For **specifications** of the Packard and other engines see pages 1055–1062.

Lubrication is termed a full-force-feed system according to the classifications of engine lubrication systems in this book.

Oil is drawn from crankcase reservoir through strainer located at the pump housing and is pumped to the main oil distributing manifold, which is supported from the crankshaft bearing caps.

From manifold oil is supplied to the nine main crankshaft bearings through holes drilled in the bearing caps. Independent oil passages in the crankshaft, leading from the main bearings, carry the oil to the connecting rod lower end bearings and through a hole drilled lengthwise in the connecting rod to the piston pins.

All camshaft bearings are lubricated by oil which is forced to the hollow camshaft from the oil lead running from the crankshaft rear bearing to the camshaft rear bearing.

After passing through the camshaft and lubricating the eight camshaft bearings, the oil passes out through holes in the camshaft sprocket onto the chain. The chain carries oil to the generator sprocket, which also has holes, allowing the oil to pass down to the generator shaft bearing. After these bearings are supplied with oil, the surplus drains back into the crankcase oil reservoir.

The cylinder walls are lubricated by oil spray thrown from the connecting rod lower end bearings. Holes drilled in the crankcase allow the oil mist to rise into the valve compartments and lubricate the valve mechanism. Baffle partitions located crosswise in the bottom of the crankcase retard surging of the oil.

Oil by-pass valve: In cold weather the crankcase oil becomes very thick and a short time elapses before it becomes thin enough to be thrown off from the connecting rods in sufficient quantities to thoroughly lubricate the cylinder walls. Unvaporized gasoline is also drawn into the combustion chambers by excessive use of the choke in starting, which tends to wash the oil from the cylinder walls.

These conditions are liable to cause a scuffing of the aluminum pistons. In order to prevent this occurrence and insure adequate lubrication of the pistons and cylinders when starting, an **oil by-pass valve** is located at the rear of the crankcase and is connected with the carburetor choke.

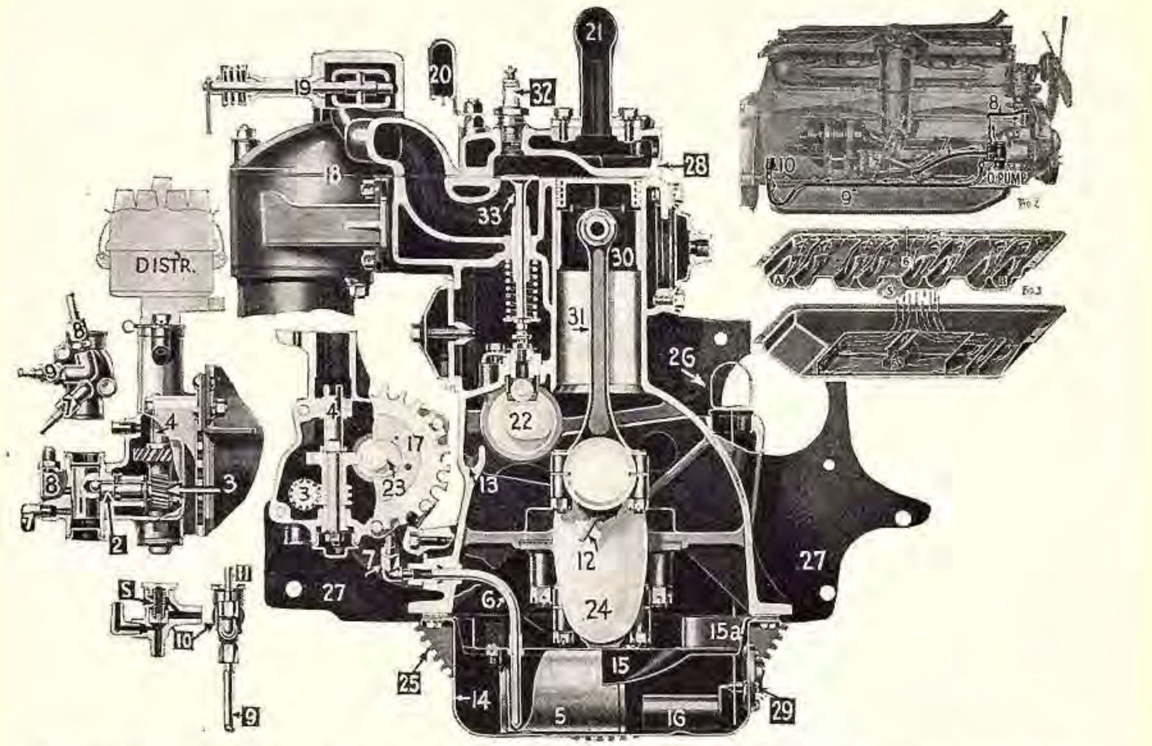
An oil manifold on the side of the cylinder block is connected to this valve and, **whenever the choke is pulled out, oil is pumped onto the skirt of each piston.** This auxiliary lubricator functions only when it is needed, which is during the starting and warming-up period. It is operated in conjunction with the choke and is shut off when the choke is pushed in.

An oil filter is mounted on the left side of the engine.

Oil pump: A gear pump is located at the lowest point of the crankcase and forces oil from this reservoir through the lubricating system as shown. The pump is operated by a shaft driven through a spiral gear on the camshaft.

The oil is strained before entering the pump through a cylindrical screen which surrounds the pump inlet. This strainer may be withdrawn and cleaned whenever necessary by first draining the oil from the crankcase and then removing the small plate on the bottom of the crankcase.

No adjustment of the pump gears is required, the **oil pressure** being **regulated** by the relief valve, which is controlled by the tension of a coiled spring. The inlet to the relief valve is connected with the pump discharge passage and any excess pressure causes the valve to open and allows the surplus oil to return to the inlet of the pump. Engine should be **warm** when checking oil pressure adjustment.



Hudson Great 8, eight cylinders **in-line** (1931) engine showing the **double flow circulating splash** oiling system. Front end sectional view.[1]

Cylinder arrangement: vertical, eight-in-line, L-head, cast in one block and integral with crankcase, water-cooled and forced circulation by pump driven by V-type fan belt, detachable head in two parts. **Valve arrangement:** poppet type valves on right side of cylinders with valves set vertical. **Valve operation:** by one camshaft on right side of engine. **Camshaft drive:** from crankshaft 24, by means of sprockets and silent timing chain. The same chain drives accessory shaft 23, which drives generator direct, also drives distributor shaft 4, through gears as shown.

The engine lubrication system on the Hudson Great 8 is termed **a double flow circulating splash system** and is not a force-feed pressure system. The **chief advantages claimed** for this system are: efficiency not affected by bearing wear, instantaneous lubrication in cold weather, agitation of oil keeps dilution to a minimum, and oil grooves in bearings are large enough to by-pass dirt or carbon particles without scoring bearings.

Oil pump circulation and cooling: A valveless oil pump of the oscillating type and of double capacity is mounted on the right side of the engine at the front, on the outside of engine. See Fig. 2. The plunger 1, Fig. 1, is operated by a shaft 2, driven by gears 3 from distributor shaft 4. This plunger draws oil through strainer 5 in lower half of oil pan or oil reservoir, through pipe 6, to an external pipe 7 leading to oil pump. Oil is forced out of pipe 8 to chain case at front of engine, and through pipe 9 to an oil distributor by-pass 10 at right rear of crankcase, thus a **double flow** of oil is alternately pumped through two independent feed lines from the oil pump.

From the by-pass 10, oil flows to the rear, or No. 8 trough, as shown at A, Fig. 3. The oil from the chain case flows to the front, or No. 1 trough B, Fig. 3. From these two points oil flows through a series of baffles and with the splash action of the connecting rod dippers 12, Fig. 1, the oil is transferred to the respective dipper troughs toward the center of engine, where it is lifted by splash and returned through C, Fig. 3, to the lower half of oil pan or oil reservoir 14.

By means of baffling, Fig. 3, the oil that returns into the lower oil pan is made to flow from the center toward the ends and then back toward the center before it can be picked up by the oil pump, thereby reducing the oil temperature 45 degrees, insuring a heavier protective film of cool oil to all bearings and operating parts.

Splash circulation: The pistons, piston pins and cylinder walls are lubricated by mist, caused by the splash of the connecting rod dippers 12, Fig. 1, in the troughs of the upper oil pan. The excess of oil drains into gutters 13 (there are 8 in Hudson and 4 in Essex) which are inclined and lead to the main bearings, thus conveying oil to a small reservoir above each main bearing, feeding them by gravity.

An oil-pressure gauge mounted on the instrument panel should show a pressure of from 3 to 4 pounds when engine is running. If oil gets below 2 lbs. it is probably due to oil being very thin, or to an air leak in one of the oil lines. Engine should be stopped and the cause found.

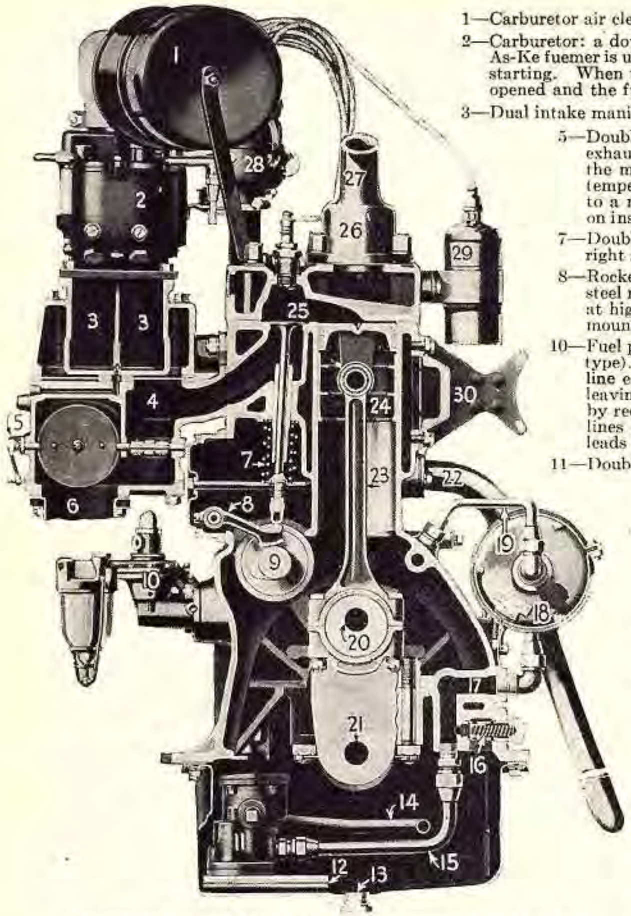
Oil pressure regulation. No adjustment is provided. In case of emergency, pressure can be increased by removing spring S shown in 10 of Fig. 1, and stretching it, but this is not a recommended practice; the cause should be found.

Amount of oil in oil reservoir of engine is shown on the **combination electric gauge** on instrument panel marked "Gasoline or Oil" when the ignition electrolock is turned "on," and the button between the ignition electrolock and choke control button is pushed in. **Bayonet type** oil gauge 26, also provided.

Add sufficient oil at filler every 250 miles to bring level to the full mark. Drain and refill reservoir every 2,500 miles, using eight quarts of medium heavy body oil. In summer use S.A.E. 30. In winter reduce viscosity to insure flow under temperatures encountered.

Names of parts not mentioned in text (see Fig. 1): 11, pipe to oil pressure gauge on instrument panel; 15, oil trough; 15a, distributing baffles in upper oil pan; 16, electric oil level gauge float; 17, chain eccentric adjusting plate; 18, exhaust and intake manifold; 19, carburetor heat control valve for heating the fuel. This valve is interconnected with throttle valve so that, as the speed is increased, less exhaust gas is diverted around the riser through which the fuel passes; 20, wiring conduit; 21, water outlet; 22, camshaft; 23, accessory shaft which drives generator direct and distributor shaft by means of gears. This shaft is driven by the same chain which drives camshaft; 24, crankshaft; 25, flywheel; 26, bayonet type oil level gauge; 27, rear engine support; 28, detachable cylinder head in two parts; 29, connection to float from combination electric oil and gasoline gauge; 30, piston; 31, connecting rod; 32, spark plug; 33, valve.

[1] **Also applies to the Essex Super-Six. Some of the differences of the Essex are:** six cylinders instead of eight; cylinder-head in one piece; cooling is thermo-syphon; has same compression ratio of 5.8 and same bore and stroke but with six cylinders; piston displacement is 175.28 cu. in., giving an actual developed horsepower of 60 at 3,300 r.p.m. N.A.C.C. hp. rating is 19.8. The Hudson Great 8 has a bore of 2 7/8", stroke of 4½" and piston displacement of 233.7 cu. in. N.A.C.C. hp. rating is 26.4.



Hupmobile, model H and U (1931), engine with **eight in-line, L-head type of cylinders and valves on the side** of cylinders, operated by one **camshaft on the side.** The Hupmobile is an example of an engine using **radiator cooling of the lubrication oil.**

1—Carburetor air cleaner and air intake silencer

2—Carburetor: a down-draft, twin type, model "DD-3" Stromberg. An As-Ke fuemer is used for vaporizing gasoline at the carburetor for quick starting. When the starter pedal is depressed, the throttle is slightly opened and the fuemer connected.

3—Dual intake manifold; 4—Exhaust passage.

5—Double butterfly heat control. Controls the passage of the exhaust gases around the intake manifold jacket for heating the mixture when engine is cold or below normal running temperature and to reduce the use of the carburetor choke to a minimum. It is connected with heat control button on instrument board; 6—Exhaust pipe.

7—Double valve springs to eliminate spring surge; wound right and left.

8—Rocker-arm type of valve-lifter made of chromium ball steel reducing the reciprocating weight, thus more efficient at high speeds. Note oil pressure passage; 9—Camshaft mounted in six bearings.

10—Fuel pump and filter (Stewart-Warner mechanically driven type). There are **two fuel-feed lines.** The **gasoline feed** line extends to within 1½" of the bottom of gasoline tank, leaving a 2-gallon reserve. The **reserve supply line** (marked by red paint) extends to bottom of gasoline tank. Both lines lead to a two-way cock from which point one line leads to fuel pump.

11—Double oil pump; 12—Oil pump intake screen; 13—Oil drain.

14—Outlet pipe for the oil cooling system; 15—Oil pipe lead from pump to oil filter.

16—Oil-pressure relief valve and regulator. Idling speed pressure adjustment is provided as well as for high speeds.

17—Lead to oil filter; 18—Direct line full flow oil filter; all oil passes through it going to the bearings.

19—Lead to oil distributing pipe and thence to main bearings and moving parts.

20—Large drilled passage through crankpins in crankshaft insures priming supply of oil when starting. Centrifugal force acting on a greater volume has a tendency to increase the pressure; 21—Same as 20.

22—Crankcase ventilator; carries off excess heat and injurious fumes from interior of engine.

23—Connecting rod; rifle drilled full length for oil-pressure feed to piston pin.

24—Piston. Light weight alloy split skirt type.

25—High-compression cylinder-head combustion chamber; compression ratio is 5.2 to 1.

26, 27—Water outlet.

28—Timer-distributor; semi-automatic advance; dual breaker-contacts; 29—Ignition coil.

30—A special designed water distributing manifold which keeps all cylinders equally cool. Cooling is forced circulation by pump.

Cylinder arrangement: vertical, eight-in-line, L-head, cast in one block and integral with crankcase, water-cooled, detachable head. **Valve arrangement:** poppet type valves on one side of cylinders with valves inclined. **Camshaft drive:** from crankshaft by means of sprockets and silent timing chain; one camshaft on the side.

Lubrication of engine is full-force-feed to all main, connecting rod, camshaft bearings, valve mechanism, and through drilled connecting rods to piston pins. There are **two oil pumps** in the oil pump housing 11. One **circulates the oil through the radiator** to be cooled. The other circulates oil under pressure for **engine lubrication** through the filter 18, and through pipe 19, to the main oil distributing manifold, thence to all bearings and moving parts as mentioned above. An oil-pressure relief valve 16 is provided in the line to prevent excess pressures being built up.

Oil cooling: As power is increased, oil temperatures generally go up, which lowers the oil viscosity beyond that which is considered thoroughly safe for main bearing loads. In the Hupmobile this condition is taken care of by partitioning off 2 inches of the water radiator core at the left side, E, Fig. 2, supplying this section with separate header tanks, top and bottom, and using it for cooling the oil. By this means oil temperatures at main bearings, it is claimed, have been reduced from a possible peak of 260° to below 200° F., under the severest conditions.

Oil is forced through this radiator core E under pressure by a separate pump, A, Fig. 2, the lead line B, however, having incorporated in it a pressure relief valve D to prevent excess pressures being built up in the core. The hot oil is taken into oil pump A from the upper level of the oil sump and cool oil is discharged through return pipe G at a lower level H in close proximity to the intake of the engine lubricating pump.

For **specifications** of the Hupmobile and other engines see pages 1055-1062. The Hupmobile employs a **helical gear free-wheeling transmission** on all models.

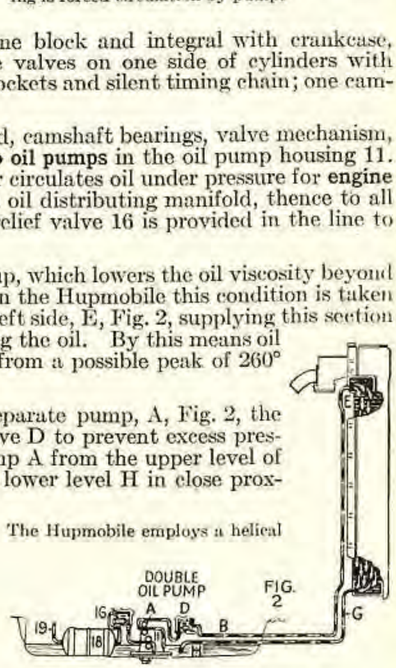
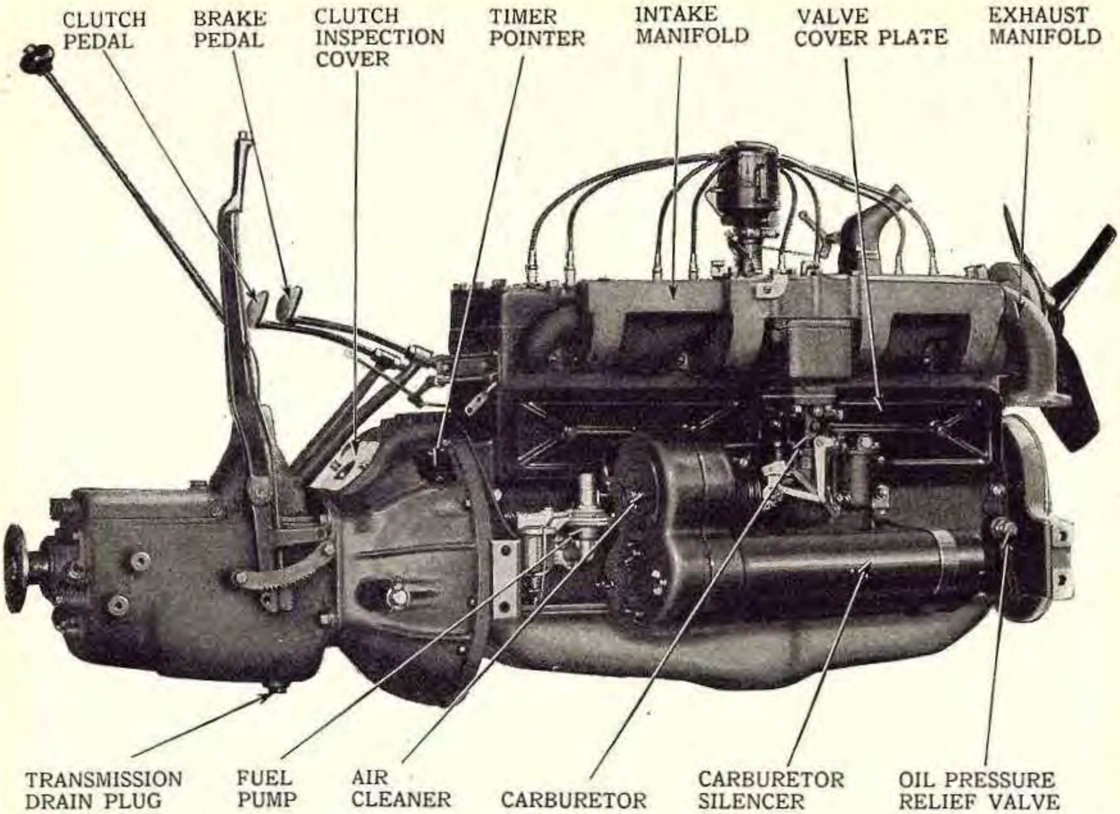
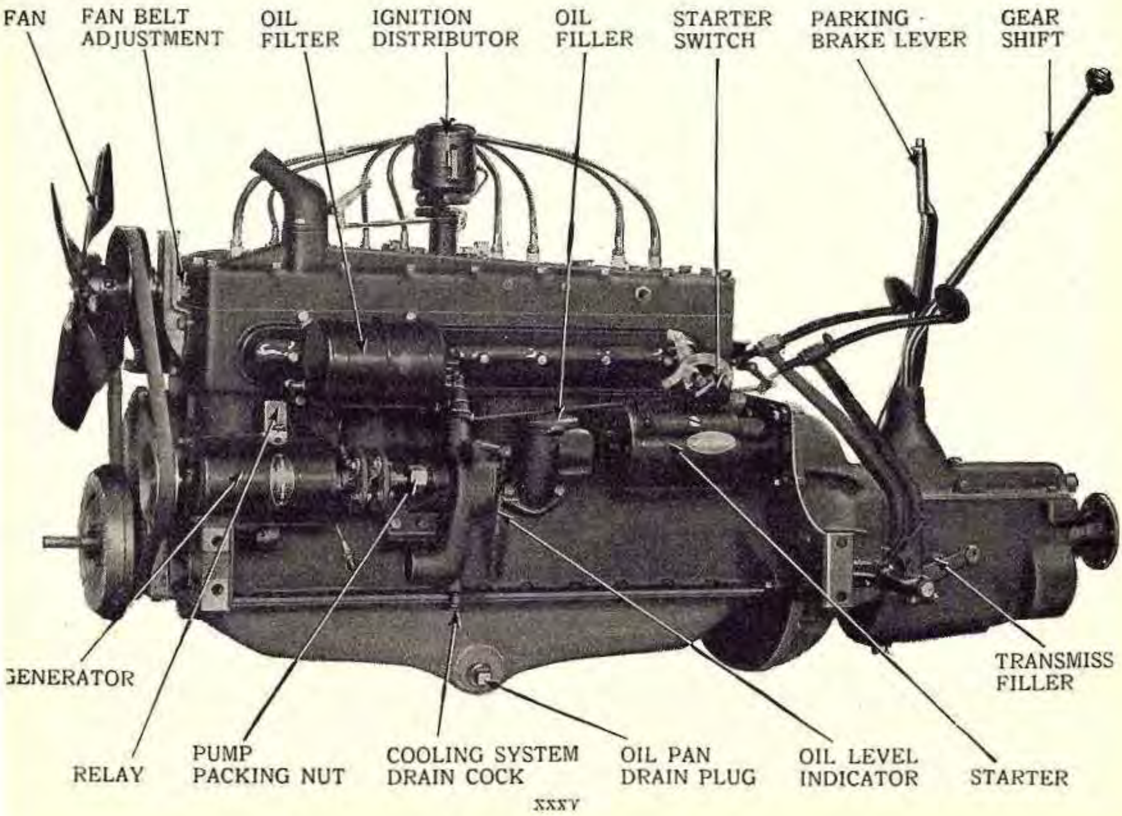


FIG. 2



The right and left side of an engine is to the right and left hands when sitting in one of the seats of the car. View shown above is the **right side** of the **Studebaker** Commander, series "70," eight **in-line,** L-head type of engine with clutch and transmission (**free-wheeling** type) combined in one unit, termed a **unit-power-plant.** The view shown below is the **left side** of the same engine. The **front cylinder** is No. 1, or cylinder nearest the radiator. For **specifications** of the Studebaker and other engines see pages 1055–1062.



ASSEMBLY OF THE AUTOMOBILE

The automobile is made up of four component units: the running gear, the power plant, the drive system, and the control members. **These parts are subdivided into other units,** and each of these will be treated separately farther on. Although the construction of the different makes of cars may vary, the principle or purpose of the parts remains the same.

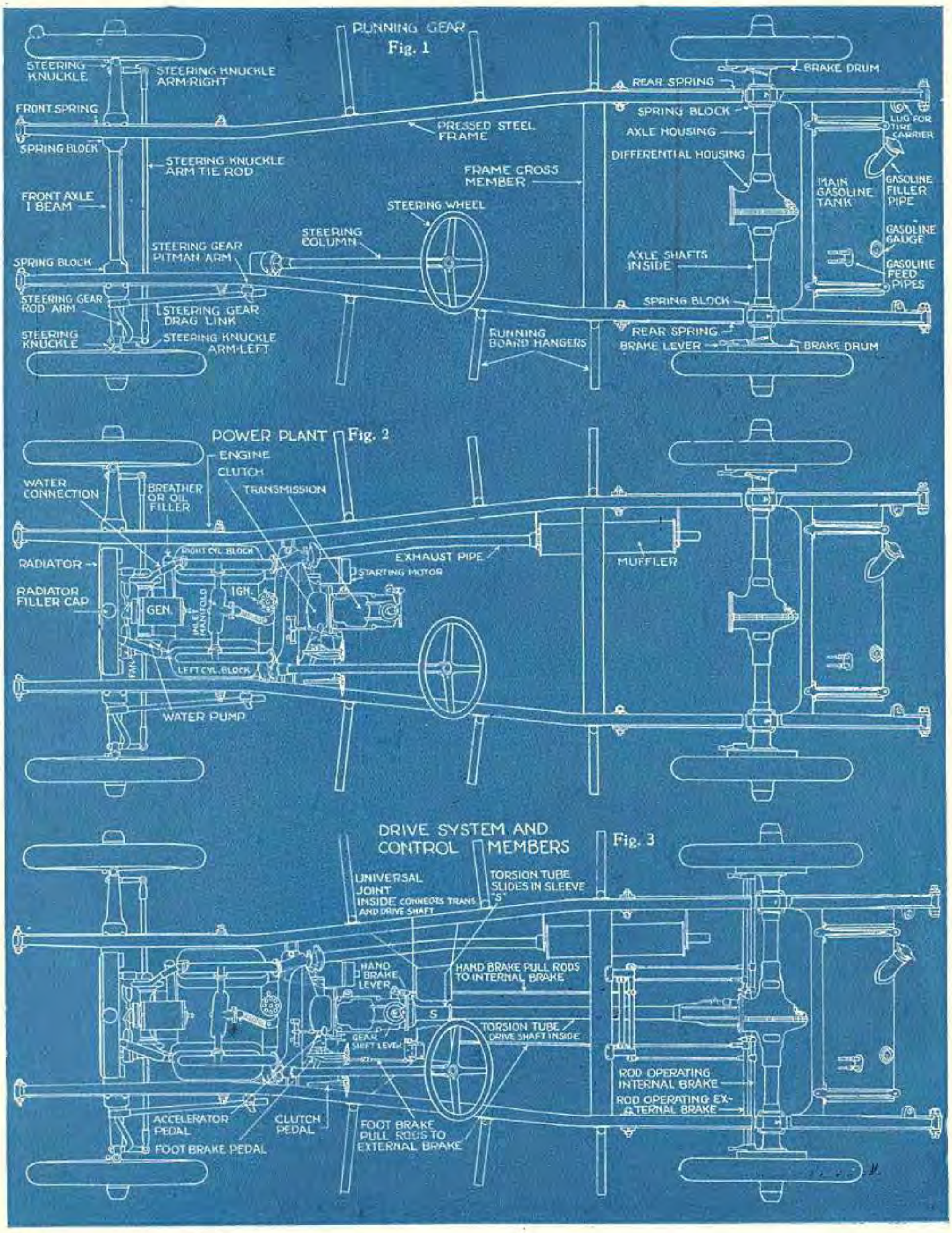


Fig. 1. **The running gear,** consisting of the front and rear axles, springs, pressed steel frame, and steering device. The main gasoline tank is shown attached.

Fig. 2. **The power plant** is now suspended on the frame of the running gear. The power plant in this example consists of an eight-cylinder V-type engine with the clutch, clutch housing, and transmission all mounted as one unit. It is, for this reason. termed a "unit power plant."

Fig. 3. The **drive system** is now attached. This consists of a propeller or drive shaft encased with a universal joint inside of the torsion tube. On many cars the drive or propeller shaft is not encased. The above is termed the **chassis.**

INSTRUCTION No. 1
ASSEMBLY OF THE AUTOMOBILE

GENERAL EXPLANATION

The Kinds of Motor Cars

There are three different kinds of motor cars: first, the gasoline motor car; secondly, the steam car; thirdly, the electric car.

The gasoline motor car is by far the most popular and it is with this that we are mainly going to deal.

The steam car, silent, smooth, and easy on tires is comparatively seldom seen.

The electric car, almost invariably in the form of a brougham or coupé, is heavily handicapped by being unable to run for more than a few hours without a fresh charge of electricity from its headquarters, and is in less general use. Our attention will be devoted to the car with the gasoline engine for the motive power.

The Component Parts of a Motor Car

A car may be made up as a whole of two distinct parts, the body and the chassis.

The body, which is the work of the body builder and which has been brought by him to a wonderful pitch of perfection, hardly concerns us, so we will unscrew the half-dozen or so bolts that secure it to the frame of the chassis and stand it to one side —for the present, at least—so that we can examine the chassis underneath.

The chassis is the entire car (Fig. 3, opposite), with the exception of the body. The chassis, for our purpose, must also be divided into its main parts as follows: the running gear, the power plant, the transmission system, the control system, the equipment and accessories.

The running gear consists of parts as follows: front and rear axles, wheels, springs, frame.

The power plant (Fig. 2, opposite), consists of parts as follows: the motor with its fuel system, the carburetion system, the ignition system, the cooling system, and the lubrication system.

The drive system consists of parts as follows: the clutch, the change-speed gears, the drive shaft with its universal joints, and the differential.

The control system consists of parts as follows: the steering device, the throttle and spark control, the hand levers, the foot pedals, and the brake system.

The construction of the parts of a motor car may vary, but their purpose is the same. While it is true there are hundreds of different firms making automobiles, they all employ in the construction of their cars the parts enumerated under the various headings. For instance, one manufacturer may suspend the power plant on the main frame, others use a sub-frame; some use a clutch of the cone type, others use a clutch of the multiple disk type—but they all use frames and they all use clutches. Farther on we shall explain the different constructions involved in these parts; but bear in mind that the fundamental principle or purpose of each part does not change.

As we progress, the reader will gain an idea of the different constructions of the component parts now in general use. For instance, there are two kinds of front axles in general use: the tubular type and the solid type. There are two types of construction of rear axles in general use: the live axle which revolves and is driven by a bevel gear and pinion, and the dead axle which does not revolve, but on which the wheels are driven by chain and sprocket; and so on, throughout the whole construction of a car.

It is now clear that if the reader masters the principle and purpose of these parts, it will be no difficult matter to understand the variations in construction, and when he has completed the study of the various constructions he will have gained sufficient knowledge to enable him to understand the construction of all cars.

Purpose of the Parts of the Running Gear

The **front wheels** run free on the axle, and guide the car. They are called the guiding wheels and are moved from side to side by means of a steering device, and the direction of the car is controlled in this manner. The rear wheels are revolved by the engine and drive the car.

The **front axle** is fitted with **steering knuckles** on which the guiding wheels run. These steering knuckles are moved by means of a rod which connects to the steering device. The front axle is fitted with **spring blocks** and spring clips which hold the springs in place.

The **rear axle** revolves. The housing over the axle is fitted with spring blocks and clips similar to the front axle, that is, if it is a "live" axle.

The **springs** act as a cushion and protect the machinery and the occupants of the car from undue vibration and shock. They also hold the frame.

The **frame** of an automobile is made of pressed steel and is the foundation which supports the power plant, change gears, levers, steering device, fuel tank, body, etc. Each part is bolted to the frame and is kept in proper relation to each of the other parts. The frame is usually suspended, with the springs resting on the axles, as shown in Fig. 1, and is called the "overhung" method of spring suspension. Sometimes the springs are fastened below the axles, called the "underslung" method of spring suspension. The front springs are usually "overhung" in either case.

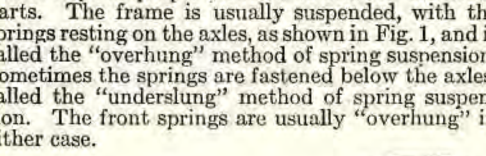


Fig. 1. In the upper illustration is shown the "overhung" spring suspension. Note that here both front and rear springs and also the frame are above the axles. In the lower illustration is shown the "underslung," a form of spring suspension in which the frame is above the axles, but with the springs below. A popular spring system is the cantilever.

A sub-frame is sometimes placed inside of the main frame to support the power and drive plant.

The **steering device** is usually attached to the frame. By turning the steering wheel, the car is guided through the control of the direction of the front wheels.

Brakes are fitted to automobiles for stopping or slowing down, and are usually fitted to a drum on the hubs of the rear wheels.

Purpose of the Parts of the Power Plant

The **engine** furnishes the power that drives the car. It is usually located in the front part of the frame, if it is a multiple-cylinder type of engine.

Suspension. Multiple cylinder engines usually have four, six, eight, or twelve cylinders. If of the double-cylinder opposed type, it is usually placed across the frame. If a multiple cylinder, "single-unit power plant," it is usually suspended at three or four points. This is called "three-point" or "four-point" suspension.

The **carburetor** mixes air with gasoline, and is connected direct to the intake pipe on the engine. The carburetor is connected to the feed pipe from the gravity tank.

The **gasoline tank** is usually placed under the seat or at the rear of the car, and gasoline is fed to the carburetor through a small pipe or by the vacuum system (as explained under Carburetion).

The **exhaust pipe** connects to the exhaust manifold and runs to the muffler, which is usually placed at the rear of the car. The exhaust pipe permits the burned gases to escape. The muffler, placed at the extreme end of the exhaust pipe, silences or muffles the noises from the explosions in the engine cylinders.

The **ignition system** is a part of the electric plant. It consists either of a storage battery and coil, dry cells and coil, a generator, or a magneto. The coil and battery electric system was formerly placed on the dash, while the magneto or generator is placed on the engine and is run by the cam shaft or crank shaft, through the medium of silent chains. The modern coil and battery system with a timer and distributor is now placed on the engine.

The **cooling system** consists of the radiator, water pipes, circulating pump and fan. The object of the cooling system is to keep the engine from getting too hot when the explosions take place inside of the cylinders.

The **lubrication system** of the engine is for the purpose of keeping the bearings and rings and other moving parts from wearing. This subject as well as the others mentioned will be treated separately, farther on.

Purpose of the Transmission and How the Rear Axle Shafts Are Revolved

The **transmission,** or the speed-change gears, is that part which transmits the power from the engine to the driving wheels through a system of speed-change gears.

A **clutch** is placed between the engine and the transmission; this permits the engine to run free, or, when "thrown in," connects the engine to the change-speed gears and drives the car. The clutch is operated by a foot pedal and is thrown "in" or "out" by the driver.

In a locomotive, the piston rods are connected direct with the wheels, through the medium of the cross-head, and connecting rod, so that when steam is applied the locomotive moves. **In an automobile,** the engine may be disconnected from the transmission by means of the clutch, so that the motion of the transmission or of the entire car may be stopped without stopping the engine.

Change-gear principle: When a bicyclist wants to race on a level track he gears his wheel up high, so that one revolution of the crank takes him the greatest possible distance. Yet if he takes this wheel on the road and encounters a hill, he must get off and walk or exert an extra lot of power—he needs a wheel geared lower.

In the same way, when an engine is required to do more than ordinary work, as climbing a hill, the transmission or change-speed gear contains from two to four changes of gears and helps out the engine by changing to the gear ratio requiring less motive power. It allows the car to move at various speeds while the speed of the engine is unchanged.

When in low gear, the engine makes quite a number of revolutions (10 or 15), while the wheels revolve once, which makes the car move forward slowly, but with considerable force, so that it can go up a steep hill or through sand or mud.

When in second or intermediate gear, the engine makes from 7 to 12 revolutions to one revolution of the wheels, which moves the car faster than the low or first change of gears, but with less force.

When in third or high gear, the engine makes from 3 to 5 revolutions to one revolution of the wheels, which gives the car high speed over good roads.

If the car should be going up a steep grade while on high gear, the work would be more than the engine could do, and it would stop unless one of the lower speeds were shifted in. There would then be considerably more pull on the wheels.

The operation of the change of gears is effected by means of a side or center lever. Change of gears can be made instantly. The transmission also contains a set of reverse gears, which, when thrown in, will reverse the motion of the car without reversing the motion of the engine.

The **transmission** may be connected so that it drives the wheels by the following methods: First, by a **driving shaft** (Fig. 2) connected to the rear axle, which it revolves by means of bevel gears, the wheels and axle turning together. This axle revolves and is called a "live" axle. Second, by a **single chain** (Fig. 3) connected to a "live" rear axle, the wheels and axle turning together (now obsolete).

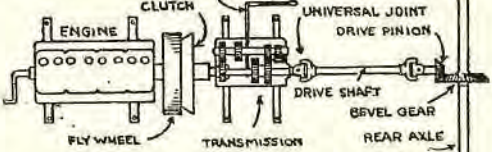


Fig. 2. Propeller or drive-shaft driving method.

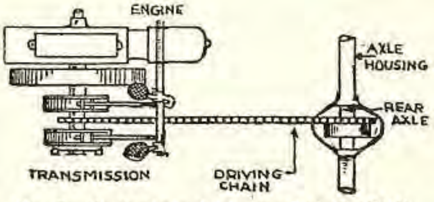


Fig. 3. Single-chain driving method (obsolete)

Third, by two **chains** (Fig. 4), one connected to each rear wheel, which run free on the axle, like a buggy. This is called a "dead" axle because it does not revolve.

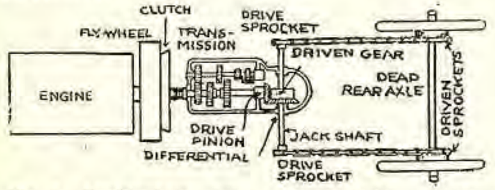


Fig. 4. Double-chain drive method. Seldom used on passenger-car automobiles, but used on trucks to a limited extent.

Drive System

The connection between the engine and the wheels is called the "drive system."

The **drive shaft** connects with the end of the transmission shaft by means of a universal joint. A universal joint is usually at the rear end connecting with the differential drive pinion shaft.

The **universal joints** permit the parts mounted on the rear axle to move up and down, thus preventing the movement of the axle from interfering with the drive of the car.

The **torque rod** is usually placed between the housing on the rear axle and the transmission case. The object of the torque rod (or torque arm, as it is now called) is to prevent the axle housing from twisting when the power or brakes are applied.

The **drive pinion** connects to the rear end of the drive shaft and drives the large bevel gear, which is connected to the differential.

The **front wheels** on an automobile run free on the axle. For this reason the outside wheel is able to revolve faster than the inside wheel when the car is turning a corner.

When a vehicle turns a corner, the outside wheels revolve faster than the inside wheels, because they travel a longer distance.

The **wheels in the rear** must do the same thing; if they were forced to revolve at the same speed, one would slide because it could not keep pace with the other.

When they run free on the axle, they would take care of this themselves, but as both are driven by the engine, the transmission or rear axle is fitted with a **differential,** at times erroneously called a **compensating gear.** This device is automatic, and permits the wheels to revolve at variable speeds, although both are driven by the engine.

Wheels

Tires made of rubber are fitted to the wheels to take up the vibrations that are too sudden for the springs to absorb.

The wheels of an automobile are smaller in diameter than horse-drawn vehicles, due principally to the fact that at the high speed the automobile travels, the wheels would have to be built entirely too heavy to sustain the strain. Automobile wheels must be very strong, because of the weight that they must support, and the strain that they are under. They are made of wood or wire (see illustrations, Figs. 5, 6, and 7).

Wheels are divided into three classes (Figs. 5, 6 and 7): wood, wire, and disk wheels, the latter type being made of wood or metal.

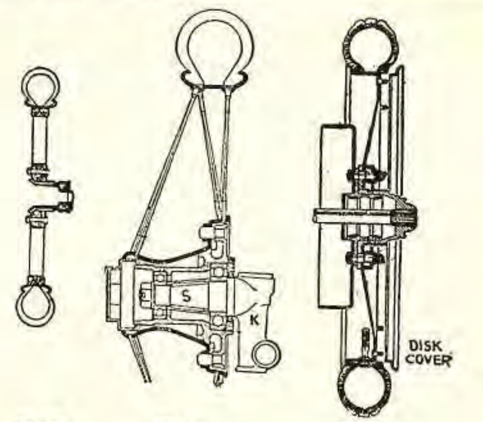


Fig. 5 Fig. 6 Fig. 7

Fig. 5. Sectional view of a "wood artillery" type of wheel
Fig. 6. Sectional view of a wire wheel.
Fig. 7. Sectional view of a disk wheel.

Wood Wheels

The wood wheel predominates, but does not possess the lasting qualities of metal, and costs less It is usually termed the "artillery type" (see Fig. 5) A steel rim is fitted over a wood felloe which holds the tire.

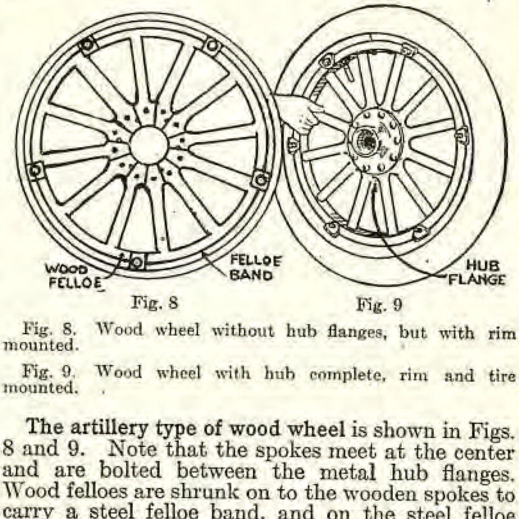


Fig. 8 Fig. 9

Fig. 8. Wood wheel without hub flanges, but with rim mounted.

Fig. 9. Wood wheel with hub complete, rim and tire mounted.

The artillery type of wood wheel is shown in Figs. 8 and 9. Note that the spokes meet at the center and are bolted between the metal hub flanges. Wood felloes are shrunk on to the wooden spokes to carry a steel felloe band, and on the steel felloe band, a steel rim is fitted to take the tire.

Easy riding qualities always have been claimed for the wire wheel, and this is largely due to the fact that the weight is centered in the hub and that the car weight is suspended from the top spokes, whereas in the wood wheel the weight is taken on the spokes at the bottom. Road shocks, therefore, are more readily transmitted through the wood spokes to the hub of the wheel than in a wire wheel. With a wire wheel, it is claimed, acceleration is much improved because the wheel is set in motion more easily by virtue of the lighter rim. In other words, the hub of a wire wheel, wherein is centered the weight of the wheel, literally wraps the spokes about it, and the spokes in turn pull the light rim after them.

If wood spokes become loose and squeak, the cause is usually due to dryness, from lack of washing. To remedy, swell the spokes by soaking well with water. If this fails, consult Index, "Wheels, spokes loose," where further discussions are referred to. When wood spokes break, new ones can be fitted. See also page 1138.

Wire Wheels

Wire wheels are lighter and are generally of the demountable type, that is, the wheels are demountable, but not the rim. The triple-spoke construction is the favored type.

When wire wheel spokes break or become loose, new ones can be inserted or loose ones tightened, similar to the treatment given to bicycle spokes. Hub caps on wire wheels must be tight, otherwise there will be an intermittent clicking noise.

The parts of a wire wheel are shown in Figs. 10 and 11. The rim on this wheel is of the clincher type. It usually is a straight-side type of rim.

Rims are not demountable on wire wheels (see Index under "Wire wheel rims)."

Wire wheels usually come in sets; five detachable and interchangeable wheels and five hubs make a set—four on the car and one spare, all detachable at the hub. All are usually interchangeable, front or rear, right or left. Unscrewing and replacing the hub cap is all that is necessary in changing the wheels. The spare wheel may be carried with the tire inflated ready for immediate attaching to any of the hub mountings. Wheels of this type are usually equipped with a built-in locking device, which adds safety without interference to the quick-change feature. See also Index under "Wire wheels."

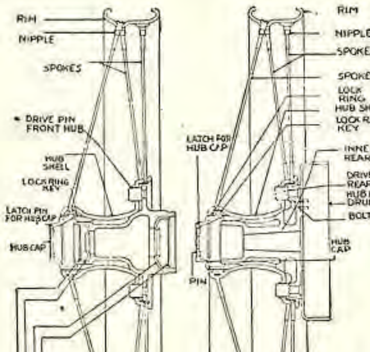


Fig. 10. Rear wire wheel with 30 x 3½ clincher rim
Note the brake drum attached to the hub flange.

Fig. 11. Front wire wheel with 30 x 3½ clincher rim
The parts are shown in the illustration.

Disk Wheels

Disk wheels are now popular and add considerably to the appearance of a car. The steel disk is usually dished and welded or bolted to the felloe, or the wheel is made in one piece with demountable rims. The hub is usually bolted to the disk. Disk wheels are also made of wood, but steel is used most.

Easier riding qualities, rapidity of wheel change, and the ability to keep them clean are some of the major things claimed for the disk wheel. See p. 602.

The wood disk wheel is made from the same grade of wood as used for airplane propellers and is laminated in such a way that the grain in each lamination runs in a different direction. These wheels are claimed to be of about the same weight as spoked wheels, but to have four times the lateral strength.

With many of the disk wheels it is not necessary to carry a spare, only a rim being necessary. On others the entire wheel is changed. See Index under "Disk-wheel rims."

Mud guards or fenders are always fitted over the wheels, to protect the car and occupants from the mud thrown by the wheels.

Meaning of Wheel Base and Tread or Track

The **wheel base** of an automobile is the distance (in inches) between the rear axles and the front axles. The long wheel base rides easier than a short wheel base. The frame must be sufficiently stiff, however, to prevent sagging from the weight resting on it. The wheel bases vary from 80 inches on runabouts to 144 inches on larger cars.

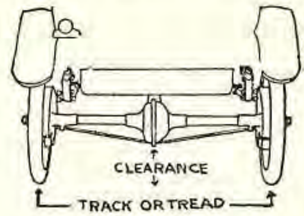


Fig. 12

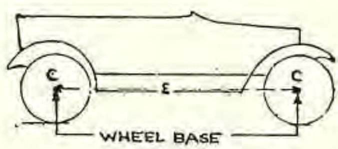


Fig. 13

The **tread** (also called track) is the distance the two wheels are apart measured parallel with the axle. The standard tread is 56 inches, measured from center to center.

The treads of wagons and carriages vary in different parts of the country. In the Southern states it is 60 inches; in the West 48, and in most of the other parts of the country 56 inches. Small, light cars are sometimes made with a smaller tread than 56 inches, but this is exceptional.

The **road clearance** is the distance from the lowest point of the car to the road. For rough roads, a greater clearance is required than for smooth roads, as a high place in the road would strike parts of the machinery that hung too low. The front axle, which is solid and heavy, is usually curved down in the center, so that it will be the first part of the car to strike a high place, thereby protecting the delicate parts behind it.

The Body

The automobile frame, with all parts of the running gear, the transmission, engine, and other parts of the mechanism, when it is without the body, is called the **chassis**. Different types of bodies may be attached to a chassis, and are generally fastened down with bolts.

Although there are many special makes of bodies which are given special names, the illustrations that follow will give the reader the names of the standard type of bodies.

AUTOMOBILE NOMENCLATURE

S. A. E. Standard

Index to Divisions

General

Where terms "front" and "rear" are used, "front" should always be toward the front end of the car. These terms are sometimes confused in regard to parts that are mounted on the dash. The front side of the dash is always that next the engine.

Where parts are numbered, No. 1 should be toward the front of the car. For instance, No. 1 cylinder is the one nearest the radiator (in conventional construction).

"Right" and "left" are to the right and left-hands when sitting in one of the seats of the car.

Studs, screws and bolts shall take names from parts they serve to hold in place, although they are assembled with other parts. For example, the cylinder stud is permanently screwed into the crankcase but holds the cylinder in place.

The name "engine" should be used rather than "motor" *to avoid confusion with electric motors.*

Division I—Cylinders

Group 1—Cylinders

Cylinder
L-head cylinder (valves on one side of cylinder)
T-head cylinder (valves on opposite sides of cylinder)
I-head cylinder (valves in cylinder-head)
F-head cylinder (one valve in head, other on side directly operated)
(Cast in block, not "cast en bloc")
(Cylinders of V-type engines should be numbered 1R, 1L, 2R, etc.)
Inlet-valve cap
Exhaust-valve cap
Valve-cap gasket
Cylinder-head
Cylinder-head gasket
Cylinder-head plug
Water-jacket top cover
Water-jacket top cover gasket
Water-jacket side (or front or rear) cover
Valve-spring cover
Valve-spring-cover gasket
Valve-spring-cover stud
Valve-stem guide
Priming-cup

Group 2—Crankcase

Crankcase
Barrel-type crankcase
Split-type crankcase (split horizontally, at or near center line of crankshaft)
Crankcase upper half
Crankcase lower half (used only when the lower half contains bearings. A crankcase of either barrel or split type, in which all the bearings are mounted directly on the part to which the cylinders are attached, is called a "crankcase," the terms "upper half" and "lower half" not being used)
Oil-pan (used for lower part of split-type or barrel-type crankcase, whether this serves as an oil-reservoir or not)
Oil-pan drain-cock (or -plug)
Breather
Oil-pan gasket
Crankshaft front bearing (upper half and lower half)
Crankshaft front bearing cap
Crankshaft bearing-cap stud (screw or bolt)
Crankshaft front bushing support (sometimes used in barrel-type crankcase)
Crankshaft rear bearing
Crankshaft rear bearing shims (other shims accordingly)
Crankshaft center bearing (if only three bearings or if all except end bearings are alike)
Crankshaft second bearing, etc. (if more than three bearings, for example, front bearing, second bearing, third bearing, fourth bearing, rear bearing)
Hand-hole cover
Hand-hole-cover gasket
Timing-gear cover
Timing-gear-cover gasket
Flywheel housing
Generator bracket (other brackets take name of part supported)

Group 3—Crankshaft

Crankshaft
Flywheel
Crankshaft timing-gear (or sprocket)
Crankshaft timing-gear key
Flywheel starter-gear
Crankshaft starter-sprocket
Flywheel bolts
Clutch-spring stud
Crankshaft starting jaw (or pin)
Crankshaft damper

Group 4—Starting-Crank

Starting-crank
Starting-crank jaw
Starting-crank shaft
Starting-crank shaft spring
Starting-crank handle
Starting-crank handle pin

Group 5—Connecting-Rods

Connecting-rod
Straight connecting-rod } V-type engine
Forked connecting-rod } V-type engine
Connecting-rod cap
Connecting-rod bushing (upper half and lower half)
Connecting-rod cap stud (or bolt)
Connecting-rod cap nut
Connecting-rod bearing shims
Connecting-rod dipper
Piston-pin bushing

Group 6—Pistons

Piston
Piston-pin
Piston-pin lock-screw (in connecting-rod or piston)
Piston-ring
Piston-ring groove

Division II—Valves

Group 1—Camshaft

Camshaft
Eccentric shaft
Camshaft timing-gear
Camshaft timing-gear key
Camshaft idler gear
Camshaft oil-pump gear
Camshaft ignition-distributor gear
Camshaft timer-drive gear
Exhaust cam
Inlet cam
Oil-pump eccentric (or cam)

Group 2—Valves

Valves should be numbered 1 Ex, 1 In, 2 Ex, 2 In, etc., according to the number of the cylinder. On V-type engines the numbers should be 1 REx, 1 LEx, etc.
Poppet valve
Inlet valve
Exhaust valve
Valve-spring
Valve-spring retainer
Valve-spring retainer lock
Valve-lifter
Valve-lifter guide
Valve-lifter-guide clamp
Valve-lifter roller
Valve-lifter-roller pin
Valve adjusting screw
Valve adjusting screw nut
Valve-rocker (either at cam or at overhead valve; if both, upper and lower)
Valve push-rod (intermediate between lifter and valve in I-head engine)

Division III—Cooling System

Group 1—Fan

Fan
Fan bracket
Fan spindle
Fan hub
Fan-hub bushing (or bearing)
Fan blades
Fan pulley
Fan belt
Fan driving pulley

Group 2—Radiator

Radiator Cores

Individual Fin and Tube Core.—An assembly of fluid tubes of any cross-sectional form to each of which are attached gills or fins of circular, square or other shape, each tube and its fin or fins forming a separate unit.

Continuous Fin and Tube Core.—An assembly of fluid tubes of any cross-sectional form, the tubes being joined together by radiating fins or plates common to all tubes or groups of tubes.

Ribbon Cellular Core.—A number of fluid passages made by joining metal ribbons at the edges and grouped to form a cellular structure. Parts of the cellular structure may be of formed or flat ribbon which is not a part of the fluid passage.

Air Tube Cellular Core.—An assembly of air tubes nested in such a way as to form fluid passages between the tubes, the passages being sealed at the ends of the tubes. In this type the fluid may flow transversely as well as vertically around the tubes.

Shell Type

Radiator Core and Tank Assembly

Radiator core
Radiator core header sheets
Radiator upper tank
Radiator filler-neck
Radiator filler-neck sleeve
Radiator filler-cap
Radiator filler-cap gasket
Radiator tie-rod fitting
Radiator baffle
Radiator inlet-fitting
Radiator lower tank
Radiator outlet fitting
Radiator drain flange
Radiator drain-cock
Radiator anchor stud or bolt
Radiator anchor stud or bolt plate
Radiator overflow tube
Radiator side bolting-member
Radiator shell anchorage clips

Radiator Shell

Radiator supports
Radiator anchor studs or bolts
Radiator support reenforcement
Radiator hinge-rod fitting
Radiator brace-rod fitting
Radiator hood-ledge liner strip
Radiator starting-crank hole cover

Cast Type

Radiator Assembly

Radiator clamping strips
Radiator clamping bolts or studs
Radiator overflow tube
Radiator sides
Radiator header gasket
Radiator hood-ledge liner strip

Radiator Core Assembly

Radiator core
Radiator core upper header
Radiator core lower header
Radiator core overflow jacket tube

Radiator Upper Tank

Radiator filler-cap
Radiator filler-cap gasket
Radiator filler-cap hinge-pin
Radiator filler-cap fastener
Radiator tie-rod fitting
Radiator hinge-rod fitting
Radiator inlet fitting
Radiator inlet gasket
Radiator inlet studs or cap-screws

Radiator Lower Tank

Radiator anchor studs or bolts
Radiator outlet fitting
Radiator outlet gasket
Radiator outlet studs or cap-screws
Radiator drain-cock or plug

Group 3—Water-Pump

Water-pump
Water-pump impeller
Water-pump-impeller key
Water-pump body (in case of doubt, body is member mounted on engine)
Water-pump cover
Water-pump shaft
Water-pump gland (part in contact with packing, whether threaded or not)
Water-pump gland nut (or screw, or other part used to compress gland)
Water-pump shaft gear
Water-pump shaft bushing (or bearing)
Water-pump packing

Group 4—Pipes and Hose

Engine water outlet
Engine water inlet
Radiator hose (upper and lower)
Radiator water-fitting (upper and lower)
Water-pump outlet pipe

Division IV—Fuel System

Group 1—Carbureter and Inlet Pipe

Carbureter
Inlet manifold (more than one connection to cylinder)
Inlet pipe (only one connection to cylinder)
Inlet manifold or pipe gaskets (at cylinder)
Carbureter gaskets

Group 2—Carbureter Control

(Throttle control rods will take names from parts they connect, shafts by location or arrangement, and brackets by parts they support)
Accelerator pedal
Accelerator pedal bracket
Accelerator pedal pin
Accelerator pedal rod
Accelerator pedal rod-end pin
Carbureter mixture hand-regulator
Carbureter choke

Group 3—Carbureter Air-heater

Carbureter air-heater
Carbureter hot-air pipe

Group 4—Fuel Tank

Fuel tank
Fuel reserve tank
Fuel gage
Fuel gage float
Fuel gage glass
Fuel tank outlet strainer
Fuel tank outlet (flange, fitting, etc.)
Fuel tank pressure flange (or fitting)

Group 5—Fuel Pipes and Feed Systems

Main fuel valve
Reserve fuel valve
Fuel pipe, main tank to auxiliary tank (or names of other parts connected)
Fuel pressure-pump (power pump)
Fuel hand-pump
Fuel pressure-gage pipe
Fuel pressure-gage tee
Fuel pressure pipe to tank
Fuel pressure-pump pipe
Fuel hand-pump pipe
Fuel hand-pump tee
Fuel pressure gage

Division V—Exhaust System

Group 1—Exhaust Manifold

Exhaust manifold
Exhaust manifold gasket

Group 2—Exhaust Pipe and Muffler

Muffler
Exhaust pipe (extends from exhaust manifold to muffler. If in more than one part name sections front and rear. For V-type engines with two pipes, name right and left).
Muffler outlet pipe

Division VI—Lubrication System

Group 1—Oil-pan or Reservoir

Oil-pan
Oil tank (when separate)
Oil-filler strainer
Oil-filler cap

Group 2—Oil-Pump

Oil-pump
Oil-pump body (any type of pump)
Oil-pump plunger
Oil-pump-plunger spring
Oil-pump inlet valve
Oil-pump outlet valve
Oil-pump shaft
Oil-pump shaft gear (outside the pump)
Oil-pump shaft gear (inside the pump)
Oil-pump following gear
Oil-pump cover

Group 3—Oil Pipes, Strainers, Gages

(Oil pipes should be named from the parts they connect, as "Oil-pump to pressure-gage pipe")
Circulating-oil strainer
Oil strainer cap
Sight feed
Sight-feed glass
Oil level-gage
Oil level-gage float
Oil level-gage glass
Oil pressure-gage

Division VII—Ignition System

Group 1—Spark-Plugs, Cables and Switches

Spark-plugs
Spark-plug cables (numbered according to cylinders)
Coil high-tension cable
(Low-tension cables should be named from the parts they connect, as: "Storage battery to ignition switch cable." In case of more than one conductor the cable should be designated as double, triple, etc.)
Ignition coil
Ignition switch
Dry cell (two or more cells make a dry battery)

Group 2—Battery Ignition Equipment

Ignition set
Ignition coil
Ignition switch
Timer-distributor
Breaker-arm
Movable breaker-contact
Stationary breaker-contact
Breaker-cam
Distributor rotor
Distributor-rotor brush
Distributor-rotor-electrode
Distributor cap
Timer-distributor shaft
Timer-distributor shaft gear
Ignition drive shaft
Ignition drive shaft gear
Manual-advance arm
Automatic-advance element
Ignition unit, magneto-base mounting

Group 3—Magneto

Magneto
Magneto distributor
Magneto breaker-box
Magneto breaker-arm
Magneto fixed breaker-point
Magneto breaker-arm point
Magneto distributor brush
Magneto-collector-ring brush
Magneto coupling, pump end
Magneto coupling, center member
Magneto coupling, magneto end

Division VIII—Starting and Generating Equipment

General

A single-unit system comprises a starter-generator
A separate-unit system comprises a generator and a starting motor separately mounted
A combined-unit system comprises a duplex starter-generator, an ignition-generator, or an ignition starter-generator
Direction of rotation is "clockwise" or "counter-clockwise" as determined by the driven shaft for magnetos, generators, starter-generators, and by the driving shaft for starting motors
Methods of mounting units are: flange, base, strap and sleeve

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Group 1—Generator

Generator
Generator main brush
Generator main brush-holder
Generator third brush
Generator third brush-holder
Generator field frame
Generator field fuse
Generator driving gear or sprocket
Generator shaft
Generator coupling (members as indicated under magneto coupling)

Group 2—Starting-Motor

Starting-motor
Starting-motor brush
Starting-motor brush-holder
Starting-motor pinion
Starting-motor intermediate gear
Starting-motor intermediate-gear shaft
Starting-motor intermediate pinion
Manual shift
Screw shift
Magnetic shift

Group 3—Starter-Generator (Parts covered by Division VIII, Groups 1 and 2)

Group 4—Ignition-Generator (Parts covered by Division VII, Group 2, and Division VIII, Group 1)

Group 5—Ignition-Starter-Generator (Parts covered by Division VII, Group 2, and Division VIII, Groups 1 and 2)

Group 6—Storage-Battery

Storage-battery
Terminal post
Case:
- Wood case
- Rubber case (monobloc)
- Composition case (monobloc)
- Tray (alkaline batteries only)
- Jar
- Cover
- Cell connector
- Vent plug (filling plug)

Group:
- Positive group
- Negative group

Plates:
- Positive plate
- Negative plate

Post strap:
- Positive strap
- Negative strap

Separators:
- Wood separator
- Rubber separator
- Wood separator with rubber retainer

Post gasket

Sealing nut

Separator hold-down

Battery hold-down

Handles:
- Plate handles
- Wire handles

Terminals:
- Clamp-lug terminal
- Taper-thimble terminal
- Cable terminal

Through-bolt

Jar spacer

Sealing compound

Electrolyte (not exceeding 1.300 in specific gravity)

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Division IX—Miscellaneous Electrical Equipment

Group 1—Lamps and Wiring

The sectioned illustration of an automobile head-lamp and its assembled parts (p. 673, 1935 S.A.E. Handbook) and the nomenclature for head-lamp parts (p. 674) were canceled by the Society in June 1935 because of obsolescence.

Head-Lamp.—A lighting unit on the front of a vehicle intended primarily to illuminate the road ahead of the vehicle.

Side-Lamps.[1]—A lighting unit mounted on either side of a vehicle and intended primarily as a marker to indicate the location of the vehicle.

Tail-Lamp.—A lighting unit used to indicate the rear end of a vehicle by means of a ruby light.

Backing-Lamp.—A lighting unit mounted on the rear end of a vehicle and intended to illuminate the road to the rear.

Spot-Lamp.—A lighting unit, mounted on a manually operated adjustable bracket, which has one focusing type reflector and one focusing type light source.

Instrument-Lamp.—A lighting unit mounted on the instrument board and intended to illuminate the instruments.

Dome-Lamp.—An interior lighting unit mounted in the top of a vehicle.

Panel-Lamp.—A lighting unit mounted either in the rear panel or in the corners of a closed vehicle.

Tonneau-Lamp.—A lighting unit mounted in the back of the front seat in open or closed vehicles.

Step-Lamp.—A lighting unit mounted on the exterior of a vehicle and intended primarily to illuminate the step or running-board.

Hood-Lamp.—A lighting unit mounted under the hood of a vehicle to illuminate the engine compartment.

Inspection-Lamp.—A portable lighting unit connected by an extension cord to the lighting system of a vehicle.

Inspection-lamp cord
Inspection-lamp plug
Inspection-lamp socket
Head-lamp support tie-rod
Tail-lamp support
(Cables and conduits should be named from the parts they connect)
Junction-box (wires not attached to box)
Junction-box screw
Junction-box cover
Fuse-box
Fuse-box cover
Fuse-block
Fuse-clip
Fuse (designated by name of part fed by circuit)
Junction panel

Group 2—Switches and Instruments

Lighting switch
Starting switch
Starting button
Ignition switch
Combined switch (Such as lighting-ignition)
Starting-ignition switch
Ammeter
Voltmeter
Volt-ammeter
Charging indicator
Cut-out relay
Cut-out relay contacts
Cut-out relay armature
Cut-out relay shunt coil
Cut-out relay series coil
Current regulator
Voltage regulator
Current-voltage regulator
Load-limit controller
Starting-switch contacts
Starting-switch contactor
Starting-switch plunger (lever or button)
Through-the-board mounting
Front-of-board mounting
Ground-return wiring
Insulated-return wiring

Group 3—Horn

Motor-operated horn
Vibrator horn
Hand horn
Horn projector
Horn diaphragm
Horn sound ratchet
Horn motor

Group 4—Miscellaneous

(Will include any additional electrical equipment such as electrical gearshift)

Division X—Clutch

General

Plate clutch (one plate clamped between two others)
Disc clutch (more than three discs)
Dry disc clutch
Lubricated disc clutch
Expanding clutch

Group 1—Clutching Parts

Disc Clutch

Clutch case (rotating member)
Clutch housing (non-rotating member)
Clutch cover
Clutch housing cover
Clutch driving disc
Clutch driven disc
Clutch driving disc stud
Clutch pressure plate (front and rear, if two—used on both disc and plate clutches)
Clutch driven spider (or drum—driving and driven if two)
Clutch cork-inserts
Clutch facing
Clutch-facing spring
Clutch spring
Clutch shaft (not attached to crankshaft)
Clutch-pilot bearing (in flywheel)

Plate Clutch

Clutch driven plate
Clutch driving plate
Clutch pressure levers
(Other parts as under disc clutch)

Group 2—Releasing Parts

Clutch release sleeve
Clutch release shoe or clutch release bearing housing
Clutch release bearing
Clutch release yoke
Clutch release yoke shaft
Clutch pedal shaft
Clutch pedal adjusting link
Clutch release yoke lever
Clutch pedal
Clutch pedal pad
Clutch brake
Clutch brake facing

Division XI—Transmission

Group 1—Transmission

Transmission case
Transmission case cover (when used as cover plate)
Transmission main drive gear
Transmission main drive gear bearing (front and rear if two)
Transmission main drive gear bearing adapter
Transmission main drive gear bearing retainer
Transmission second and high main shaft gear
Transmission low and reverse main shaft gear
Transmission main shaft
Transmission main shaft rear bearing
Transmission main shaft rear-bearing adapter
Transmission main shaft rear-bearing retainer
Transmission countershaft
Transmission countershaft gear cluster
Transmission countershaft drive gear } If a built-up cluster
Transmission countershaft second-speed gear }
Transmission countershaft low-speed gear }
Transmission countershaft reverse gear }
Transmission reverse idler-gear
Transmission reverse idler-gear bushing (or bearing)
Transmission reverse idler-gear shaft
Transmission main shaft pilot bushing (or bearing)
Transmission countershaft front bushing (or bearing)
Transmission countershaft front-bearing retainer
Transmission countershaft rear bushing (or bearing)
Transmission countershaft rear-bearing retainer

Group 2—Shifting Mechanism

Control housing (when used to mount control lever or control lever and shifting mechanism)
Control shift frame (when used to mount shifting mechanism only)
Transmission second and high shift fork
Transmission second and high shift rail
Transmission low and reverse shift fork
Transmission low and reverse shift rail
Transmission poppet
Transmission poppet spring
Transmission interlock rail

Group 3—Control

Control lever
Control-lever ball handle
Control-lever ball-handle insert
Control-lever fulcrum ball

Group 4—Propeller-Shaft

Propeller-shaft
Propeller-shaft front universal-joint (assembly—"propeller-shaft" may be omitted)
Propeller-shaft rear universal-joint (assembly—"propeller-shaft" may be omitted)
Propeller-shaft front bearing (with enclosed shaft)
Transmission shaft universal-joint flange (substitute name of any other shaft on which flange is mounted)
Universal-joint flange yoke
Universal-joint slip yoke
Universal-joint plain yoke
Universal-joint center cross (ring or block)
Universal-joint bearing bushing
Universal-joint pin (may be designated as long and short, straight and shoulder, etc.)
Universal-joint inner casing
Universal-joint outer casing
Universal-joint casing packing
Universal-joint casing nut
Universal-joint trunnion (for trunnion type joint)
Universal-joint trunnion block

Division XII—Rear Axle

General Types

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.

Plain Live Axle—Has shafts supported directly in bearings at center and at ends, carrying differential and road wheels.

(The plain live axle is practically obsolete.)

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. August 1916.

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 shaft for alignment. The wheel may be driven by a flange or a jaw clutch.

The full-floating axle shaft is relieved from all strains except torsion, and in one possible construction, tension and compression.

Types of Axle Drive

The different types of live axle can be driven by *Bevel Gear, Spiral Bevel Gear, Worm, Double-Reduction Gear* or *Single Chain.*

In other constructions, the rear wheels are driven by *Double Chains, Internal Gears,* or *Jointed Cross-Shaft.*

Group 1—Housing

Rear-axle housing (if one piece)
Right and left halves (if two pieces)
Bevel (or worm) gear housing } (if three pieces)
Right rear-axle tube }
Left rear-axle tube }
Rear-axle-housing cover
Differential carrier (bolted to housing)
Rear-axle spring-seat
Axle brake-shaft bracket (right and left)
Wheel brake-support, right and left ("wheel" may be omitted)
Wheel brake-shield ("wheel" may be omitted)

Group 2—Torque-Arm and Radius-Rod

Radius-rods

Group 3—Drive Pinion

Axle drive bevel pinion (or worm)
Axle drive pinion (or worm) shaft
Axle drive pinion front bearing
Axle drive pinion rear bearing
Axle drive pinion thrust-bearing
Axle drive pinion front bearing adjuster
Axle drive pinion front bearing adjuster lock
Axle drive pinion rear bearing adjuster
Axle drive pinion rear bearing adjuster lock
Axle drive pinion adjusting sleeve (containing both bearings)
Axle drive pinion (or worm) carrier

Group 4—Differential

Four-Pinion Two-Piece Case, Bevel Drive

Differential[1]
Bevel-drive pinion[2]
Bevel-drive gear
Differential case flange half
Differential case plain half
Differential bearing sleeve
Differential case bolt
Bevel-drive gear rivet or screw
Differential side gear
Differential spider pinion
Differential spider

Two-Pinion One-Piece Case, Bevel Drive

Differential[1]
Bevel-drive pinion[2]
Bevel-drive gear
Differential case
Differential bearing sleeve
Bevel-drive gear rivet or screw
Differential side gear
Differential cross-pin pinion
Differential cross-pin
Differential cross-pin lock
Differential side gear spacer

Worm-Gear Drive

Differential[1]
Worm[2]
Worm gear
Differential case, right hand
Differential case, left hand
Differential bearing sleeve
Differential case bolt
Worm-gear rivet or screw
Differential side gear
Differential pinion
Differential spider or cross-pin
Differential cross-pin lock
Differential side gear spacer

Group 5—Axle Shafts

Axle shaft (right and left)
Axle shaft wheel flange (or clutch)

[1] *Differential.*—A differential comprises a case and internal parts only.
[2] *Bevel-drive pinion or worm.*—A bevel-drive pinion or worm may be of either the "bored" or the "shaft" type. March 1923.

Division XIII—Braking System

General

In the following list of brake parts the terms "outer" and "inner" are used, being applicable to any case of two sets of brakes on the rear wheels. Where the brakes are external and internal these terms may be substituted for "outer" and "inner." Where one brake is located at the wheels and the other at the transmission the terms "wheel brake" and "transmission brake" should be substituted. With other concentric or side-by-side brakes the terms "outer" and "inner" should be retained, "outer" indicating in the latter case the ones nearer the wheels.

The list is made up for external contracting and internal expanding brakes. If both brakes are of one type the necessary changes will be obvious. The designation of brake parts on the rear axle as foot-brake or hand-brake parts, or by equivalent terms, is too remote to be clear, especially in the case of stock axles whose brakes may be connected either way according to chassis design. Nearly the same condition prevails in regard to designating parts on the chassis according to whether they are connected to the inner or outer brakes at the axle.

The terms "service brake" and "emergency brake" should not be used. Better designations are "foot brake" and "hand brake"; or if both brakes are foot-operated, "right foot-brake" and "left foot-brake."

Group 1—Outer Brake

Outer brake band
Outer brake band lining
Outer brake band adjusting nut (yoke, etc.)
Outer brake band lever
Outer brake lever shaft
Outer brake shaft inner end lever
Outer brake shaft outer end lever

Group 2—Inner Brake

Inner brake shoe (or band)
Inner brake shoe (or band) lining
Inner brake toggle (link, etc.)
Inner brake toggle lever
Inner brake toggle shaft
Inner brake cam
Inner brake camshaft
Inner brake camshaft (or toggle shaft) lever

Group 3—Pedal (or outer) Brake Control

Outer brake rod
Outer brake rod yoke
Outer brake intermediate shaft (or tube)—right and left
Outer brake intermediate shaft (or tube)—right lever
Outer brake intermediate shaft (or tube)—left lever
Outer brake intermediate shaft (or tube)—center lever
Outer brake right equalizer lever
Outer brake left equalizer lever
Outer brake equalizer
Brake pedal
Brake pedal rod
Brake pedal rod yoke
Brake pedal pad
Brake pedal shaft

Group 4—Hand (or inner) Brake Control

Inner brake rod
Inner brake rod yoke
Inner brake intermediate shaft (or tube)—right and left
Inner brake intermediate shaft (or tube)—right lever
Inner brake intermediate shaft (or tube)—left lever
Inner brake intermediate shaft (or tube)—center lever
Inner brake right equalizer lever
Inner brake left equalizer lever
Inner brake equalizer
Brake hand lever rod
Brake hand lever rod yoke
Brake hand lever
Brake lever or sector
Brake lever latch
Brake-latch spring
Brake-latch button
Brake-latch spoon
Brake-latch rod

Division XIV—Front Axle and Steering

Group 1—Axle Center

Front axle center
Front spring seats
Front axle bushing

Group 2—Steering-Knuckles

Right steering-knuckle
Left steering-knuckle
Steering-knuckle bushing (upper and lower)
Steering-knuckle pivot
Steering-knuckle-pivot nut
Steering-knuckle thrust-bearing
Right steering-knuckle arm
Left steering-knuckle arm
Steering-knuckle gear rod arm

Group 3—Steering-Rods

Steering-knuckle tie-rod
Steering-knuckle tie-rod end
Steering-knuckle tie-rod clamp bolt
Steering-knuckle tie-rod pin
Steering-gear connecting-rod

Group 4—Steering-Gear

Steering-gear case
Steering-gear-case cover
Steering-gear bracket
Steering-gear arm
Steering-gear shaft (if separate from sector or other operating member)
Steering-wheel rim
Steering-wheel spider
Steering-wheel tube (or shaft)
Spark and throttle sector
Spark and throttle sector tube
Spark hand-lever
Spark hand-lever tube (or rod)
Throttle hand-lever
Throttle hand-lever tube (or rod)
Steering-column tube (stationary)
Steering-column cowl (or dash or floor) bracket

The various bushings in the steering-column take names from parts to which they are permanently fitted, being further distinguished, as upper and lower, inner and outer, if necessary. Bushings in the steering-gear case take names from the worm and sector or other main operating parts which they support, as: Steering-gear worm upper bushing; although the steering-wheel tube may be the member which turns inside the bushing.

Steering worm
Steering-worm sector (or gear) (worm and sector gear)
Steering-worm shaft

Division XV—Wheels

Group 1—Front Wheels

Front wheel felloe
Front wheel felloe band
Front wheel rim
Rim bolts
Rim clamps
Front wheel hub
Front wheel hub-flanges
Front wheel hub-cap
Front wheel outer bearing
Front wheel outer bearing inner race
Front wheel outer bearing outer race
Front wheel outer bearing balls
Front wheel outer bearing ball retainer
Front wheel outer bearing rollers
Front wheel outer bearing roller cage
Front wheel inner bearing (parts same as outer bearing)
Front wheel bearing spacer
Front wheel bearing nut
Front wheel bearing lock nut
Front wheel bearing locking washer
Front wheel brake-drums (if front wheel brakes are used)

Group 2—Rear Wheels

Rear wheel hub
Rear wheel hub-flange
Rear wheel hub-cap
Rear wheel outer bearing
Rear wheel inner bearing
Rear wheel brake-drum
(Other parts named like front wheel parts)

Division XVI—Frame and Springs

Group 1—Frame

Frame side member (right and left)
Front cross member
Rear cross member
Center cross member
(As above if only three cross members, as below if more than three)
First cross member
Second cross member, etc.
Sub-frame side member (right and left)
Sub-frame cross member (front and rear)
Right rear gusset (upper and lower)
(Gussets at other cross members named according to member)

Group 2—Frame Brackets and Sockets

Front spring front bracket (right and left)
Front spring rear bracket (right and left)
Rear spring front bracket (right and left)
Rear spring rear bracket (right and left)
Running-board bracket (front, right, etc., if not duplicates)
Running-board bracket brace
Engine front support bracket
Engine rear support bracket
Torque-arm bracket
Radius-rod bracket

Group 3—Front Springs[1]

Front spring (right and left)
Front spring shackle
Front spring shackle-bolt (upper and lower)
Front spring front bolt
Front spring rebound-clip
Front spring seat
Front spring seat pad
Front spring clip
Front spring clip plate
Front spring center-bolt

Group 4—Rear Springs[1]

Rear springs (upper and lower for elliptic and three-quarter elliptic)
Rear spring pivot bolt (or pin) } (for half-elliptic cantilever spring)
Rear spring pivot seat }
Rear spring double shackle } (for platform spring)
Rear side spring }
Cross spring }
(Other parts as for front springs)

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Division XVII—Hood, Fenders and Shields

Group 1—Hood

Hood
Hood sill
Hood handle
Hood fastener
Hood fastener bracket (spring, lever, etc.)

Group 2—Engine Shield

Engine shield
Engine shield fastener
Engine shield bracket (spring, etc.)

Group 3—Fenders and Running-boards

Running-board (right and left)
Running-board linoleum covering
Running-board outside binding
Running-board inside binding
Running-board front binding
Running-board rear binding
Running-board shield (right and left)
Right front fender
Left front fender
Right rear fender
Left rear fender
Fender support socket
Right front fender front support
Right front fender rear support
(Other fender supports accordingly)

Group 4—Windshield[1]

[1] Names for windshield parts have not been selected. January 1930

Division XIX—Accessories

Group 1—Speedometer

Group 2—Tire-pump

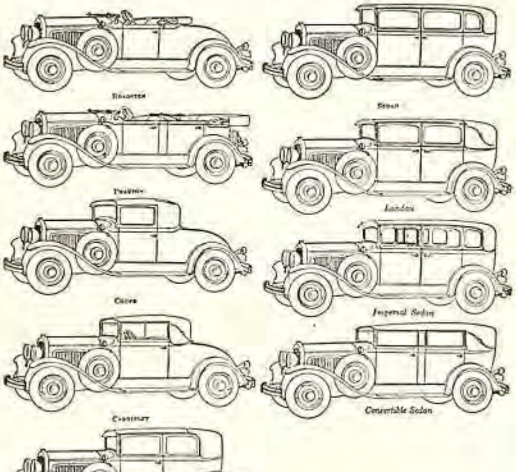
Tire-pump
Tire-pump driving gear
Tire-pump shaft gear
Tire-pump idler gear

[1] Side-lamps cover such types as are generally known as bullet, cowl, fender or parking, pillar or windshield lamps.

The S.A.E. Standard for Automobile Nomenclature was developed by the Nomenclature Division, being adopted originally by the Society in August, 1916. The various parts have been revised as follows: Division I, Groups 2 and 6—By the Engine Division, March, 1926: Division I, Group 3—By the Gasoline Engine Division, January, 1939: Division II, Group 1—By the Electrical Equipment Division, March, 1926: Division III, Group 1—By the Engine Division, March, 1926: Division III, Group 2—By the Radiator Division, September, 1926: Division VII—By the Electrical Equipment Division, March, 1926: Division VIII, Group 6—By the Storage-Battery Division, March, 1926: Division IX, Group 1—By the Lighting Division, September, 1926; Division IX, Group 2—By the Electrical Equipment Division, March, 1926: Division X—By the Transmission Division, January, 1927 Division XI, Group 1—By the Transmission Division, September, 1926: Division XII, Group 4—By the Transmission Division, March, 1927: Division XIII, Group 4—By the Transmission Division, September, 1926: Division XV—By the Axle & Wheels Division, January, 1927. Division XVIII, Types of Body—By the Passenger-Car Division, January, 1930: Body-parts nomenclature by the Passenger-Car Division, February, 1929. (See page 5 of this book for "*Body Nomenclature.*")

Body Nomenclature

Types of body following is reprinted from the S. A. E. Handbook, issued by the Society of Automotive Engineers, Inc., New York City, N.Y. Revised by the Passenger-Car Division and approved by the Standards Committee, January, 1930.



Roadster.—An open-type body having one cross seat. A compartment in the rear deck accommodates business equipment or luggage. The top is of weatherproof fabric and may be folded. Equipment includes removable side-curtains and provision is usually made for folding the windshield.

Sport Roadster.—The rear deck is provided with a rumble seat accommodating additional passengers. Equipment frequently includes golf locker in the rear deck. In other respects this type is similar to the Roadster.

Phaeton.—An open-type body with two cross seats. usually accommodating five passengers. Folding-type windshield and folding weatherproof fabric top with removable side-curtains are usual equipment.

The seven-passenger Phaeton is generally the same except the additional length necessary for the auxiliary seats in the tonneau.

Sport and Imperial Phaeton.—Similar to the Phaeton in general type with various refinements or extra equipment. Wire wheels, trunk rack and ultra-modish finish are common attributes of this type. The Imperial type is accepted to indicate a tonneau windshield.

Touring Car.—Generally longer bodies than the Phaeton, permitting the use of auxiliary seats in the tonneau, for the accommodation of additional passengers. In other respects similar to the Phaeton.

Coupe.—An enclosed single-compartment body. Passenger capacity varies with arrangement of seats or the length of wheelbase. Two doors are provided; back panels and top are permanent and the rear deck accommodates a luggage compartment. Small coupes have a single cross seat accommodating two or three passengers, while the larger coupes frequently provide a staggered seating arrangement which, with an auxiliary seat beside the driver, may accommodate as many as five passengers. The larger types are also generally provided with quarter windows.

Sport Coupe.—A Coupe especially adapted for sport use, with fixed top, frequently of fabric material with landau joints. The rear deck is usually provided with a rumble seat accommodating additional passengers. Various refinements or extra equipment are frequently provided such as ultra-modish finish, wire wheels, and golf club locker in rear deck. In other respects this type is similar to the Coupe.

Cabriolet or Convertible Coupe.—Similar to the Sport Coupe with provision for converting to an open-type. The rumble seat and fender wells are usual but not restrictive features of this type.

Coach.—An enclosed two-door type body, with permanent back panels and top. A full-width cross seat in the tonneau accommodates three passengers. Two separate seats in the front accommodate the driver and an additional passenger, and by folding down, allow unobstructed exit or entrance to rear-seat passengers. Fender wells and trunk racks are frequently provided but are not inherent features of this type.

Sedan.—An inclosed four-door type of body with permanent back panels and top. A full-width cross seat in front and rear. Passenger capacity from five to seven according to wheel-base or body design. Auxiliary folding seats in rear for accommodation of extra passengers in the larger types. May or may not be provided with windows in the rear quarter.

Variations from the standard Sedan type may be variously designated as: 2-Window Sedan, 3-Window Sedan, Club-Sedan, Close-Coupled Sedan, Landaulet Sedan, etc., but there is not sufficient uniformity in these variations to justify specific standardization.

Landau.—A closed-type body with provision for opening or folding the rear quarter, by the use of landau joints. This usually precludes the use of quarter windows.

Landaulet Sedan.—Similar to the Landau Sedan in appearance but made with a stationary rear quarter. Landau joints are mounted on the rear quarter but are non-operative.

Imperial Sedan.—A drop or sliding glass partition between the driver's compartment and the tonneau is the distinguishing feature between this type and the Sedan, which it resembles in all other essential respects.

Town Car.—Same as Imperial Sedan with or without rear-quarter windows and without a fixed roof over front compartment. A folding or removable weatherproof fabric top over the front compartment is a usual but not restrictive feature of this type.

Convertible Sedan.—Similar to Sedan type with provisions for converting to an open-type car. Both the all-weather feature and the top are convertible.

The distinction between the **Delivery Wagon** and **Truck** is in size and weight. The delivery wagon is usually a shaft-driven solid, or pneumatic-tired car, whereas the truck is a double-chain or shaft-driven solid or pneumatic-tired, heavier machine (not S.A.E.).

INSTRUCTION No. 2

DRIVE METHODS: Drive-Gear Reduction

VARIOUS DRIVE METHODS

The power from the engine is transmitted through the transmission; and is applied to the propelling of the car by those parts called the drive.

There are three methods of transmitting power to rear-axle shafts: the **double-chain drive**, requiring a "dead" rear axle; the **single-chain drive** (seldom used); and the **shaft or propeller-shaft drive**, which requires a "live" rear axle.

There are seven drive methods: single chain (obsolete); **double chain; internal gear** (page 929); **double reduction** (page 925); **double reduction internal** (page 933); **worm** (pages 17, 914, 920, 954, 956); **bevel gear** (Fig. 3 below). The last mentioned is the type generally used on passenger cars.

Double-Chain Drive

The double-chain drive is seldom used on pleasure cars, but is used quite extensively on trucks. Trucks use chains, because trucks carry heavy loads and often have solid "dead" axles.

When, as is usual in cars of this type of drive, the engine is in front, the crank shaft is parallel to the sides of the car, and therefore at right angles to the rear axle. The power developed at the crank shaft must therefore be turned at right angles in order to apply it to the wheels (see Fig. 1). This is done by means of bevel gears, which are in the transmission case.

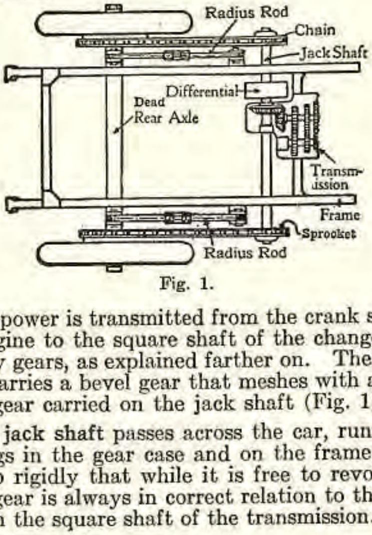


Fig. 1.

The power is transmitted from the crank shaft of the engine to the square shaft of the change-speed gear by gears, as explained farther on. The square shaft carries a bevel gear that meshes with another bevel gear carried on the jack shaft (Fig. 1).

The jack shaft passes across the car, running in bearings in the gear case and on the frame. It is held so rigidly that while it is free to revolve, its bevel gear is always in correct relation to the bevel gear on the square shaft of the transmission.

The jack shaft is in two sections, between the inner ends of which the differential is placed, the differential, of course, being beside the bevel gear that drives the jack shaft.

At each end of the jack shaft, outside of the frame, is a sprocket which is in line with a corresponding sprocket on the rear wheel of that side (Fig. 2). Over each pair of sprockets passes a chain that transmits the revolutions of the jack shaft to the wheels which run loose on the ends of the dead axle.

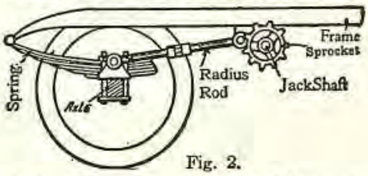


Fig. 2.

The chain most commonly used for automobiles is called a "roller chain." It consists of side pieces in pairs, each pair being secured to the adjoining pairs by rivets passing from side to side. On these rivets are steel rollers which revolve as they touch the sprockets. These rollers fit the space between the teeth of the sprockets, and as the chain bends around the sprockets the rollers are stationary, while the rivets turn inside of them.

To give the best service, the chain must run true; that is, the sprockets over which they run must be in line, the links of the chain must fit the teeth, and the sprockets must be exactly circular. If the sprockets are out of line, the chain will be forced to bend sideways. If the links do not fit the teeth, there will be a grinding that will cause rapid wear, and there will be danger of the chain jumping off. If the sprockets are not exactly circular, during one part of the revolution the chain will be slack, and during the other part will be drawn tight, stretching it.

The double-chain drive has advantages on heavy cars. By its use the weight of the car is carried by a "solid" or "dead" axle, which is lighter than a divided "live" axle of the same strength can be. If a solid axle is bent, it can be straightened easily, while it requires an expert mechanic to straighten a bent live axle.

The disadvantages of double-chain drive are the difficulty of properly lubricating the chains, their rapid wear in consequence, and the liability of chains to stretch and jump off the sprockets.

The worm-gear drive for trucks, with substantial axles of the "live" type, are now considered superior to the double-chain drive.

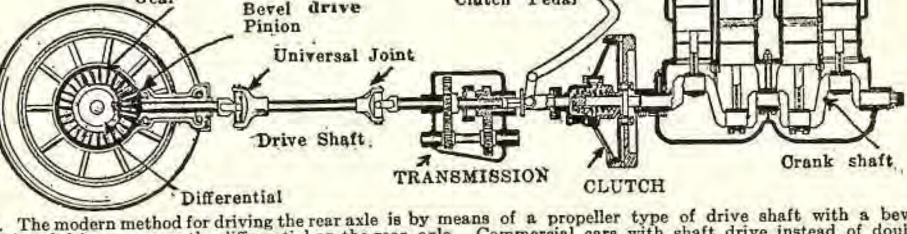


Fig. 3. The modern method for driving the rear axle is by means of a propeller type of drive shaft with a bevel drive pinion and bevel-driven gear on the differential on the rear axle. Commercial cars with shaft drive instead of double-chain drive often use the worm drive.

Propeller or Shaft Drive

In this type, a shaft connects with the square main shaft of the transmission and is extended to the rear axle, where it ends with a small bevel gear called the **drive or driving pinion.** See **Figs. 3, 4, and page 28.**

This driving pinion meshes with a bevel gear on the differential housing that is mounted between the inner ends of the two parts of the live rear axle, called the **axle-driven** gear, or differential "ring gear," or "master gear," "crown wheel," etc.

The propeller or driving shaft always has one, and sometimes two, universal joints in between the gear box and drive pinion on rear end, so that the moving of the rear end, as the axle receives the jolts of a rough road, does not affect its driving.

The drive and driven gears are contained within a casing or housing that supports the bearings for the parts of the axle and also the end of the driving shaft, so that the bevels are held in the same relation to each other, regardless of the moving of the axle.

The advantages of this type of drive are that all of the moving parts are enclosed and protected from dust, and run in grease or oil, which means perfect lubrication.

Radius Rods

Radius rods, also called "distance rods" and "strut rods," are mostly used on commercial cars using a double-chain drive. They extend from a point alongside of the frame in line with the jack shaft, thence to the rear axle. Thus they keep the chain at the proper tension and the distance from sprocket to sprocket the same, no matter how rough the road. A **turn buckle** is provided to insure adjustment. Radius rods are not used on propeller-shaft-driven cars in the manner described above, but on two or three propeller-shaft-driven cars they are used as shown in Fig. 7. Many worm-drive trucks are equipped with radius rods.

The Torque Member

Torque means turning movement, or twist. The **torque arm, torque tube, radius rod,** or the **rear springs** represent four different methods of preventing torque reaction. The torque arm, or radius rods extend from the cross-member near the transmission to the housing on the rear axle (construction varies).

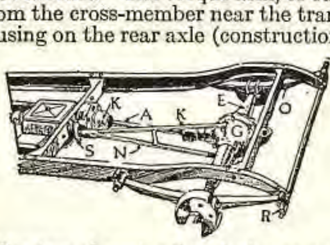


Fig. 4. One type of construction of a torque arm is shown in the illustration. Note the arm (N), extending from the rear axle housing to a spring arrangement or torque pillar attached to a cross member, in line with the drive shaft. See illustration (S) (N).

The tendency for the driving pinion to climb the ring gear when starting or driving a car causes the rear axle housing to twist in the opposite direction to the road wheels. So it is **torque reaction** which the torque member prevents.

What is known as the **"Hotchkiss drive method"** is where the torque and the drive are taken through the semi-elliptic rear springs. The main leaf of each of these is made strong enough for this added duty, and the construction does away with torsion tube, torque arm, and radius rods.

A torque tube is often used instead of a separate torque arm. The propeller or drive shaft revolves inside of the tube (see Fig. 6).

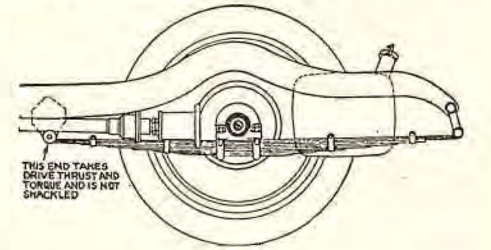


Fig. 5

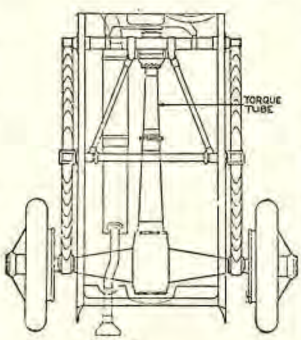


Fig. 6.

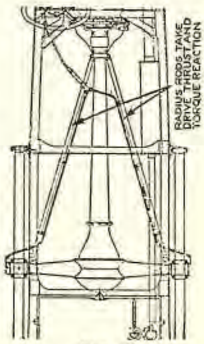


Fig. 7.

Fig. 5. "The Hotchkiss drive." A semi-elliptic spring is used to take the thrust. The forward end of the spring is not shackled, but oscillates on a pin, and this takes the thrust and torque. The rear end is shackled and is free o move under stress.

Fig. 6. A torque tube, which takes both the drive and torque; Rolls-Royce rear axle. See also Fig. 7, page 16.

Fig. 7. Radius rods on the Dusenberg, which take both the drive and torque (illustrations from *Motor World*).

Gears and Chains

Spur gears are noisy and are not used very much except for the transmission. They were formerly used for driving the cam shaft. The **helical,** or spiral tooth gear or silent chain, is now used to a great extent for driving the cam shaft.

The worm and worm gear are used extensively as a final drive on the rear axle of trucks.

Fig. 8

The helical or spiral gear with straight face can be placed as shown in the illustration above, and may thus be used to drive pumps and distributors. **The bevel helical tooth gear** is used extensively for the final drive on rear axles of automobiles, and is termed a bevel gear with a helical or spiral tooth.

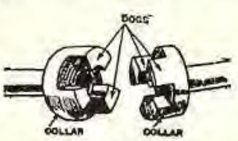
The bevel gear with straight teeth, as shown, is used for final drives, but the helical tooth bevel gear, being more quiet, has taken its place to a large extent.

The worm and worm gear make a wiping contact and the helical, more of a rolling contact. When accurately made, worm gears run with great smoothness and silence. The worm may engage either from above or below the gear wheel. The angle of the worm and gear may be as much as 45 degrees. The worm is made of hard steel and the worm gear of bronze. See Index under "Adjusting of the worm gear on a truck rear axle."

The sprocket chain is used on double-chain-driven trucks. See Index under "Chains for trucks," showing the roller-type sprocket chain.

The silent chain, with special sprockets to take the chain, is used extensively for driving the cam shaft, generator, etc., especially on "V"-type engines. See Index under "Silent chains."

The setting of bevel gears so that they will mesh properly without noise requires careful adjustment, as there must be as little play as possible without having the teeth bind. See Index under "Adjusting drive pinion."



DOG CLUTCH
Fig. 9.

The dog clutch is used in the transmission and can be used for couplings for various driving purposes, as for instance, with the magneto, etc.

When the "dog clutch" is used in the transmission, one dog is placed on the clutch shaft and the other on the square main transmission shaft. On modern transmissions, gears with internal teeth are used instead of the "dog clutch."

Drive Pinion and Driven Ring Gear

The drive pinion (R3) is shown in the illustration below (Fig. 10). This pinion is attached to the end of the drive shaft.

The differential ring gear (N3) is also shown in Fig. 10. This gear is attached to the differential housing, and is driven by gear (R3). Thus the drive is transmitted to the rear-axle shafts through the differential.

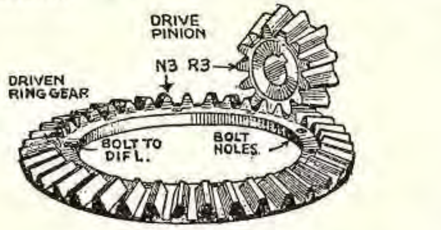


Fig. 10.

Note that both gears (R3) and (N3) have beveled teeth which are straight. The type of gears in general use have beveled teeth which are not straight but helical or spiral shaped.

DRIVE-GEAR REDUCTION

The speed of the crank shaft is reduced so that the road wheels turn once while the crank shaft revolves from three to five times with the high-speed gear engaged.

On cars with single-chain drive (now obsolete) this is done by having the transmission sprocket smaller than the axle sprocket. If the reduction is to be three to one, that is, if the crank shaft revolves three times to one revolution of the axle, the axle sprocket will have three times the number of teeth that the transmission sprocket has.

The reduction on side-chain-driven cars is sometimes made at the bevel driving the jack shaft, but usually at the sprockets.

On shaft-driven cars, the reduction is made at the rear axle-drive gears. The driven gear (N3) (Fig. 12) on the rear axle is given as many more teeth than the drive pinion (R3) on the driving shaft as is necessary for the reduction that is required.

In the worm drive, the reduction is governed as explained under "Worm-gear ratio"; see Index. In other words, the size of the worm could be changed without its changing the speed. (The angularity of course would have to be the same in both cases.)

To make the point clear as to just how the speed reduction is brought about in the worm drive, imagine the screw thread on a vise shaft which draws the jaws together. If that thread is coarse, with only a few to the inch, the jaws would move toward each other rapidly and of course it would take some power to move it; if, on the other hand, there were quite a number of threads to the inch, the jaws would move more slowly but it would take less power to exert the same pressure.

When the "gear ratio" of a car is spoken of, it is often referred to as the reduction between the engine crank shaft and rear axle. Thus, for instance, a "gear ratio of 4 to 1" is where the drive shaft makes four revolutions to one revolution of the road wheels on the high gear.

This term, "gear ratio," should be termed "total gear reduction," as the term "gear ratio" could be applied to the transmission, or to the rear axle. Thus a distinction is made as is explained below.

Difference Between "Rear-Axle Gear Ratio," "Transmission-Gear Ratio" and "Total-Gear Reduction"

Rear-Axle Gear Ratio

"Rear-axle gear ratio" refers to the number of times the propeller shaft (P), Figs. 11, 12, turns over to one revolution of the rear axle differential ring gear, axle shafts and wheels.

To find the rear-axle gear ratio on any car, divide the number of teeth in the driven gear (N3) on the differential, which in this instance has 71 teeth, by the number of teeth on the drive gear, which in this instance has 16; thus $71 \div 16 = 4.437$ revolutions of the propeller shaft (P), to one of the axle shafts or wheels.

Transmission Gear Ratio

"Transmission-gear ratio" refers to the ratio between the engine crank shaft and the propeller shaft **P.**

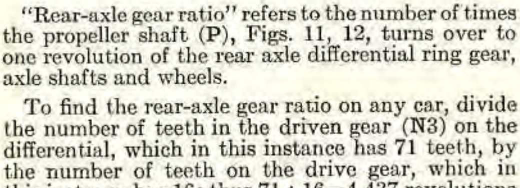


Fig. 11. Direct or high gear. Note that the drive is direct from the engine crank shaft to the drive pinion (R3), to the driven ring gear (N3). Gears (R) and (N) are meshed at all times.

On direct or high gear (Fig. 11), the ratio is 1 to 1, meaning that the engine crank shaft turns over one revolution to one of the propeller shaft (P), because the engine crank shaft is connected direct through the transmission to the propeller shaft P. Thus it is termed "direct drive."

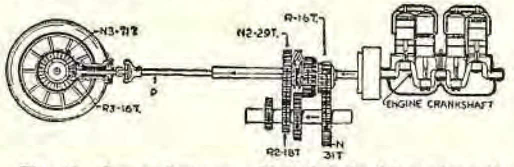


Fig. 12. Low or first gear. Note that the drive is from the crank shaft to the drive gear (R), to the driven gear (N), to the drive gear (R2), to the driven gear (N2), to the drive gear (R3), to the driven gear (N3).

On first or low speed (Fig. 12), the ratio is 3.121 to 1, meaning that the engine crank shaft turns over 3.121 times to 1 of the propeller shaft (P).

To find the transmission-gear ratio, multiply all of the driven gears together and all the drive gears together and divide the product of the driven gears by the product of the drive gears as follows:[1]

N,31teeth×N2,29t÷R,16t×R2,18t=3.121 obtained thus: 31×29=899, the product of the driven gears and 16×18=288, product of the drive gears, therefore, 899÷288=3.121.

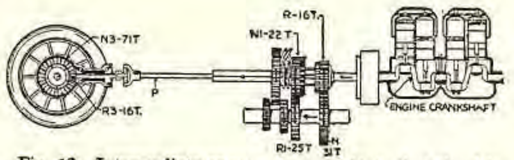


Fig. 13. Intermediate or second gear. Note that the drive is from the engine crank shaft, to the drive gear (R), to the driven gear (N), to the drive gear (R1), to the driven gear (N1), to the drive gear (R3), to the driven gear (N3).

On second speed (Fig. 13), the transmission ratio in this example is 1.705, meaning that the engine crank shaft makes 1.705 revolutions to 1 of the propeller shaft P. This transmission ratio is found by following the same rule:

N,31t×N1,22t÷R,16t×R1,25t=1.705.[1]

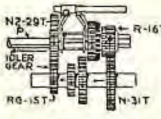


Fig. 14

Fig. 15

Fig. 14. Reverse gear. Note that the drive is from the drive gear (R) to the driven gear (N), to the drive gear (RG), to the idler gear, to the driven gear (N2), to the drive shaft (P), to the rear axle. The idler gear gives a reverse motion to shaft (P).

Fig. 15. Neutral gears. Note that the drive is from the drive gear (R) to the driven gear (N). Gears (R) (N) and shaft (S) revolve independently of shaft (P). Thus the rear axle is not connected with the crank shaft of the engine.

On reverse speed (Fig. 14) the transmission ratio in this example is 3.74 to 1, meaning that the engine crank shaft turns over 3.74 times to 1 revolution of the propeller shaft (P). This transmission ratio is found by following the same rule.

N,31t×N2,29t=899÷R,16t×RG,15t=240,

thus:

899÷240=3,74.

Note: Sliding gear (N2) is pushed over to the extreme left and meshes with an "idler gear" behind gear (RG). The idler gear then meshes with (N2) and reverse gear (RG). This gives a reverse motion to propeller shaft (P). The teeth on the "idler gear" are not considered, as it is both a driven and a drive gear.

[1] Driven gears are designated in the illustrations as (N), (N1), (N2), ect. Drive gears are designated as (R), (R1), (R2), etc.

Total Gear Reduction

"Total gear reduction" refers to the number of times the engine crank shaft turns over to one revolution of the axle shafts or rear wheels. This is governed by the diameter of any gear transmitting power to the rear-axle shaft.

To find the total gear reduction, multiply the "transmission-gear ratio" by the "rear-axle ratio."

To find the total gear reduction when in first or low speed, multiply 3.121, the transmission ratio, by 4.437, the rear-axle ratio, and we have 13.847. Thus the engine crank shaft turns over 13.847 times to 1 of the rear-axle shafts or rear wheels.

To find the total gear reduction when in second speed: 1.705×4.437=7.565 revolutions of the engine crank shaft to 1 of the rear wheels.

To find the total gear reduction of third or high speed: 1×4.437=4.437 revolutions of the engine crank shaft to 1 of the rear wheels.

To find the total gear reduction of reverse: 3.74×4.437=16.594 revolutions of the engine crank shaft to 1 of rear wheels.

The foregoing examples of ratios are those used on the Cadillac Type 59 car. The Cadillac sometimes gives a 14-tooth drive pinion (R3) on the heavy closed cars and for touring cars used in hilly countries. The rear-axle ratio would then be: 71÷14=5.071 rev. of propeller shaft P, to 1 of the rear wheels.

Miscellaneous Ratios

Ford: Rear axle ratio N3, 40 teeth÷R3, 11 teeth=3.636. Transmission ratio, 1st speed 2.75; 2nd speed 1; reverse 4.

Overland 4: Rear axle ratio, N3, 45 teeth÷R3, 10 teeth= 4.5, transmission ratio, 1st speed, 3.62 to 1; 2nd, 2.03 to 1; high, 1 to 1; reverse, 4.83 to 1.

Dodge: the rear-axle ratio is 4.17 to 1.

On some cars, for instance the Locomobile model 48, Mercer Series 5, and Pierce-Arrow Models 31 and 51, there are 4 speeds and on 4th the transmission ratio is 1 to 1. On Locomobile 48 and Pierce-Arrow 51, first speed transmission ratio is 4 to 1. On the Mercer, 3.75 to 1.

On some cars with four speeds, the 4th speed is higher than 1 to 1; for instance the Wasp with 4 cylinders 4¾×5½, the 4th speed transmission ratio is .73 to 1. The rear-axle ratio is 3.7, therefore the total gear reduction would be .73×3.7= 2.701 revolutions of engine to 1 of rear wheels. On 3rd speed the Wasp transmission ratio is 1 to 1; on 1st or low, 2.69 to 1. The total gear reduction on 1st speed is 2.69×3.7=9.953 revolutions of the engine crank shaft to 1 of the rear wheels.

Truck-Gear Ratios[1]

Federal 2-ton truck: Rear-axle ratio, 9.25, transmission ratio, 1st speed, 4.40; 2nd, 3.08; 3rd, 1.76; 4th, 1; reverse, 5.28.

Federal 5-ton truck: Rear-axle ratio, 13.66, transmission ratio, 1st speed, 4.99; 2nd, 3.16; 3rd, 1.79; 4th, 1; reverse, 5.78.

Replacing a Drive Pinion

When replacing a drive pinion (R3) with one of a different diameter, it is always necessary also to replace the driven ring gear (N3), because the teeth will mesh too tight at either the big end of the tooth or the little end of the tooth, due to the fact that the teeth are cut at a different angle. See Index: "Differential gear, how to replace."

Relation of Engine Crank Shaft to Periphery of Road Wheels

If the rear axle ratio on a certain car is 4.437 to 1, and say for instance, high gear is being used, then the rear wheels, no matter how large or how small the wheels or tires may be, will revolve 1 revolution to 4.437 revolutions of engine crank shaft.

It is then clear that the larger the rear wheels or tires, the harder will be the pull on the engine, and that the smaller the rear wheels or tires, the easier will be the pull by the engine.

[1] See Index under "G. M. C. 'two-range' truck transmission."

Note. These pages refer to early-model cars. The method of computing the ratios is practically the same on later models.

INSTRUCTION No. 3

STEERING; SPRINGS; BRAKES

STEERING PRINCIPLE

Principle of Steering

The steering device is placed on the left-hand side of the car. On early model cars it was placed on the right-hand side.

The principle: In steering a wagon, pulling on one of the reins swings the horse to that side. The shaft or pole is attached to the axle, and the axle is pivoted to the king pin, and all swing with the horse.

If you go straight ahead, the front and rear wheels of any vehicle move in straight lines. To make a turn to one side or the other, the front wheels are swung so that they are at an angle with the rear wheels.

Whenever the front wheels stand at an angle with the rear wheels, the vehicle will turn, and it will continue to turn until the front wheels are swung back to a straight line again.

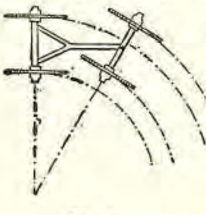


Fig. 1

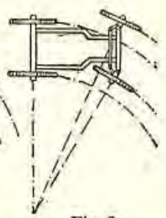


Fig. 2

Fig. 1. Showing how a front axle of a horse-drawn vehicle gives the direction in which a horse-drawn vehicle runs.

Fig. 2. Showing how the front wheels of an automobile give the direction in which the car runs. See next column, giving the meaning of "turning radius."

In a horse-drawn vehicle, the front wheels are square with the axle, for wheels and axle swing together. (See Fig. 1.)

In an automobile, the front axle does not swing, but each wheel swings on a pivot at the end of the axle, known as the **Ackerman principle.** (See Fig. 2.) See also page 910.

It would not be practical to steer an automobile as a horse-drawn vehicle is steered, for the axle would have to be very heavy to support the weight, and besides, it would be so hard to swing it that steering would be difficult. Another reason is that the body would have to be raised up high, so that the wheels could go under it in making a short turn.

A fixed front axle is always used on automobiles. The pivots on which the front wheels swing must be as close to the hubs of the wheels as possible, for the closer they are, the less leverage there will be to overcome, and the easier it will be to steer, with less liability to break.

When a wagon or automobile turns a corner, it moves in the arc of a circle.

In a horse-drawn vehicle, the front axle, because it swings on the king pin, always points to the center of the circle (Fig. 1). Notice that both wheels are perpendicular to the same radius of the circle and to the axle in Fig. 1.

The front axle of an automobile is fixed and cannot turn, and therefore only its pivoted ends point to the center of the circle (Fig. 2). Notice in Fig. 2, that axle does not move, but that each wheel moves.

When running straight ahead, the front wheels of an automobile are square with the axle. When turning, the front wheels are not square with the axle, but at an angle with it.

Because each wheel is square with its axle end, and both axle ends point to the center of the circle, each wheel is square, or perpendicular to, a radius of the circle. If both were perpendicular to the same radius, which they are not, the wheels would be parallel with each other.

Thus, while the front wheels of a horse-drawn vehicle are always parallel to each other, the front wheels of an automobile turning a corner are not parallel to each other on the same radius.

The steering mechanism must be so arranged that the front wheels are parallel when the car is running straight ahead, but stand at an angle with each other when turning a corner.

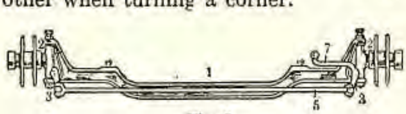


Fig. 3

Each of the pivoted axle ends (2, Fig. 3), which are called "steering knuckles," has a steering knuckle arm (3), projecting from it.

The ends of these two arms are connected by a rod called a "steering knuckle tie-rod" (5). When the drag link is moved endways, both wheels move with it.

The two steering arms are not parallel, but incline a little toward each other. If they were parallel, the two wheels would be parallel, no matter how the tie-rod was moved. As they are not parallel, moving the tie-rod moves one of the wheels through a greater angle than the other, depending on the direction in which the tie-rod is moved.

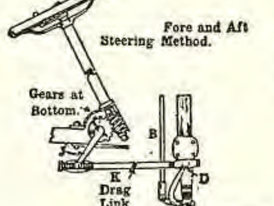
Turning radius: The radius in which a car can turn. For example, a turning radius of 15′ would mean that the car could be turned in a circle measuring 15′ from its center or 30′, or can be turned in a street 30′ wide if on one side of the street. If the steering device is on the left, a car can usually be turned in less space by turning to the right and vice versa.

Factors determining the turning radius are: (1) wheel base; (2) maximum angle at which the front wheel can be turned from the front. The average turning radius is 12½′ to 15′, or a circle of 25′ to 30′ dia. See Fig. 2, page 10, which will no doubt make the explanation clearer.

Steering Methods

There are two methods in general use: (1) the "fore and aft" method; (2) the "cross method."

The "fore and aft" method is shown in Fig. 4. With this method the reduction gearing is usually



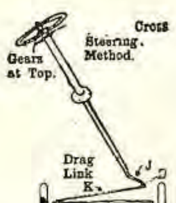


Fig. 4 (left). The "fore-and-aft" method.

Fig. 5 (right). The "cross steering" method.

Note: The rod (K) in Figs. 4 and 5 is usually termed a "drag link." The S.A.E. have recommended the use of the term "steering gear connecting-rod" for this part in the bottom of the steering device and the tie-rod (B) is usually behind the front axle.

The "cross steering" method is shown in Fig. 5. With this method the reduction gearing can be either at the top or bottom, and the tie-rod (B) can be either in front or behind the front axle.

The Ford and model "Four" Overland and Chevrolet "Four Ninety" employ planetary gears for reduction. The Ford gears are at the top of the steering column (Fig. 9), and on the Overland model "Four" and Chevrolet, the planetary gears are at the bottom.

Types of Steering Gears

There are a number of methods for reducing the ratio of movement of the steering column shaft to that of the arm (J).

(1) **Pinion and sector type** (see Fig. 6).

(2) **Worm and sector type** (Fig. 7). Note that the teeth are only on a section of the sector.

(3) **Worm and worm-wheel type** (Fig. 8).

(4) **Planetary type.** Note that the gears are at the top of the device on the Ford (Fig. 9).

(5) **Screw and nut type** (Fig. 10). Movement of this nut is up and down which moves the arm (J).

(6) **Screw and half-nut type** (Fig. 11). This is the Lavine steering gear. Adjustment is at the bottom of this device.

The breaking of any part of the steering connections is more likely to cause a wreck than the breaking of any other part of the car, and must be watched

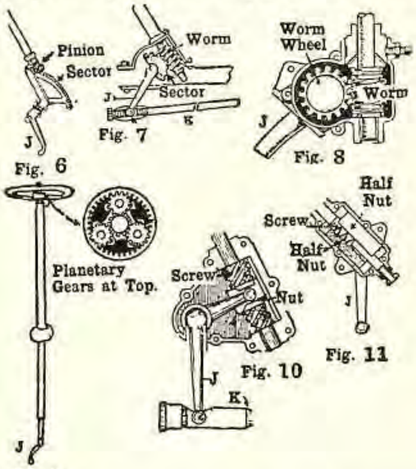


Fig. 9

carefully. The parts must be kept tight enough to prevent play, but must not be so tight as to make steering hard. All parts must be kept well lubricated.

(See Index for "Steering gears, adjusting.")

SPRINGS

All vehicles intended to move at more than a very slow speed must be provided with springs. Springs not only protect the occupants from the vibrations of a rough road, but also keep the machinery from being shaken to pieces.

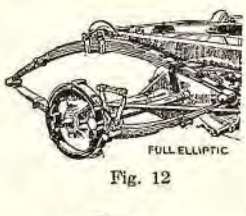


Fig. 12

Fig. 13

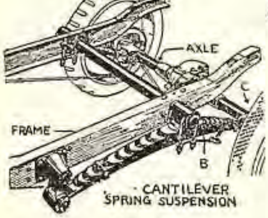


Fig. 14

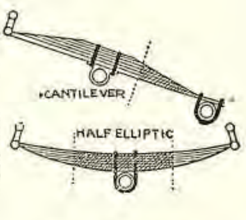


Fig. 15 (upper)
Fig. 16 (lower)

The size and strength of the springs depend on the weight of the vehicle. Springs that are too weak will not give sufficient protection, and if they are too strong they will not have enough resiliency.

Types of springs in general use are: Full elliptic, half or semi-elliptic, quarter-elliptic, three-quarter elliptic, and cantilever.

The full-elliptic was formerly used on a great many cars for the rear, as in Fig. 12. In some instances it was used in front.

The cantilever spring system (Figs. 14 and 15) is probably the most popular present-day practice. The illustration shows how it compares with the ordinary half-elliptic principle shown in Fig. 16.

In the cantilever spring the forward end is shackled and the axle is attached to the rear end. The center of the spring is attached to a trunion or bearing on the frame. Thus the spring has a certain amount of movement about its center. One good feature of this form of spring is that it reduces the unsprung weight of the axle. The shaded parts of the respective springs show the comparative amount of the unsprung weight. In the cantilever form of spring the heaviest part of it is supported by the frame. See also Fig. 5, page 7 (Hotchkiss drive).

The half-elliptic spring (Fig. 16) is used for the rear and, to a great extent, for the front, as in Fig. 13.

Fig. 17. Three quarter elliptic.

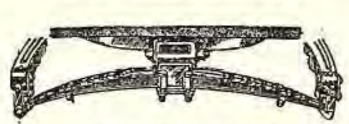


Fig. 18. Half-elliptic-end suspension.

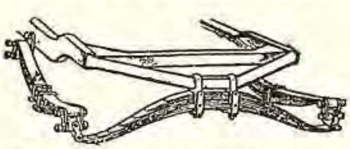


Fig. 19 Three half-elliptic spring-coach style of suspension.

Other arrangements of half-elliptic springs for the rear are shown in Figs. 17, 18, and 19.

SHOCK ABSORBERS

The tires are primary shock absorbers and if you wish to get the full benefit from tires, **keep them inflated** up to the point of supporting the load, but not at too high a pressure if cushioning effect is desired. The low pressure **balloon tire** is an excellent shock absorber and protects the car as well as the passengers (see also page 594).

The springs are secondary shock absorbers and to get full benefit from the springs, which slide on each other when in action, keep them well and constantly **lubricated between the leaves** (see pages 172, 762, 763).

Breakage of a spring means breakage of one or more of the leaves. Breakage almost always occurs in the expansion that follows a heavy compression, and not during the compression. In other words, it is the **rebound** that usually breaks the spring.

Devices called **shock absorbers** are attached to the springs to check the **up** or **rebound** movement, and are supplementary devices to aid the tires and springs in absorbing the shock when driving over uneven or rough roads. **There are four types of shock absorbers in general use:** (1) friction type; (2) pneumatic or air type; (3) spring type; (4) hydraulic type.

Friction type: The spring rebound is retarded by friction.

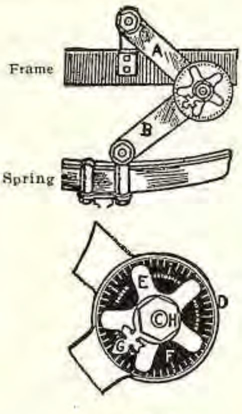


Fig. 20.

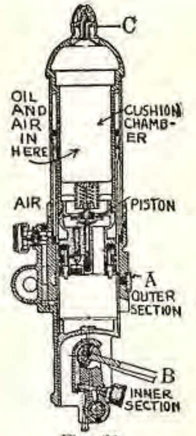


Fig. 21.

Fig. 20. Example of a friction type shock absorber (Hartford): Arms (A) (B) are attached to frame and axle. All these movable frictional parts offer constant resistance to the vibration of the spring in both directions. When the wheel strikes an obstruction, the arms come together, but instead of flying back, as does the free spring, it is retarded by the friction and moves gradually to its normal position, as the friction is always the same while the tension of the spring diminishes as it approaches its normal postion.

An adjustment dial (F) and indicator (G) provide means of securing the correct tension for the car. A spider compensating spring (E) takes up any little wear automatically, thus keeping the friction uniform after adjustment is made.

There are several different constructions of the friction type. The "Stabilator" (page 729), "Stewart," and "Amco" are some makes of a different construction (not illustrated).

Pneumatic or air type: The downward motion of the spring is cushioned by air, and the rebound is checked by air. The oil is used as a piston seal.

Fig. 21. Example of a pneumatic or air-type shock absorber (Westinghouse): An air chamber is made up of two sections, one of which telescopes into the other. The outer section (A) is attached to a bracket on the frame of the car. The inner section is attached to one end of the springs (B). The chamber is partly filled with oil, through the filling plug in cap (C). The filling plug is fitted with a Schrader tire type of air valve through which the chamber may be charged with air at any desired pressure.

Auxiliary spring type: The downward motion is cushioned by an extra or auxiliary spring, and the rebound is checked by either the same spring or another.

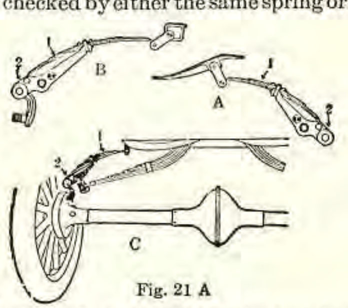


Fig. 21 A

Fig. 21A. Example of an auxiliary spring type shock absorber for the Ford (K-W Road Smoother). It consists of a curved leaf spring (1) mounted on an assembly (2) of such design that the downward motion is cushioned and the rebound is checked. When striking an obstruction, the shock is gently absorbed by the leaf spring which straightens out before the rebound begins. The rebound is checked as soon as it begins, through the link suspending this device from the frame.

There are two auxiliary springs (A) in front and two in the rear (B), on each side. (C) shows one side of the rear. This shock absorber also checks side-sway and has six points of free movement which keep the body level, regardless of road conditions.

There are several different constructions of the spring-type shock absorber.

Hydraulic type: The rebound is checked by the viscosity of oil, the working parts being immersed in oil.

The **Hoo-Dye is an example of a hydraulic type** which controls both the recoil and the compression. Manufactured by the Houdaille Co., Buffalo, N. Y.

BRAKE CONTROL AND CONNECTIONS

Automobiles are fitted with two sets of brakes, called the "running service" or "foot brake," and the "emergency" or "hand brake," the terms "foot brake" and "hand brake" being the correct terms.

The foot brake is applied by pressing on a foot pedal, and is the one most in use because of its convenience, and is used most when running. Because it is used most, it requires more attention.

The usual method of connecting the foot brake is by a contracting band on the outside of the brake drum on the rear wheel hubs, called the "external contracting band brake."

The hand brake is usually applied by a lever at the side (or center) of the driver's seat, so placed that he may apply his whole force to it. This brake is seldom used while running. It is usually applied when the car is left standing, in order to keep the car from rolling down an incline. The

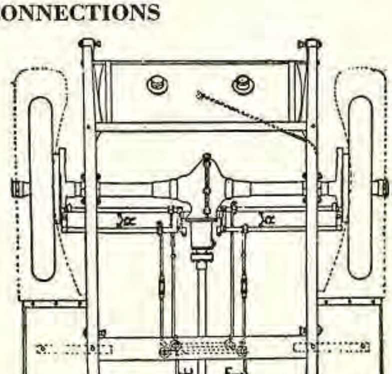


Fig. 22. Method of connecting the two brakes in rear. The adjustment for equalizing the pull on each rod, can be made at the turn buckles.

hand-brake lever connects in almost every instance with the **internal expanding brake** inside of brake drum on rear wheel hubs, but occasionally will be found connected by a contracting band over a drum mounted on the main transmission shaft. See also bottom of page 885.

The foot-brake pedal is the right pedal and the left pedal is the **clutch pedal,** on almost all cars.

Brake Equalizers

When the foot-brake pedal or hand-brake lever is applied, the pull should be the same on each brake on each wheel. If one brake rod is longer than the other the brake effect is not equal on both wheels, and this has a tendency to make the car skid.

To overcome this, a brake equalizer is used, the principle of which is shown in Fig. 22. The rods (**R**) are placed in bearings; the rod (**F**), connects with the foot brake, and rod (**H**) with the hand brake.

If a brake squeaks, it is an indication that it is dirty and needs cleaning. The dirt clogs the pores in the surface of the lining and glazes it over. Gasoline or, better, kerosene, will remove the dirt. The wheel should be removed and the linings cleaned with a stiff brush, such as a tooth or nail brush.

Types of Brakes

There are two distinct types of brakes in general use: the **external contracting** and the **internal expanding** type.

The external band brake is a flexible steel band faced with an asbestos or fabric composition, called "Raybestos" or "Multibestos," etc. Setting the brake causes friction between the brake drum and the linings, hence the use of asbestos composition.

Band brakes are of two kinds: Single acting and **double acting,** the latter being an improvement over the former.

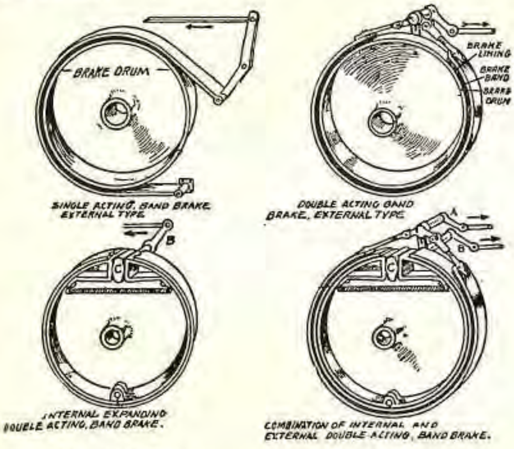


Fig. 23 (upper) Fig. 24 (upper)
Fig. 25 (lower) Fig. 26 (lower)

The single-acting band brake (Fig. 23) binds only when the drum is revolving in one direction, having very little grip when the drum is revolving in the same direction in which the band is being pulled. This form is going out of use for automobiles, for it cannot be depended on to hold the car from running down hill backward.

The double-acting band brake (Fig. 24) is more practical, for it holds with the drum revolving in either direction. In this form, both ends of the brake are attached to the lever or pedal, and are so arranged that while one end is being pulled in one direction, the other end is being pulled in the opposite direction. This binds on the drum so tightly that it may be depended on to hold the car in any position.

The brake-band may either be contracted around the outside of drum, called the **"external brake band,"** or **expanded** within it so that it bears against the inside wall of the drum, called the **"internal expanding brake."** Sometimes the internal brake is made of metal.

The internal type of brake formerly in use is shown in Fig. 27. This is a double-acting, expanding type, and which acts internally against the inside of the drum. This brake shoe is lined with Raybestos, Thermoid or some similar material. The internal brake can be actuated by a **cam** (**C**, Fig. 25; also Fig. 3, page 884) or by a **toggle-joint** Fig. 4.

A combination of internal expanding and external contracting brakes are shown in Fig. 26. Lever (**A**), connected with **foot-brake pedal,** operates the **external brake** and lever (**B**), connected with the **hand-brake lever** operates the **internal brake.** See also Fig. 27, below.

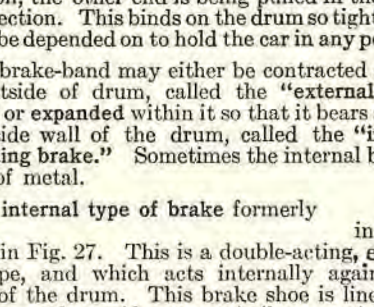


Fig. 27. **A combination of an internal expanding and external contracting brake on brake drum of rear-wheel hub. OB** is the outer or external and **1B** is the inner or internal. **B** is the hand-brake rod operating the internal brake. **H** is the foot-brake rod operating the external brake. An example of adjusting this type of brake is shown on page 889, Fig. 9, which is similar. **For the method of adjusting and relining brakes, see Index.** This subject is treated in the Repair Section of this book.

Brake drums are of two types: **single** and **double,** the former being in general use. See page 885.

The two-wheel brake system
The two rear wheels are usually fitted with a combination internal expanding and external contracting type of brake similar to Fig. 27.

The four-wheel brake system utilizes a brake on all four wheels, and they may be internal expanding, external contracting, or a combination.

The four-wheel type of brake has the advantage of equalizing the braking strain on the four wheels, eliminating skidding, and making possible quick stops at high speeds with a very smooth action. It also lengthens the life of tires and brake lining.

There are three principles of operation of the **four-wheel brakes:** the **mechanical,** the **hydraulic,** the **air principle.** See page 885.

TYPICAL EXAMPLES OF A LIGHT CAR AND A HEAVY CAR

Illustrations and specifications of the two well-known cars shown below will give a comparison of the relative difference between a light car and a heavy car.

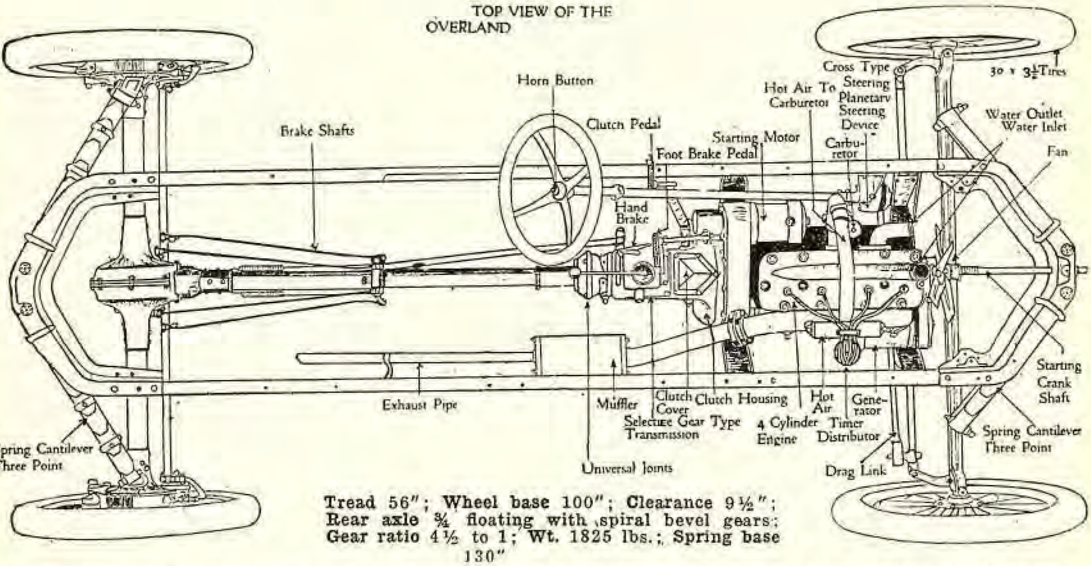
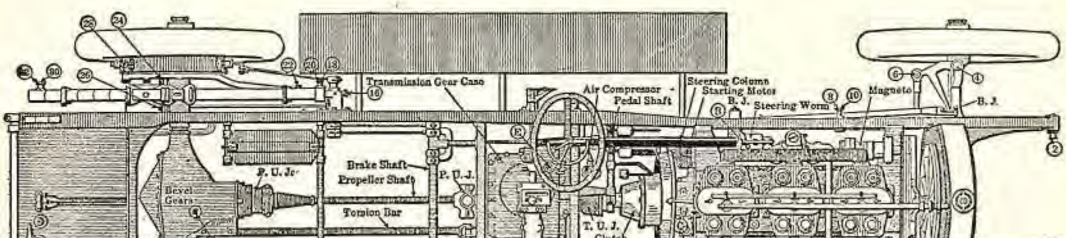


Fig. 28. Example of a 4-cylinder car (Overland 4). Note the spring suspension used on this make of car, which is termed "triplex suspension," meaning that there are three points of contact on suspension. Engine, 4 cylinders; bore, 3-⅜", stroke 4"; actual h. p., 27; crank-shaft main bearing, 3; wheel base, 100"; tread, 56"; rear-axle ratio, 4½ to 1; rear-axle shafts, ¾ floating; transmission sliding gear, three speeds and reverse; clutch, lubricated single-plate type; unit power plant; tire sizes, 30" x 3½"; water capacity, 3¾ gal.; weight, approximately 1825 lbs.; clearance, 9½". See Specifications, pages 1055 to 1062, for later Overland specifications.



Locomobile Chassis. The "38" Type R-7. The "48" Type M-7

Fig. 29. Example of a 6-cylinder heavy car (Locomobile 48). Engine, 6-cylinder; bore, 4½"; stroke, 5½"; actual h. p., 90; crank-shaft main bearing, 5; wheelbase, 142"; tread, 56"; tire sizes, 37" x 5"; fuel capacity, 30 gal.; water capacity, 7¾ gal.; transmission, four speeds and reverse; clutch, multiple dry disk; rear axle, full floating. See Specifications, pages 1055 to 1062, for later Locomobile specifications.

INSTRUCTION No. 4

AXLES; DIFFERENTIALS; BEARINGS

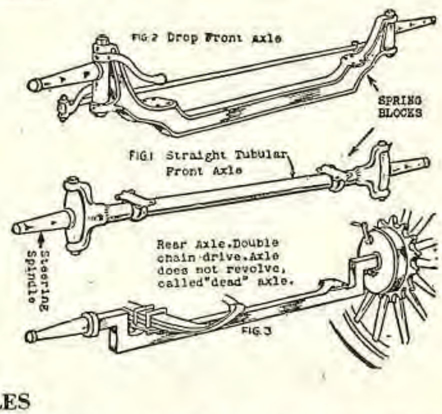
FRONT AXLES

The front axle of a modern car carries about 80 per cent of the weight of the engine, and must at the same time withstand the shocks and jars that it receives through the steering wheels; it must therefore be strong and stiff. It also carries about 20 per cent to 40 per cent of the weight of the entire car.

Front axles are of two types: tubular and **solid** (Figs. 1 and 2). Formerly, axles were made of heavy steel tubes, but steel drop forgings with a cross-section of the form of the letter I, called "I-beam" type are considered to give better results.

The center of the axle is usually bent down, so that it is the lowest point of the car except the wheels; this is done in order to protect the mechanism from being struck by high spots in the road. A rock or stump, standing up high enough to hit the fly wheel, will first strike the axle, which is strong enough to withstand a blow that could easily damage the engine.

The steering spindles are that part of the front axle on which the front wheels revolve and are made of nickel steel, heat treated. The steering spindles are sometimes fitted with either roller or ball bearings. The **steering knuckle** is that part which fits into the yoke of the axle. The **steering arm** of the device connects with the steering knuckle thrust arm, and the movement of the steering wheel guides the direction of the wheels. See page 910 for **types of front axle steering knuckles** (the **Elliott** and **Lemoine**).



REAR AXLES

There are two types of rear axles: "dead axle" and "live axle." (Load is 60 to 80 per cent of car weight.)

Dead axles are stationary, with the wheels running free on the end of the axle, and are usually made as shown in Fig. 3. The wheels are usually revolved by chain and sprocket.

Live rear axles is the name given to axles that revolve with the wheels, and are known as "plain" live axle, "semi-floating" axle, "three-quarter floating" axle, "full-floating" axle.

The **axle shafts** on a live axle are in two sections (see **G**, Fig. 7, page 16). The inner end connects with the differential gears; the outer ends connect to the wheels. It is necessary to support the axle parts in a strong **housing** (**H**) and to brace it in order that the parts of the axle do not sag or get out of line.

Types of Live Rear Axles

There are **two types:** the "plain live rear axle" and the "floating live rear axle."

The plain live rear axle is the type where the **inner ends of the axle shafts support the differential.** See Fig. 3A. Note that the bearings are on the axle shafts. If the axle shafts are withdrawn the differential **would** drop out of place.

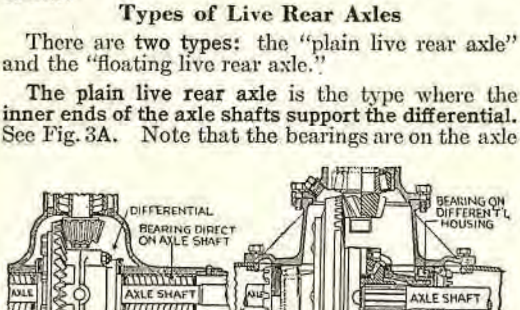


Fig. 3A. Plain live type of rear axle.
Fig. 3B. Floating type of rear axle.

To remove axle shafts the complete rear axle assembly must be removed from the car and the "divided housing" separated. See also pages 862, 863.

The floating rear axle is the type where **the differential supports the inner ends of the axle shafts.** See Fig. 3B. Note bearing is on outer ends of differential housing. If axle shafts are withdrawn differential **would not drop** out of place.

Types of Floating Rear Axles

There are **three types,** the "full-floating," "semi-floating," and the "three-quarter floating." The floating type is used more than the plain live type. See also page 863.

The type of floating axle is determined by: (1) whether or not the wheel bearing is on the outer end of the axle shaft or on the axle housing; (2) the location of the bearing or bearings; (3) the method of connecting the axle shaft with the wheel.

Full-floating type (Fig. 4). Two bearings in each rear wheel are mounted on the axle housing, placed on each side of the center of the wheel. Thus the wheels run on the housing and the housing supports the weight, not the axle shafts.

All of the bending stress due to weight or static force and to skidding force is carried by the housing.

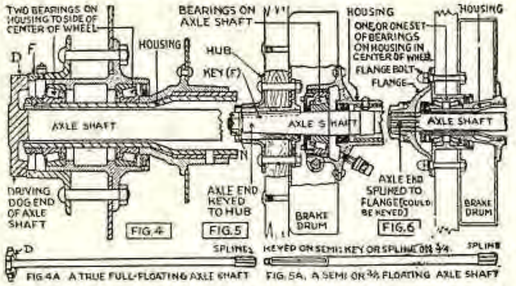
The outer ends of **the axle shafts are not supported by the wheels** which do not depend upon the axle shafts for alignment. The wheel could run independently of the axle shaft in its bearings on the housing if necessary. Thus the axle shafts turn freely within the housing and bear only the torque (twisting effect) or stress of turning the wheels. The axle shafts are said to "float" within the housing.

The **wheel can be driven** by a jaw clutch or flange, but the true full-floating axle is driven by a jaw clutch (**D,** Figs. 4 and **4A**) which fits into notches in the driving flange (**F**). Note (**D**) is an integral part of the axle shaft.

Note: On some types of full-floating axles (see Fig. 35, page 877), the axle shaft is keyed (sometimes squared, or splined on others) to the flange and to remove the axle shaft the flange bolts are removed. This is termed a "seven-eighths floating type."

To remove axle shafts (Fig. 4), it is **not** necessary to remove wheels. Remove hub caps (not shown) and withdraw shafts (see also page 864). **Techni-**

cally speaking, the axle is not a true full-floating type if the shaft is keyed to the wheel.



Semi-floating type (also called a "fixed-hub" type) is shown in Fig. 5. Outer ends of axle shafts are fixed, or keyed to the hubs of wheels, usually with keys (F) and nut (N).

The **bearings** (one on each outer end) are mounted directly on the axle shafts; thus the axle shafts support the weight, and carry the bending stress, torque, and the skidding and turning force.

To **remove axle shafts** (Fig. 5): The axle shafts on most semi-floating axles can be withdrawn from the axle housing without removing the entire rear axle, but it is necessary first to remove the wheels by loosening nuts (N) and draw the wheel off with a wheel puller; see pages 863, 864, 883 for further instructions.

For removing differential on different types of rear axles, see pages 863, 879.

The **three-quarter floating type,** also called the "flanged-hub" or "flanged-shaft" type, is shown in Fig. 6. The rear axle housing extends into the hubs of wheels as in the full-floating type. The outer ends of axle shafts fit into the hub flange and are splined as in Fig. 6 (could be keyed), and the flange is bolted to the wheel hub. Only one bearing is used on each wheel hub, usually placed directly under the center of the wheel and mounted on the axle housing (the two bearings in Fig. 6 are considered as one set of bearings).

The outer end of **axle shafts are supported by the wheels** which depend upon the axle shafts for alignment.

In the flanged-shaft axle, especially where only one bearing is used under the center of the wheel, the stresses (strains) are quite similar to those in the semi-floating type. The skidding force and that of turning corners is on the axle shafts.

To remove axle shafts (Fig. 6) it is not necessary to remove the wheel, but to remove the flange bolts and pull out the flange and axle shafts. See also pages 863, 868, and Fig. 27, page 921.

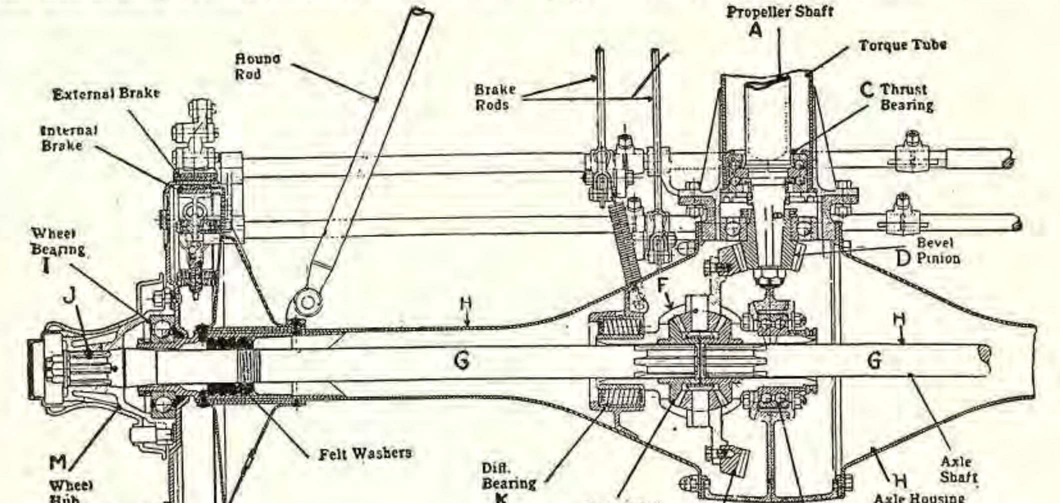


Fig. 7. Illustration of a three-quarter floating type of rear axle (Marmon as an example), complete with bevel driven gear (E). The driving axle shaft (G), does not support any dead weight. The road wheels run on ball bearings (I) carried on the outer sleeve or casing of the axle. The details are as follows: (A) propeller-shaft connection; (B) driving-pinion shaft; (C) ball-thrust bearings; (D) bevel-driving pinion; (E) large bevel; (F) differential gear; (G) half of driving axle; (H) tubular outer casing or sleeves (I) ball bearing for wheels; (J) driving ends of axle (squared or keyed); (K) roller bearings in differential case; (L) drum of internal and external brake; (M) hub of detachable wire wheel; (N) casing enclosing bevel gear and differential.

Note. The power is transmitted from the driving bevel (D) to large gear (E) this being bolted to the case of the differential (F), thence by the inside pinions to each half of the driving axle. It is usual to "anchor" the outer casing enclosing the differential gear to the chassis by means of torque tube or hound rods bolted to the upper and lower points of the gearcase which counteract the tendency for the whole casing to twist round from the reaction of the driving effort. On some cars the rear springs are made to serve as torque rods. The **thrust,** which is heavy between gears (D) and (E) is taken up by ball bearing (C).

TYPES OF REAR-AXLE DRIVE GEARING

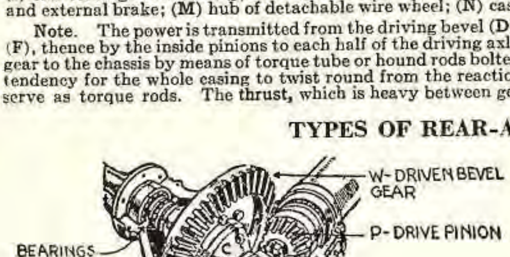


Fig. 8.—Straight-tooth bevel gears.

The power of the engine is transmitted at right angles to the rear axle and road wheels by means of **bevel gears** (P and W, Fig. 8), or by a worm and worm gear (Fig. 10). **Bevel gears are used on passenger cars** and the teeth are either **straight cut** (Fig. 8), or **spiral,** or **helical** (Fig. 9). The **ratio** of the diameter of these gears ranges from 3½ to 1, to 5 to 1, and the ratio determines the **high gear or direct drive** of the car.

The "spiral" or "helical tooth bevel gear" (Fig. 9), is a popular type of gear tooth used to a considerable extent. This type, if accurately made, is very silent.

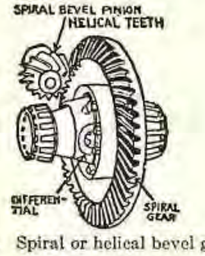


Fig. 9. Spiral or helical bevel gears.

In a straight-tooth bevel gear (Fig. 8), any given tooth goes in and out of mesh at one time along its entire length. In the helical bevel the meshing starts at one end of the given tooth and gradually moves towards the other end. Therefore, two helical teeth are in mesh at all times.

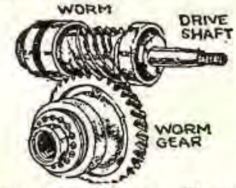


Fig. 10. The worm type of gear. The worm can be overhead or underneath the worm gear.

The "worm and worm gear" is used quite extensively on electric and commercial cars or trucks, where a large reduction of gearing is necessary. It is replacing the double-chain drive. It is made with the worm overhead, or underneath. The worm drive is very quiet and efficient.

The "single-chain drive" is now obsolete. It will not therefore be dealt with.

THE DIFFERENTIAL

Purpose of the differential: It is necessary to fit an automobile with **differential or compensation gears,** in order that the rear wheels may revolve at different speeds when the car turns a corner, while at the same time both are being driven by the engine. This gear is automatic, and operates according to the resistance of the road against the wheels.

Principle: There is more resistance to the turning of the inside wheel than the outside wheel when the car is turning; consequently the outside wheel may revolve faster. It is necessary for the outside wheel to revolve faster, because it has a longer distance to travel than the inside wheel. The same applies to a wagon, but the wagon wheels run free on the axle, therefore a compensating device is not necessary.

In illustration of this, see Fig. 12, and note that if the car is turning to the right, the wheel **A** must revolve faster than wheel **B**. Also refer to Fig. 11, and note that the axle shaft **A**, being attached to the wheel, must revolve faster than axle shaft **B**, when turning to the right and vice versa if turning to the left. Therefore, to compensate for this difference in speed of the two wheels and axle shafts, bevel gears (**E**) on the ends of the axle shafts (Fig. 11), mesh with the small bevel gears (**D**), called "compensating" or "differential gears," which are free in bearings on the housing or differential case attached to driven-ring gear **R**.

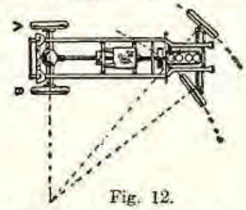


Fig. 12.

As long as the car travels straight ahead and the resistance of both rear wheels is the same, these gears (**D**) do not turn, but when the car turns, then greater resistance is offered to the inside wheel; therefore the compensating gears (**D**) with their spindles (**DI**), turn in their bearings, permitting the outside wheel to revolve faster than the inside wheel. In fact, the inside wheel could be stationary or revolve backwards if necessary.

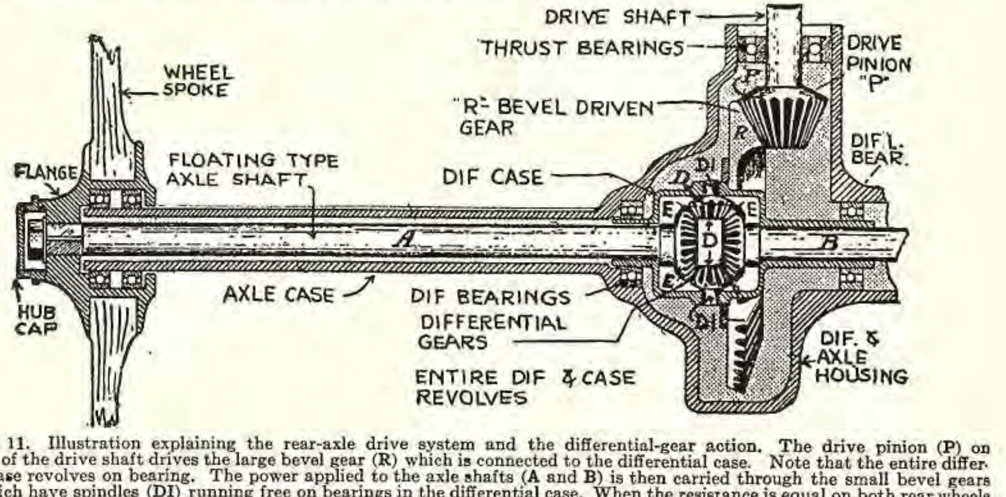


Fig. 11. Illustration explaining the rear-axle drive system and the differential-gear action. The drive pinion (**P**) on the end of the drive shaft drives the large bevel gear (**R**) which is connected to the differential case. Note that the entire differential case revolves on bearing. The power applied to the axle shafts (**A** and **B**) is then carried through the small bevel gears (**D**), which have spindles (**DI**) running free on bearings in the differential case. When the resistance is equal on both rear wheels and split-axle shafts (**A** and **B**), the gears (**D**) drive the bevel gears (**E**) on the end of the axle shafts, thus causing each axle shaft to revolve at the same speed. If resistance is greater on one axle shaft than on the other, the small bevel gears (**D**), with their spindles (**DI**), turn free in their bearings, thus permitting axle shafts (**A** and **B**) to turn at different speeds.

A study of Figs. 11, 12, 13, and 14 will make this principle clear. Note that the drive of the rear axle

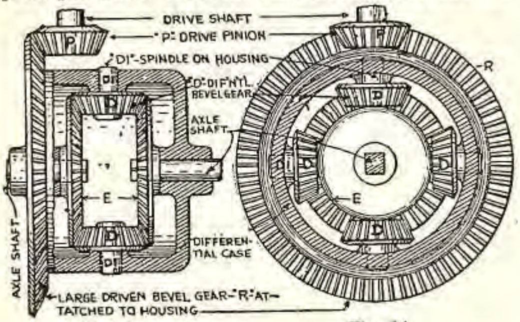


Fig. 13 Fig. 14

is through the drive pinion P, to gear R, thence through the differential case attached to it, then through the compensating gears D, to the bevel gears E, attached to the ends of the rear-axle shafts. You will observe that either axle shaft (A or B) could be held stationary, yet the other shaft could revolve.

Example of Differential Action

In order further to understand the action of the differential, refer to Fig. 11. Let us assume that the gear ratio of the rear axle is 4 to 1, which would mean that the ratio of bevel-driven gear (R) to drive pinion (P) would be 4 to 1. Consider that the engine is running at the rate of 1,000 r.p.m.

Consider gears (D) stationary, that is, we will assume, for the sake of explanation, that the spindles (DI) cannot turn on their bearings. Since the engine is running at 1,000 r.p.m., and the gear ratio is 4 to 1, the bevel-driven gear (R) would revolve $1{,}000 \div 4 = 250$ r.p.m. Since the gear (R) is directly attached to the differential case, the latter will also revolve at the rate of 250 r.p.m. As we have considered the differential gears (D) as being stationary with respect to the differential case, they merely act as a direct connection between the differential case and the axle-shaft gears (E); consequently gears (E) will also revolve at 250 r.p.m., causing axle shafts (A) and (B) with their wheels to revolve at 250 r.p.m. This is exactly what happens when the car is traveling straight ahead, since there would be no effort exerted to cause gears (D) to revolve; consequently we can consider them stationary as assumed above.

Now consider gears (D) free to revolve, that is, we will permit the spindles to turn in their bearings. Now let us hold the axle shaft (B) stationary, and see what happens. The gear (E) attached to (B) will also remain stationary. The gear (R) and the differential case will still revolve at 250 r.p.m., thus causing the spindles (DI) to pass around the stationary gear (E) attached to (B) at the rate of 250 r.p.m. This would cause the gears (D) to revolve rapidly within the differential case as they rolled around the stationary gear (E) attached to (B). Now let us consider what happens to the gear (E) attached to the axle shaft (A). The motion of the differential case would tend to revolve (A) at 250 r.p.m. as explained above, but the rapid rotation of the gears (D) would also impart a further rotative effort to the gear (E) attached to (A), with the result that (A) would revolve faster than 250 r.p.m. This is exactly what would happen if the car was abruptly turned to the right, as (B) would then remain stationary.

The relative speed of (A) to (B) can easily be determined, because the sum of the speeds of (A) and (B) will always equal twice the speed of the driven bevel gear (R). Let us assume that (R) revolves at 250 r.p.m. as stated: then the sum of the speeds of (A) and (B) would be twice $250 = 500$. If (B) is permitted to revolve at 250 r.p.m., then (A) will also revolve at 250 r.p.m., since their sum is 500. If (B) is only permitted to revolve at 100 r.p.m., then (A) will revolve at 400 r.p.m., since $100+400 = 500$, or, in other words, $500-100=400$. If (B) is permitted to revolve at 200 r.p.m., then (A) will revolve at $500-200=300$ r.p.m.

Thus is seen the effect of the differential when the car is making a sharp or gradual turn. When making a gradual turn, (B) will revolve at nearly the same speed as (A), while, when making a sharp turn, there will be a great difference between the speeds of (B) and (A).

Q. 1: If the car was driven through mud, snow, sand, or on a greasy street, and the wheel attached to the axle shaft (B) (Fig. 11) should strike an obstruction that would cause that wheel to stop, describe what would happen.

Ans: Gear (E) attached to axle shaft (B) would also stop, thus causing the wheel attached to axle shaft (A) to spin, since it has slight traction on the slippery road.

Q. 2: Suppose you were starting from a standstill on a slippery road and one wheel should start to spin, and the car failed to move, what would be the reason and remedy?

Ans.: The wheel which is spinning would have no traction, that is it could not grip the road; thus it would spin and the other wheel, even though it had traction, would remain stationary. The remedy would be to put on skid chains, if available, or to tie a piece of rope around the tire, or to throw dry dirt or twigs under the wheel which spins, in order to give it traction or grip.

Q. 3: When the wheel spins, for example, the one attached to axle shaft (B) (Fig. 11), what action is taking place in the differential?

Ans.: The drive pinion (P) would be driving the driven bevel gear (R) thus causing the differential case to revolve with it. The axle shaft (A) with its gear (E) would remain stationary; the differential gears (D) would revolve rapidly around the stationary gear (E) attached to axle shaft (A). The motion of the differential case would tend to rotate gear (E) attached to (B) at the same speed as that at which the differential case is rotating, and the speed of (B) will be further increased by the fact that the gears (D) are revolving rapidly, as formerly explained.

When a double-chain drive is employed, the differential is placed on the jack shaft. The jack shaft is in two parts similar to a live axle.

Spur-gear differential: Most of the differential gears are of the bevel-tooth type. The spur-gear type (Fig. 15) is seldom used. Note that the illustration is that of a differential with a sprocket which was formerly used on a single-chain driven car.

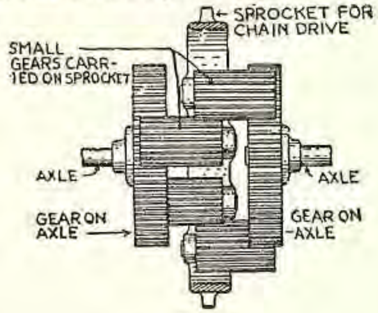


Fig. 15

BEARINGS [1]

Every part of the car that moves with a rotary, sliding, or other motion is supported in bearings, which together with proper lubrication reduce wear and friction.

There are three different types of bearings in general use: the **plain, roller and ball bearings.**

[1] See page 1063: "How to order bearings."

Bearings are called upon to do two kinds of work: to take a **radial** load or a **thrust** load or a **combination** of both.

A radial load is a load or pressure perpendicular to the shaft supporting the load. For instance, the wheel bearings of an automobile, when running on a perfectly level road, are subject to radial loads.

Thrust load is a load or pressure parallel to or in direction of the shaft. When the automobile strikes a curve, a thrust load is imposed on the bearings in the wheels—that is, to the side, or endwise.


Fig. 16


Fig. 17


Fig. 18

Fig. 16. Pure radial load.

Fig. 17. Combined radial and thrust load.

Fig. 18. An awkward way of resisting a combined end-thrust and radial load.

We might illustrate the relation between thrust and radial loads in this way: A man could be considered as being subjected to pure radial load when walking on an absolutely level surface (Fig. 16), but when this man walks along a hillside, without either ascending or descending the hill, as illustrated in Fig. 17, he is subjected to a combination of radial and thrust load; the thrust load having a tendency to push him down the hill.[1]

If a straight roller were called upon to take a thrust load as well as a radial load, it might be compared to the man in Fig. 18, he would need a crutch to prevent his toppling over. Therefore a ball-thrust bearing would be necessary at the end of the straight roller bearing (Fig. 22, below).

Plain bearings are usually on the main crank shaft, cam shaft, and connecting rods of an engine and take a radial load. Plain bearings can also be designed to take thrust loads.

Roller bearings are used in the wheels, rear axle, transmission, and other places and when straight, as in Fig. 19, they can only take a radial load. The roller itself runs over an inner race and inside of an outer race, case hardened.

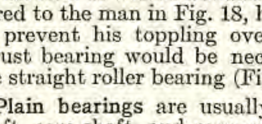


Fig. 19

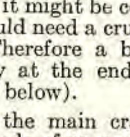


Fig. 20

When a roller is tapered, it runs over a cone-type hardened race (Fig. 20), and inside of an outer race, arranged as in Fig. 21. This type of roller bearing will take a radial and a thrust load without the use of a separate thrust bearing.

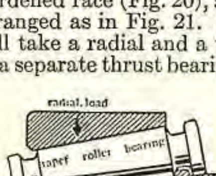


Fig. 21

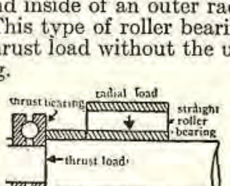


Fig. 22

[1] From *American Automobile Digest.*

The groove in the race and roller (Fig. 21) take the thrust load as well as the cone shape of race.

A straight roller bearing, to take a thrust load as well as a radial load, would require a separate thrust bearing (Fig. 22).

Ball bearings are also used on the wheels, rear axle, transmission and other places and are divided

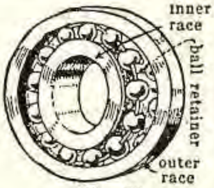


Fig. 23

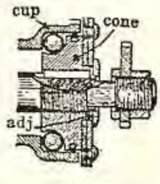


Fig. 24

into three general classes; cup and cone, annular, and thrust.

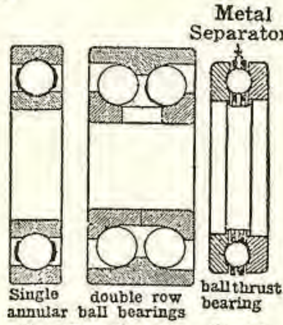


Fig. 25 Fig. 26 Fig. 27

The cup and cone bearing is shown in Fig. 24, and is used on many cars in the front wheels. This type of bearing is used extensively on bicycles. It is designed for radial loads, but is capable of withstanding considerable thrust also. It is adjustable.

The annular ball bearing is a bearing with an inner and outer race, which is grooved and hardened. They are not adjustable. This type can be a "single row" of balls (Figs. 23 and 25) or "double row" (Fig. 26). The single row takes a radial load.

The races of the double row are so shaped that it will withstand considerable thrust as well as a radial load. It is used where space would not permit the use of a separate radial and thrust bearing. This bearing is used extensively for supporting the drive pinion and taking the drive-shaft thrust in the rear axles.

The ball thrust bearing is shown in Fig. 27. This bearing can be used only where the load or stress is strictly a thrust or end-to-end load. This type is often used in clutches and is extensively used on the propeller shaft driving the propellers of motor boats.

The two parts the balls touch are called races. The one or two balls at the lower side support the entire weight and must be strong enough to hold up without being crushed. In automobiles, the balls are large and run in size up to 1 in. di. hardened and polished.

Sometimes balls wear flat or crack; if so a click will be heard and they must be replaced with perfect balls at once.

If one or more of the balls break in the annular self-contained bearing, pick out the pieces and run in on it and immediately secure another complete, or have it repaired by the manufacturer or a concern specializing in this work. If a ball breaks in a cone-type bearing it can be replaced.

INSTRUCTION No. 5

CLUTCHES: Principle and Construction

GENERAL EXPLANATION

Purpose of the Clutch

The word "clutch" as used in connection with automobiles, indicates a device attached to cars having change speed gears of the sliding type, which permits the engine to be connected with, or disconnected from, the transmission, so that the car may or may not move while the engine is running.

The clutch is connected and disconnected from fly wheel of the engine by a foot lever.

When disconnected from the flywheel of the engine there is then no connection between the engine and rear axle.

When the clutch is connected with the flywheel of the engine, the power of the engine is connected with a rear axle—if the gears of transmission are not in "neutral" position.

If gears are in neutral position, the power of the engine would end at the end of the secondary shaft of transmission.

While other types of transmissions require clutches, they are of special kinds, and will not be referred to in this instruction. (The Ford, for instance, uses a different principle.)

Because a steam engine has behind it the pressure of the boiler, it can be called on to supply much more than its regular horse power for short intervals. A gasoline engine has no reserve power to call on, and cannot deliver more than a fixed horse power.

When the gasoline engine is required to start the car, it must overcome the inertia of the car. This might be greater than the power of the engine could accomplish, and the engine might be stopped instead of the car being started.

If the clutch made an immediate connection between the engine and the drive, the power of the engine would have instantly to overcome the inertia of the standing car.

The power of the engine coming from the revolving of the fly wheel, and the explosion that might be occurring in one of the cylinders, it would probably be stopped instead of the car being started.

If, however, the clutch is made so that the engine takes hold gradually, the inertia of the car will be overcome, and it will move faster and faster as the clutch permits the engine to apply its power more and more.

This is done by making the clutch in such a way that when it is applied, it slips, instead of instantly making a connection between the engine and the drive.

When the clutch is "let in," it connects the crank shaft of the engine through the fly wheel with the transmission through the clutch shaft, and if the gears are in the "neutral" (gears out of mesh) position, the counter or secondary shaft in the gear case of transmission will revolve without moving the car.

If the clutch is "in" and the gears are meshed, the course of the power from the crank shaft of the engine (Fig. 1) will then be through clutch, through gears, through drive shaft, driving pinion, large bevel gear on differential, through differential gears to axle shafts and wheels.

Clutches have two chief parts: one part (usually the fly wheel) is attached to the crank shaft of the engine, the other part (cone or disk or plate) is attached to the clutch or main shaft of the transmission.

When the two parts are separated, that is to say when the "clutch is thrown out" by the clutch pedal, they are independent of each other and the engine can run without moving the car.

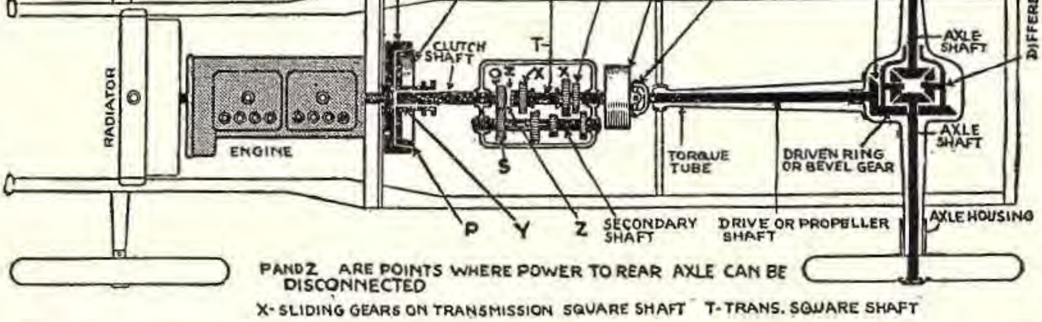


Fig. 1. Illustration explains how the power is transmitted from engine to clutch, thence to secondary or counter shaft. Note drive parts are fly wheel, clutch, clutch shaft, drive gear (O), secondary shaft gear (S), and gears on secondary shaft. The driven gears are the sliding gears (X) on the square shaft (T).

Note. This power to the rear axle is disconnected at point (P) when the clutch is "out," at which time the clutch and clutch shaft turn free from the fly wheel, and at (Z) when the drive and driven gears are in "neutral" or not in mesh. (This end of the square shaft (T) runs free in the end of the clutch shaft, and is not actually separated at (Z), as shown above.)

Clutch Action

Note in Fig. 1 the power from the engine is transmitted to the clutch shaft only through the clutch when in the rim of the fly wheel (if disk or plate type, then by the disks or plates as explained under that type of clutch).

Observe that the clutch shaft does not connect with the engine, but runs free at the end (Y), at all times in the hub of the fly wheel. The cone part of the clutch is connected with the clutch shaft so that when the cone turns, the clutch shaft must also turn. But observe that the cone slides on the square part of the clutch shaft so that it can be pushed out by the pedal or in by the spring. See also, Figs. 2 and 3.

When the friction part of the cone is out of the fly wheel, power ends at the fly wheel.

When the clutch is in, then power ends at the end of the secondary or countershaft, if gears are in neutral, in which position they are seen in Fig. 1.

When the two parts are connected, that is, when the clutch is "let in" by releasing the clutch pedal, the clutch cone on the clutch shaft is forced into frictional contact with the inside face of the fly wheel by means of a clutch spring and held there. The two parts being thus connected force the clutch shaft, gears (O and S) and secondary shaft to revolve with the engine, but do not drive the car unless the gears on the secondary shaft and the square shaft (T) are in mesh, or unless connection is closed at Z (Fig. 1) by dogs or an internal gear connection, which would be high speed.

When the clutch is "let in," the part on the fly wheel does not grip the part on the cone clutch immediately, unless they are moving at the same speed.

If they are moving at different speeds, which is usually the case, or when the part on the transmission is stationary, the two parts slip. This slipping continues until the two parts revolve at the same speed, when they bind together firmly. When "thrown out," they must separate instantly.

A disk or any other type of clutch used with the gear type of transmission is placed in the same relative position, back of the fly wheel, between the fly wheel and gear case. Although the construction may vary, the reader will note that the clutch is necessary on all cars.

Clutch pedals: The left-foot pedal on all cars of standard design is the "clutch pedal" and on the right the "foot brake pedal."

Types of Clutches

There are four types of clutches in general use: the **cone, disk, plate,** and **expanding** type.

The disk clutch (formerly called the "multiple disk") is a clutch with more than three disks and can be a **lubricated** disk clutch or **dry** disk clutch. A **plate** clutch is one wherein one plate is clamped between two others.

The Cone Clutch

This type of clutch is built into the fly wheel, and the fly wheel forms one of its parts. The rim of the fly wheel is broad, and the inside of the rim is made slightly funnel-shaped, forming the surface against which the cone part of the clutch presses (Fig. 2). The surface of the cone that bears against the fly wheel rim is often covered with leather. Some manufacturers use fabric material, running in oil. This part can be replaced.

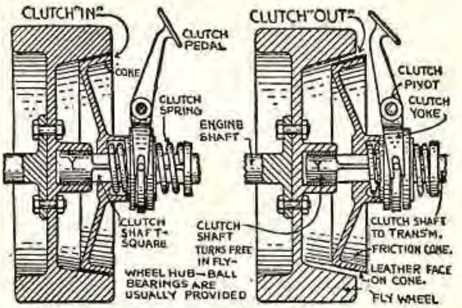


Fig. 2 Fig. 3

The Disk Clutch

The disk clutch (formerly termed "multiple disk"), consists of a number of disks which are pressed together when the clutch is "in," the friction between them causing one to drive the other. This type of clutch is very compact, and is frequently built inside of a metal housing cast to the engine frame. See Fig 4, next page.

To illustrate the principle of the disk clutch place a silver dollar between two silver half-dollars, and squeeze them together between the thumb and forefinger of one hand. With the other hand, try to revolve the dollar, but not moving the halves. It requires only a slight squeeze to produce sufficient friction to make it impossible to move the dollar.

Multiple disk clutches are of two general types: those that operate in an oil bath and those that run dry; called **lubricated** and **dry** types.

The **lubricated** disk clutcn **runs in oil;** its disks are usually alternate steel and bronze or all steel disks. The type that **runs dry** is usually composed of steel disks, one set of which is faced with a friction material of woven asbestos fabric.

Principle of the Lubricated Disk Type of Clutch

Parts: Fig. 5 shows the parts of the clutch separated from each other. The disks (A) are attached to the flange on the engine shaft; the smaller disks (B) are attached to the transmission shaft. The large disks (A) and small disks (B) are placed alternating.

The two flanges (F and **F1**) have pins extending from them, the disks (**A** and **B**) having holes so that they may be slipped on the pins or studs (**P, P1**)

The studs (**P1**) of the small disks (B) pass through the openings in the large disks. Thus the outer edges of the small disks come in contact with the inner edges of the large disks. All of the small disks (B) connect with flange **F1**, which has a square hole and slides on the clutch shaft by movement of the clutch pedal.

All the large disks (A) connect with the flange (F), which is connected to the engine shaft.

Assembled clutch: As will be seen from Fig. 4, which is the clutch assembled, the two flanges are connected only by the friction between the large and small disks, when the spring presses the parts together. The entire clutch is placed inside a casing, and runs in oil.

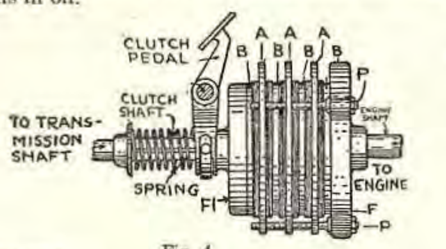


Fig. 4

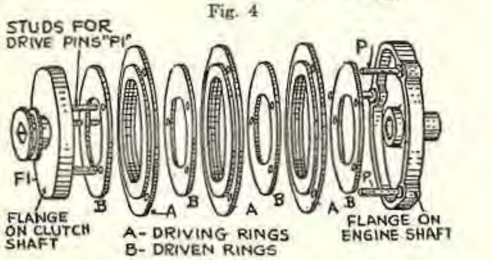


Fig. 5

When the clutch pedal is pressed forward, the clutch is "thrown out," the oil then flows between the disks and when the clutch is "in" and the spring presses the disks together, the oil is squeezed out from between them. While it is being squeezed out the clutch is slipping, and it begins to bind when the pressure has squeezed it out and the disks in consequence feel the effect of the friction. When the clutch is "thrown out," one set of disks may revolve independently of the other, for they are not connected in any way.

Hele-Shaw Lubricated Type of Disk Clutch

In the Hele-Shaw disk clutch (Fig. 6), a similar principle is adopted. The plates consist of a number of alternate bronze and steel disks much thinner. They are corrugated to increase the grip.

Half the plates are rotably connected by grooves with the driving member, and the alternate half with the driven member. When the clutch pedal is

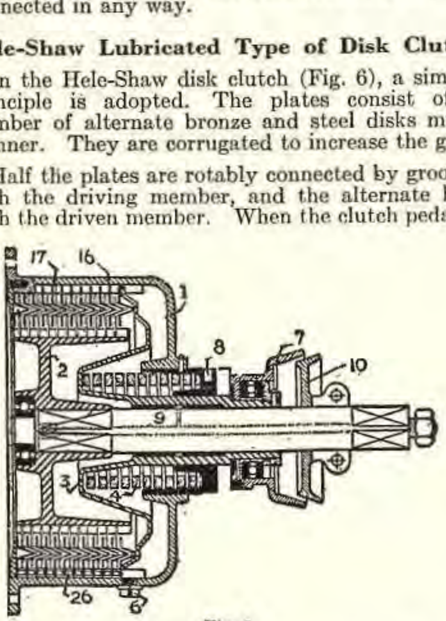


Fig. 6

released, the clutch spring presses these disks together, and they all rotate as a solid mass. When the clutch pedal is depressed, the spring pressure is removed and the plates separated.

Referring to the illustration (Fig. 6) the outer oil-tight case (1), to which the driving bronze plates (16) are keyed, is bolted to the fly wheel of the engine. The inner core (2) is keyed directly to the clutch shaft and to it are keyed driven steel plates (17).

The clutch is shown engaged as normally held by the spring (4) which actuates the ring (7) and the sliding presser (3). To facilitate quick disengagement, small springs (26) are fitted between the disks.

The case is oil-tight, provision being made for the replenishment of the oil through a plug (6) for the purpose.

Adjustments are made by means of an adjusting nut (8), and excessive spinning or dragging is prevented by a cone brake (10).

Principle of the Dry Disk Type of Clutch

Fig. 7 illustrates a dry disk type of clutch used on the Cadillac. The driving disks (A) are covered on both sides with a friction material, composed largely of asbestos, and are driven by six keys in the clutch ring (H) which is bolted to the engine fly wheel (G).

The driven disks (B) are not covered. These disks are carried on the clutch hub (E) and drive it through six keys on the hub. The clutch hub is keyed to the transmission shaft (F).

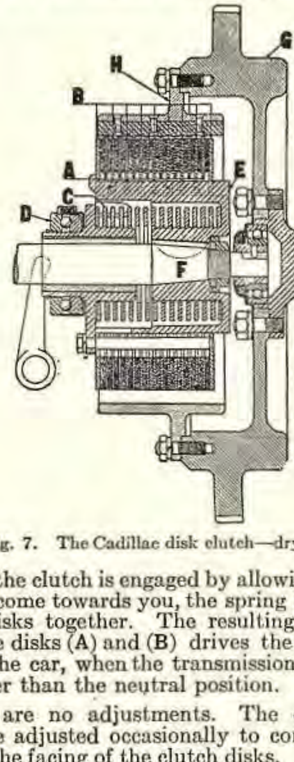


Fig. 7. The Cadillac disk clutch—dry type.

When the clutch is engaged by allowing the clutch pedal to come towards you, the spring (C) forces all of the disks together. The resulting friction between the disks (A) and (B) drives the clutch shaft (F) and the car, when the transmission control lever is in other than the neutral position.

There are no adjustments. The clutch pedal should be adjusted occasionally to compensate for wear on the facing of the clutch disks. There is one point (D) on the clutch for lubrication.

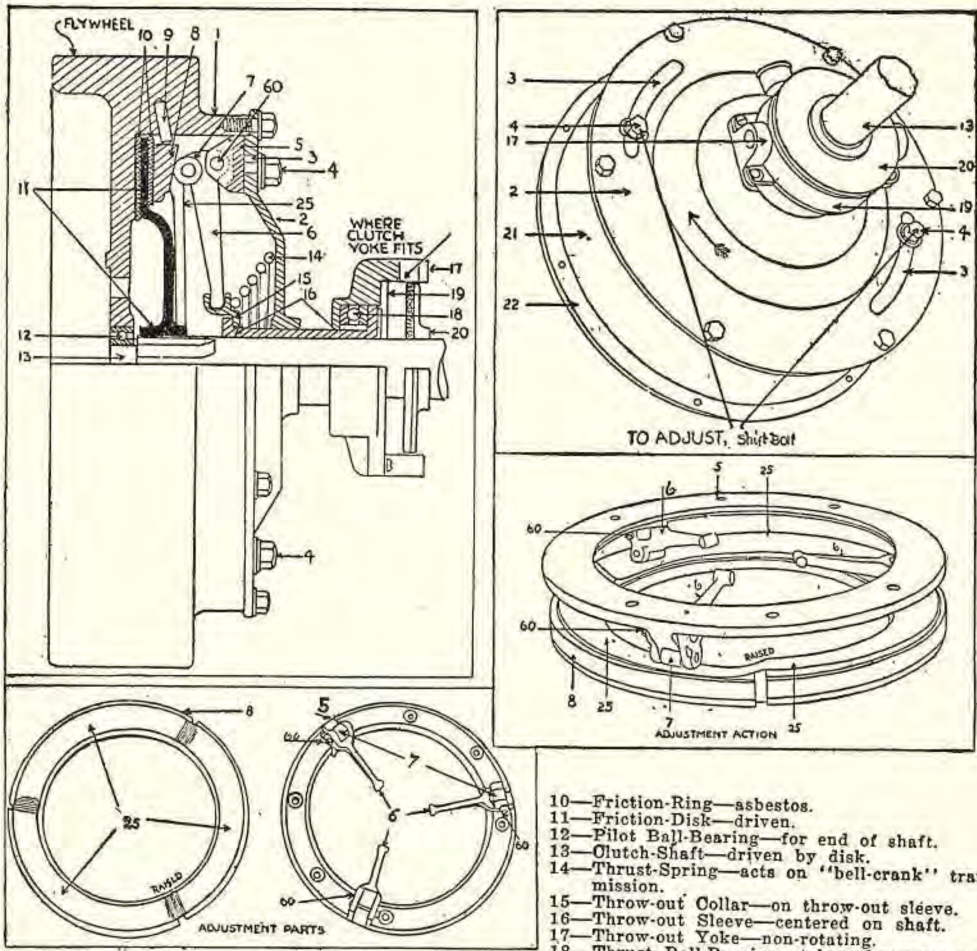
There are 17 steel plates, having 9 driven disks and 8 driving disks. The coil spring is held under 300 lbs. compression.

The Single-Plate Clutch

The S. A. E. term the disk clutch (formerly called the "multiple disk") a clutch with more than three disks.

The **single-plate clutch** is where one plate is clamped between two others. It is a popular type of clutch. It is a variation of the disk type, the latter comprising a large number of narrow disks, while the single-plate type usually consists of but three broad disks or plates, the ordinary type having two driving plates and one driven plate.

An example of a single-plate clutch is described in detail in the following matter. In this type, the clutch effect is created by wedging the plate. The type which will now be described is the Borg and Beck make, shown in Fig. 8, next page.



1—Clutch-Casing—cast with fly wheel.
2—Casing-Cover—carrying adjustment-ring.
3—Cover-Slot—for adjustment-bolt.
4—Adjustment-Bolt—for take-up action.
5—Adjustment-Ring—mounts thrust-levers.
6—Thrust-Lever (bell-crank)—mounts roller.
7—Thrust-Roller—acts against thrust-ring.
8—Thrust-Ring—acts against asbestos ring.
9—Driving-Pin—for thrust-ring.
10—Friction-Ring—asbestos.
11—Friction-Disk—driven.
12—Pilot Ball-Bearing—for end of shaft.
13—Clutch-Shaft—driven by disk.
14—Thrust-Spring—acts on "bell-crank" transmission.
15—Throw-out Collar—on throw-out sleeve.
16—Throw-out Sleeve—centered on shaft.
17—Throw-out Yoke—non-rotating.
18—Thrust Ball-Bearing—takes throw-out pull
19—Brake-Plate—rigid on throw-out yoke.
20—Brake-Collar—keyed on shaft.
21—Detachable-Casing—self-contained clutch.
22—Mounting-Flange—bolts against fly wheel.
23—Driving-Bolt—for thrust-ring (not shown).
24—Shaft, Brake and Universal Connection (not shown).
25—Adjustment-Incline—take-up seat for roller.
60—Bell-Crank Pivot—mounts thrust-lever.

Fig. 8

Borg & Beck Single-Plate Clutch

Principle: This type of clutch runs dry. The action is best understood when it is kept in mind that among the revolving parts, only the driven group: disk (11), shaft (13), and brake collar (20), can stand still when the fly wheel is running; all other parts being "anchored" to the fly wheel, must always revolve and drive with the latter.

When clutch is "in": The asbestos friction rings (10), though not positively attached to either the driving or the driven parts, will, in practice, "freeze" to the unpolished faces of the inner case of fly wheel and thrust-ring (8). They will thus always run bodily with the fly wheel.

When clutch is "out": The foot lever is applied which telescopes the coil spring (14) back, by action of the throw-out sleeve (16), which causes the roller (7) to withdraw a sufficient distance from the face of the thrust-ring (8), to permit the latter, with its companion friction-ring (10), to "back away" bodily, from friction-disk (11), thus releasing the disk from the friction-grip, and permitting it and other driven parts to come to a stop, while the fly wheel and parts anchored to it revolve.

Adjusting the Single-Plate Dry Clutch

Take-up action:[1] The roller-seat face of the thrust-ring (8) is formed on three, equal succeeding, take-up "inclines" (25); the ring being ¼-inch thicker, at the high end of each "incline" (25) than at the beginning, or low end. The three thrust-levers (6) are mounted upon, and equally spaced by, the adjustment ring (5); and this ring is adjustably mounted against the inner face of the cover (2), by means of the adjustment-bolts (4), of which there are two, through slots (3) in the cover.

When the bolts (4), are "slacked," and shifted in their cover-slots (3), they control and shift with them the ring (5), the latter carrying with it the levers and rollers (6 and 7), thus shifting all the rollers to new seats against the non-shifting thrust-

[1] See also Index under "Borg & Beck clutch," which is also discussed in the Repair Section of this book.

ring; and, these seats being farther up the ring "inclines" (25). Where the inclines are thicker in cross-section, the ring is necessarily thrust so much farther toward the other friction parts, to compensate for any friction wear, and to maintain, at all times, a perfect friction grip.

Therefore to **adjust the clutch,** the clutch is held entirely out. With the clutch thus held "out," it is only necessary to "slack" the adjustment-bolts (4), tap either of them "clockwise," in the slot (3) on the cover, a quarter or half-inch or any other distance required, thus shifting the ring (5), and carrying the levers and rollers to new seats, upon thicker sections of the thrust-ring. This compensates for the friction wear which made the adjustment necessary.

If too much oil gets into the clutch and causes slipping: It will be necessary in this case to unscrew the bolts (4) about three turns, have someone hold out clutch, and let the oil drain out. It is also desirable to squirt gasoline into the interior of the clutch to wash out the oil. If slipping continues, the trouble is due to oil working into the clutch housing and it must be separated from the main oil supply of the oil pan of the engine.

Removing clutch: First remove the transmission. Mark the clutch cover that bolts to the fly wheel with a punch and place a corresponding mark on the fly wheel, in order that it may be put back in the same position. The cover plate must not be turned.

Replacing clutch: There are two asbestos fabric rings; one lies against the face of the fly wheel (10), next to this comes the driven plate (11), then another friction washer (10). The cast thrust ring (8) comes next, but before installing, make sure that the driving pins (9) are in place in the inside of the fly-wheel rim. Drop the thrust ring (8) in position, so that the three slots fit over the pins (9). The adjustment ring (5), with its parts assembled to it, should not be installed. The adjusting ring (5) fastened to the cover plate by means of two cap screws and cover plate bolts to the fly wheel.

A clutch brake is provided, and this comes into action when the clutch pedal is pushed all the way down. The purpose is to stop the transmission gears from spinning when the clutch is disengaged. The throw-out collar (15) presses against the brake collar (20). The clutch brake is mounted on the transmission shaft and is faced with asbestos fabric.

If the clutch is worn, trouble will be experienced when shifting gears into first speed when car is standing. The clutch will appear to drag and will continue to drive the transmission gears when fully disengaged, so it will be difficult to mesh the gears. To remedy this remove the oil pan; have someone hold out the clutch, while the throw-out clutch and collar are examined to see if the collar (20) actually touches the brake or not. If it does not, the transmission should be removed, and if the brake-friction facing is in good condition, there is no need of installing a new one. See that the throw-out is not coming in contact with the brake flange and ascertain if it should be adjusted so that these two points form a contact.

Note. Always remember to drive with the foot off the clutch pedal. Make sure that the clutch pedal does not strike or press against the toe board. See also, Index under "Adjusting clutches."

UNIVERSAL JOINTS

A universal joint is a flexible connection between two shafts, which permits one to drive the other, although they may not be in line. Refer to Figs. 9, 10, and 11 and study the principle. Universal joints are usually placed forward and rear of the drive shaft. They are also termed "cardan joints."

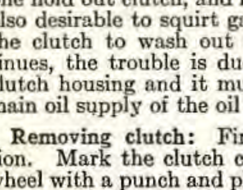


Fig. 9.
Universal joint in a straight line.

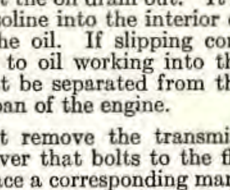


Fig. 10.
Out of line.

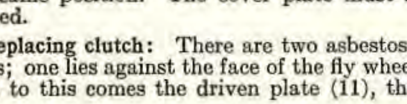


Fig. 11. Angular drive.

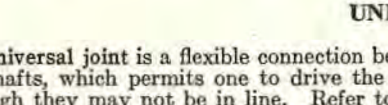


Fig. 12. Straight-line drive.

Universal joints are necessary on automobiles with shaft drive, for while one end of the driving shaft is attached to the transmission shaft, which is on the frame, the other end is connected to the axle, and is constantly moving up and down as the wheels follow the roughness of the road. If no universal joints were used, the shaft would jam in its bearings from the up and down movement of one end of it.

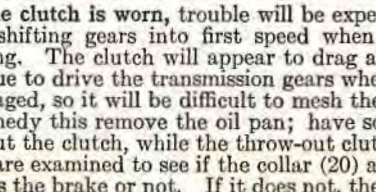


Fig. 13

Another type of universal joint is the flexibie Thermoid-Hardy (Fig. 13). This joint is used only on "straight-line" drive. It consists of flexible discs secured to spiders on the ends of the shaft by means of bolts and corrugated washers. This assembly is bolted between a spider on the rear of the transmission and another on the front of the pinion shaft. The only attention these joints require is to see that all bolts are kept tight.

See Index for "Universal joints, adjusting," etc.

Angular and Straight-Line Drive

The angular drive is where the transmission is above the axle, as in Fig. 11.

The straight-line drive (Fig. 12) is where the drive shaft is in line when the car is carrying an average load, and is thrown out of line only to the extent that the chassis moves up and down on the springs. The variation is as great in one direction as another, but on the angular type, the shafts are never in alignment and the universals are required to act through a considerable angle.

INSTRUCTION No. 6

TRANSMISSION: Principle and Construction; Gear Shifts

GENERAL EXPLANATION

Purpose of a Transmission

When a bicyclist wants to race on a level track, he gears up his wheel with a larger sprocket, so that one revolution of the crank takes him farther. Yet if he takes his wheel, with this large sprocket on the pedal shaft, out on the road where there are hills, he must get off and walk or exert an extra lot of power. This clearly shows that if a bicyclist wants to speed while on the level, and yet take all hills, he must change the drive sprocket.

The same principle applies to the automobile. For this reason the automobile is provided not only with two changes of gears (instead of sprockets), but sometimes with three and even four changes of gears. These gears are contained in a gear-box usually placed back of the clutch.

The principle upon which all change-speed gears work is the fact that when two gear-wheels or spur-gears are meshed together the larger wheel turns more slowly than the smaller wheel.

As an example, a gear-wheel with 10 teeth, in mesh with a second wheel having 20, would revolve twice as fast as the latter, the explanation being that when the 10-tooth gears of the smaller wheel have moved round once they will have engaged with only 10 teeth of the larger wheel, and therefore will have turned the larger wheel through only half a revolution; that is, it will be necessary for the smaller wheel to revolve twice in order that the larger one may revolve once.

With this piece of elementary information, we will observe that in the gear-box (see below) there are two shafts—the upper one coming from the engine through the clutch, and the lower one continuing to the back axle.

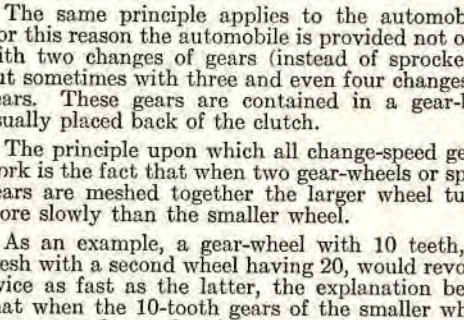


Fig. 1. This illustration is intended to simplify the explanation. In actual practice the arrangement is slightly different.

Each shaft is fitted with three different sized gear-wheels numbered in the illustration, 1, 2, and 3. Those on the upper shaft are fixed to the shaft itself, but those on the lower shaft are able to slide on a keyway, to right and left along the shaft. The shaft is not round like the upper one, but is squared, so that although the sleeve of the gear-wheels can slide backward and forward, they cannot revolve independently of the lower shaft.

In order now to vary the speed of the car, it is only necessary to slide the gear-wheels along the lower shaft until the correct two gears come into mesh to form the gearing required.

The illustration, for instance, shows the intermediate speed-gear in mesh, but were we to move the gears to the right so that wheels 1 and 1 come into mesh, we should put the car on its first speed, that is its lowest speed, so that, with the engine running normally, the car would be moving very slowly, the driving gear being much smaller than the driven gear.

When, however, the sleeve is moved to the left, so that gears 3 and 3 mesh, the effect is reversed. Now we have the driving gear much larger than that driven, and the result will be that when the engine runs normally the car will be traveling at a very high speed.

The sides of the teeth of the gears are usually made like the point of a chisel, so that when two gears are brought together they will mesh easily. (To "mesh" means that the teeth of two gear-wheels become engaged.)

Types of Transmissions

There are three types: the **sliding-gear, planetary,** and **friction-disk** type.

The **planetary** type used on the Ford (Fig. 8), is explained in the Ford Instruction. The **friction-disk** type (Fig. 9) is now seldom used.

There are two types of **sliding-gear** systems: the old-style **progressive** type (Fig. 2) and the modern **selective** gear type, pages 27 and 28.

The **progressive** type was discarded because it was necessary to pass one gear through another which made a clashing noise and was difficult at times to operate.

With the **selective** type it is not necessary for the sliding gear to pass through another gear. It is easier and quicker to operate and considerably less noisy. It is with this type that we shall deal.

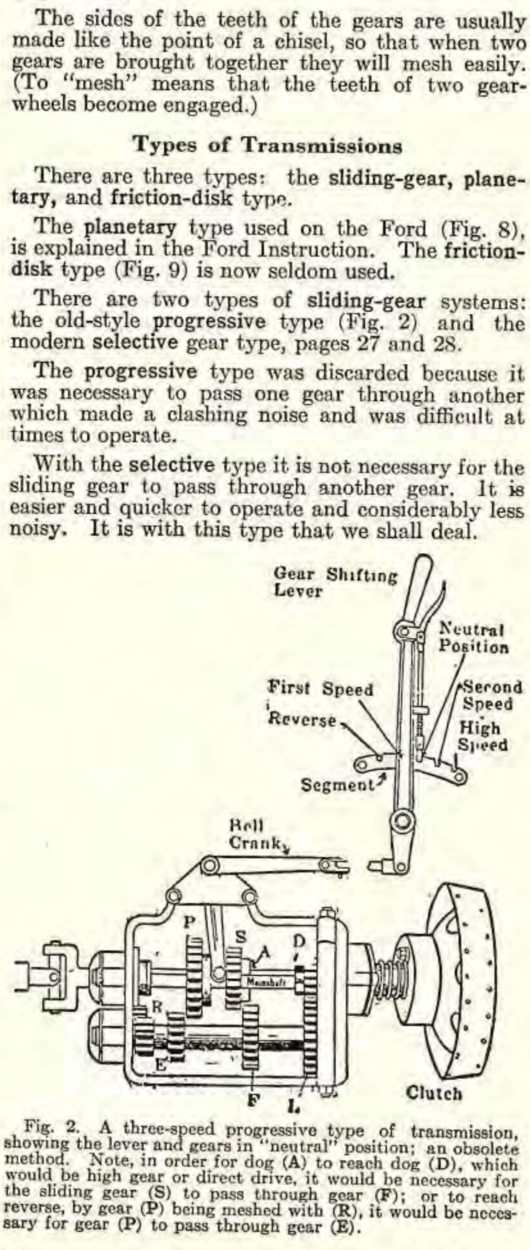


Fig. 2. A three-speed progressive type of transmission, showing the lever and gears in "neutral" position; an obsolete method. Note, in order for dog (A) to reach dog (D), which would be high gear or direct drive, it would be necessary for the sliding gear (S) to pass through gear (F); or to reach reverse, by gear (P) being meshed with (R), it would be necessary for gear (P) to pass through gear (E).

Location of the Transmission

The location of the transmission on the modern type of car is where the transmission and clutch are connected to the engine in one unit, termed a "unit power plant" (Fig. 3).

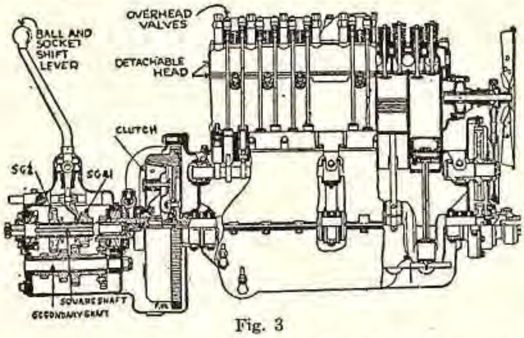
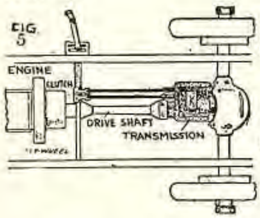
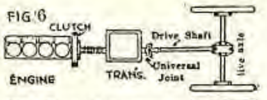
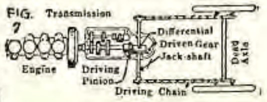


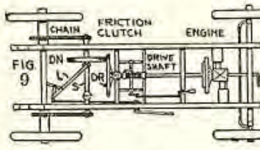
Fig. 3

On some of the earlier type of cars the transmission was placed adjoining the rear axle housing (Fig. 5).









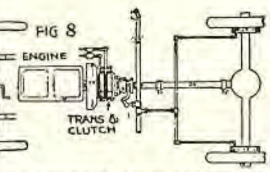


Fig. 6 shows the transmission separated from the engine. This method is used on the Locomobile.

Fig. 7 shows the location of the transmission when used with a double-chain drive and a dead rear axle.

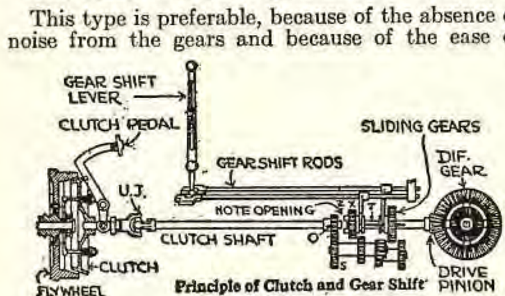
Fig. 8 is the Ford planetary transmission location, explained under Ford Instructions.

Fig. 9 is a friction-disk type of transmission, used on cars of the early period. The drive disk (DR) connected to the drive shaft transmits the power through the driven disk (DN) to the jack shaft, thence by sprockets and chain to the dead rear axle.

The change of speeds is obtained by sliding the driven disk (DN) on the keyed shaft (S) by the lever (L). By this means several ratios of speeds could be obtained. The disadvantage, however, was due to slipping. This type is now seldom used.

The Selective-Gear Type of Transmission

This type is preferable, because of the absence of noise from the gears and because of the ease of



Principle of Clutch and Gear Shift
Fig. 10

operation. The gear-change ratio, or gear desired, is "selected" by movement of the gear-shift lever, and the shift can be made without one gear passing through another.

The relation of the gears to the clutch is shown in Fig. 10. The principle of the selective type of transmission is shown on pages 27 and 28.

Referring again to Fig. 10, note that the power is transmitted from the fly wheel to the clutch, thence from the clutch shaft to gear (O and S), through the sliding gear for first or second speed. For high speed, small dog-clutches on the sliding gear (X), on the square shaft (T), mesh with dogs on gear (O), which makes the drive direct to the rear axle. See also Fig. 12.

Relation of Parts

How the change of gears is obtained. Note, in Fig. 12, the square shaft (130) is independent of the clutch shaft (134). Also note, in Fig. 11, that the gear (128) and the driven gear on the countershaft, as well as the countershaft itself (129), always turn together. Thus power from the engine would end at shaft (129), providing sliding gears (SG-1 and SG-2) were in the position shown, which is "neutral" position.

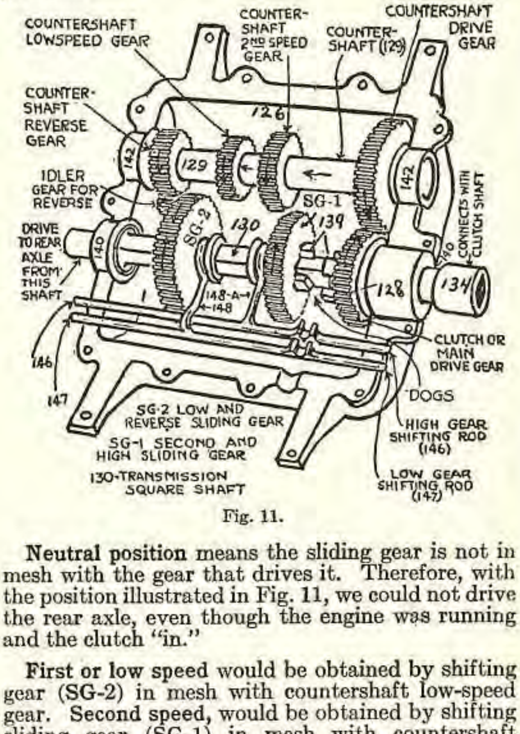


Fig. 11.

Neutral position means the sliding gear is not in mesh with the gear that drives it. Therefore, with the position illustrated in Fig. 11, we could not drive the rear axle, even though the engine was running and the clutch "in."

First or low speed would be obtained by shifting gear (SG-2) in mesh with countershaft low-speed gear. **Second speed,** would be obtained by shifting sliding gear (SG-1) in mesh with countershaft second-speed gear. **Third or high speed,** would be

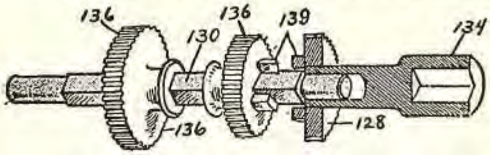


Fig. 12. Transmission square drive shaft (130) and sliding gears (136).

obtained by shifting (SG-1) forward so that dogs (139) would grip; then the drive would be direct to the rear axle, but the countershaft and its gears would also turn, but not being in mesh with the driven gears it would make no difference. **Reverse** would be obtained by shifting (SG-2) back until it meshes with the idler gear, which would reverse the direction of drive shaft (130).

Remember—gears cannot be shifted until the lever is brought to "neutral" position.

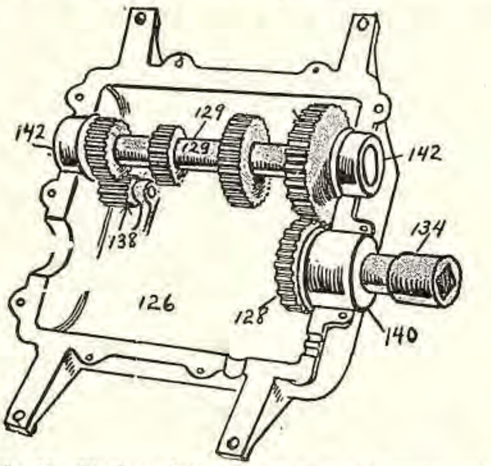


Fig. 13. The lower half of transmission with countershaft (129) and its gears which are permanently attached thereto. Idler gear (138), clutch or main drive gear (128), and clutch shaft (134) are also illustrated.

A Modern Selective-Gear Type of Transmission

The transmission in Figs. 11, 12 and 13 gives a clear explanation of the relation of one part to another.

The modern transmission now uses internal gears instead of "dogs." For instance, see Fig. 18, page 28. Note that instead of "dogs" (139, Fig. 12), the gear (8, Fig. 18) has internal teeth which mesh with a smaller gear on the side of gear (9).

The transmission (Fig. 18) is connected to the engine. It is therefore termed a "unit power plant." There are three speeds forward and one reverse.

Operation of the Gear-Shift Lever

There are two types of gear shift levers: the "gate" principle and the "ball-and-socket" type. The latter is used more than any other type.

The gate type: The gate type is shown in Figs. 14 and 15. A simplified explanation as to how the shift lever operates in relation to the shift bars (146 and 147) and shifting or sliding gears (SG-1 and SG-2) will be made clear by referring to Figs. 11 and 14.

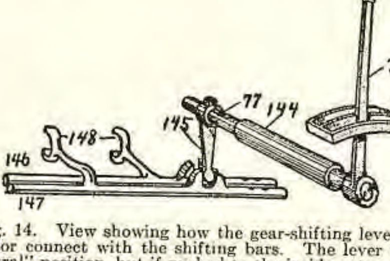


Fig. 14. View showing how the gear-shifting lever and the selector connect with the shifting bars. The lever is now in "neutral" position, but if pushed to the inside gate or selector, it would shift the inside bar (146); if pushed to the outside gate position it would shift the outside bars (147). Note, that the lever moves sidewise as well as forward and backward.

The movement of the gear-shift lever for different speeds varies on different cars. For instance, in

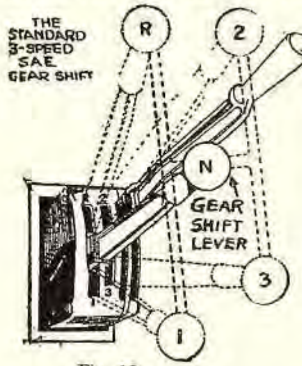


Fig. 15

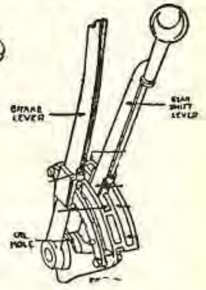


Fig. 16

Fig. 15. A three-speed forward and reverse gate type gear shift.
Fig. 16. A four-speed forward and reverse gate type gear shift.

Fig. 15, to obtain **first or low speed,** the gear-shift lever, which is now neutral (N), is moved sidewise to the left and then back. To obtain **second speed,** it is moved sidewise to the right and then forward; for **third, or high speed,** to the right and back; for **reverse,** to the left and forward.

The four-speed gate type of gear-shift (Fig. 16) corresponds with that shown in Fig. 20, page 29.

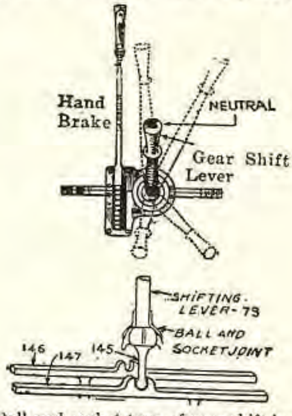


Fig. 17. Ball-and-socket type of gear-shift lever, with three speeds forward and reverse. The gear-shift lever (73) is now upright in the center of the socket and is in "neutral" position.

The ball-and-socket type of gear shift shows almost identically the same principle as the gate type, except the movement of lever (73), (Fig. 17), is in a "ball and socket" instead of a "gate." Note that arm (145) serves the same purpose as arm (145) (Fig. 14). This is the type in general use.

S. A. E. Standard Gear-Shift Movements[1]

The gear shifts as recommended by the Society of Automotive Engineers are illustrated on page 29.

The transmission, giving **three** forward speeds and one reverse speed (gear changes) is in general use. On some few large cars, and also on most types of trucks, the four-speed transmission is used. Figs. 19 and 22, page 29, illustrate the **standard S.A.E. three-speed gear shift** as used on the majority of passenger cars (see also pages 635 to 639) and light-duty trucks. The "selector" can be of the "gate" or "ball-and-socket" type, the latter being almost universally used.

[1]See page 912 for "S. A. E. standard truck gear shift."

Clutch shaft (19) is permanently connected with the main drive or clutch gear (9) of the transmission. The other end (CE) works free in a ball bearing in the flywheel, but does not connect with the flywheel.

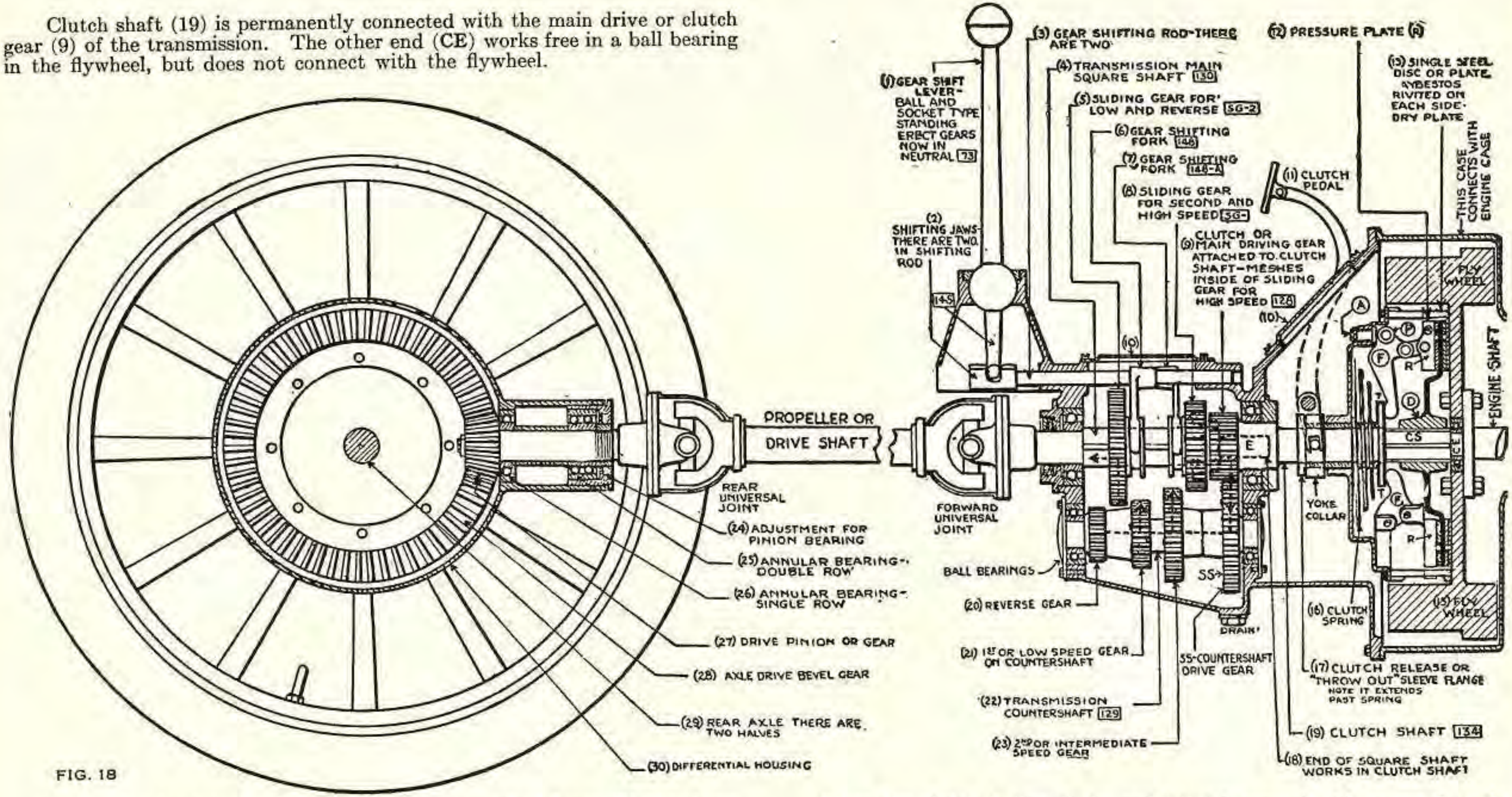


FIG. 18

When the clutch is "in," a spring (16) presses against flange (T) of a sleeve, causing the three fingers (F) working on pivots (P) to apply pressure through pressure plate (R) (a ring); this in turn applies pressure against the single plate. The single plate (13) is fitted with friction rings riveted on each side. This friction material clutches flywheel. The drive is then through driven plate (13) to plate hub (D), then a square section of the clutch shaft (CS) to the main drive gear (9). Note (CS) part of clutch shaft is squared and clutch plate hub (D) slides thereon.

When the clutch is "out," the pedal (11) is pressed; this causes the yoke collar to press against flange (17) of the sleeve. This action causes flange (T) on the other end of the sleeve to relieve the pressure against fingers (F). This releases the pressure against the single plate (13) and disengages clutch with flywheel.

The adjustment of fingers (F) or pressure against the plate is at (A). This type of clutch runs without oil.

Note. Figures in the squares at the end of the wording of Fig. 18 compare with reference figures on transmission on page 26 (Fig. 11).

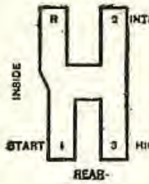


Fig. 19

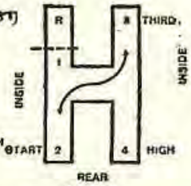


Fig. 20

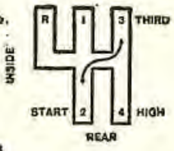


Fig. 21

Fig. 19. The S.A.E. Standard three-speed gearshift positions: (1) low or first speed; (2) intermediate or second speed; (3) third or high speed; (R) is reverse. Note that reverse and second speed are forward movements. Fig. 20. The S.A.E. standard four-speed gearshift positions. This corresponds with Fig. 16 (page 27). Note the reverse (R) is a further movement in the same slot with first-speed movement. Fig. 21. Four-speed; same as Fig. 20, except that the reverse (R) is in a separate slot, to the side of the first speed (1).

Note: The location of reverse position on a four-speed gearshift is optional, but protection by a latch or the equivalent must be provided against the accidental engagement of the reverse. See also page 912.

Example of Gear Shifts

The gear-shift principle (Fig. 22) is the "ball-and-socket" type and standard S. A. E. movement, as shown in Fig. 19. **The transmission** is of the "selective-gear" type, three speeds forward and one reverse. (Studebaker model "EJ" is used as an example.) Note that the gear-shift lever (1) is now upright and in **neutral** (N) position. If shifted according to the movements, first, second, third and R, the various transmission-gear ratios will be selected as shown in Fig. 22 below.

Remarks Relative to Changing Gears

To start the engine: See that the gear-shift lever is in neutral position. The clutch is then in, but the car will not move. Turn on the ignition switch and crank the engine.

To start the car: Speed up the engine slightly. Throw out the clutch by pressing the left foot pedal. Shift the gear-shift lever to first speed. Let in the clutch. Speed up the engine to give momentum to the car, and if on a level road, you can then throw out the clutch, quickly shift to third speed, and then let the clutch in. If on a hill, go to second speed instead of third, and then shift to third speed after the car is well under way.

To stop the car: Throw out the clutch, apply the foot brake, and slow the engine down. After the car stops, shift gears to neutral, then let clutch in. In order then to stop the engine, turn off the ignition switch.

Changing gears from a higher to a lower speed, when the car is running, is seldom done, as the speed of the engine is controlled instead, unless in a congested district it is necessary to run very slow, or if taking a hill and the engine pounds. This indicates that the hill is too steep for the power of the engine, and a change to a lower gear should be made at once by throwing out the clutch and shifting the gear lever.

Never shift to a lower gear when running at a fast speed, as there is danger of stripping the teeth from the gears.

Never shift to reverse gear unless the car is at a dead standstill.

Note. The shift gears by shifting ought to be made without a particle of noise if the clutch is thrown out when shifting. If there is noise, then it is usually due to the clutch not being fully thrown out or dragging or spinning, or to the transmission shaft, or to the fact that the transmission shaft is out of line owing to worn bearings.

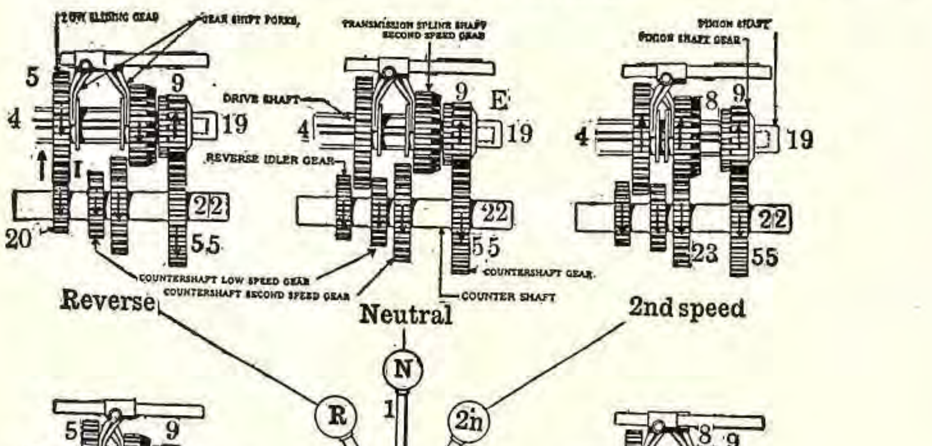


Fig. 22. **First speed:** The drive is from (19) to (9), to (55), to (21), to (5), to the transmission square shaft (4), to the rear axle. (Arrows on the gears indicate the direction in which the gears turn.)

Second speed: (19) to (9), to (55), to (23), to (8), through square shaft (4), to the rear axle.

Third speed, or high gear on direct drive: (19) to (9), to (8), through the transmission square shaft (4), to the rear axle. Note: Gear (8) fits over teeth at the side of gear (9); thus the drive is direct through shaft (4). The shaft (22) and its gears revolve, but no power is transmitted through them.

Reverse: (19) to (9), to (55), to (20), to the free-running idler gear (I) (directly back of an in-mesh with gear 20), to (5) to the transmission square shaft (4), to the rear axle. This idler gear, interposed between (20) and (5), gives a reverse motion to shaft (4). The lever (1) shows the standard S.A.E. three-speed gearshift (ball-and-socket type of gearshift lever).

INSTRUCTION No. 7

THE GASOLINE ENGINE: Principle and Construction

GENERAL EXPLANATION

There are three producers of motive power for automobiles: (1) **The gasoline engine,** also called an **internal combustion engine,** so called because the fuel combusts or burns inside the engine cylinder, between cylinder head and piston, or in the combustion chamber. This type of engine could use either gasoline, kerosene, or alcohol, but in this treatise we will deal with gasoline as a fuel. (2) **The steam engine** is an **external combustion type,** the combustion taking place under the boiler, separate from the engine. (3) The **electric motor** derives its power from an electric storage battery.

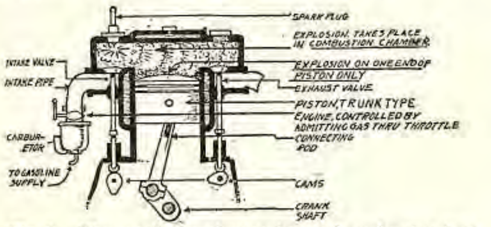


Fig. 1. The gasoline engine; an internal combustion type.

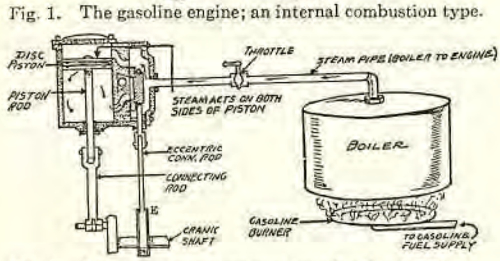


Fig. 2. Steam engine; an external combustion type.[1]

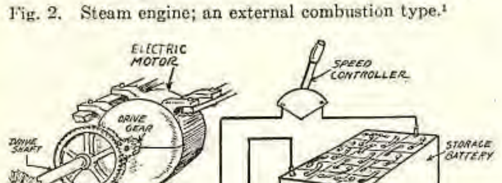


Fig. 3. The electric motor and its source of electric supply; the storage battery.

In this instruction we will deal with the gasoline engine only.

Note. The word motor is often used to designate the engine but if one wishes to be technical and correct it should always be referred to as engine. The word "motor," however (owing to the popular practice), is used in many instances in the book.

Gasoline engines are sometimes made with but one, or perhaps two, cylinders. A few motor cars formerly had engines of three cylinders. At the present time automobile gasoline engines have four, six, eight, twelve, or sixteen cylinders. Seven, nine, fourteen, and other numbers of cylinders are used in aviation engines. Motor boats use engines with as many as twelve to twenty-four or more cylinders. But whether the engine has one or any number of cylinders, the explanation of how it works, or its *principle,* always remains the same.

All gasoline engines work on practically the same principle. They must be of a four-cycle or a two-cycle type (the four-cycle type is dealt with in this instruction). The valve arrangement may be one of several kinds, described farther on. Different types of ignition are employed, which will be discussed later. We mention this so that, when you see an engine with a different ignition or a different valve arrangement, you will remember the principle is the same. The two-cycle gasoline engine (treated separately in another instruction in this book) differs from the four-cycle engine principally in the method used to introduce the gasoline and to exhaust the burned gases in order to obtain a power stroke every revolution of the crankshaft. The Diesel engine (treated separately in another instruction) differs from the gasoline engine principally in the method used to introduce and ignite the fuel.

When a compressed mixture or charge of gasoline vapor and air is set on fire, it burns with great rapidity and produces intense heat, which **causes the gases to expand** and **thus** develops the pressure against the head of the piston, which operates the crankshaft of the engine. This combustion is so rapid that it is usually spoken of as an "explosion"; this word is often used, although the word "combustion" is more correct. The intensity of the pressure decreases as the piston travels downward on power stroke, because the gases have more space in which to expand.

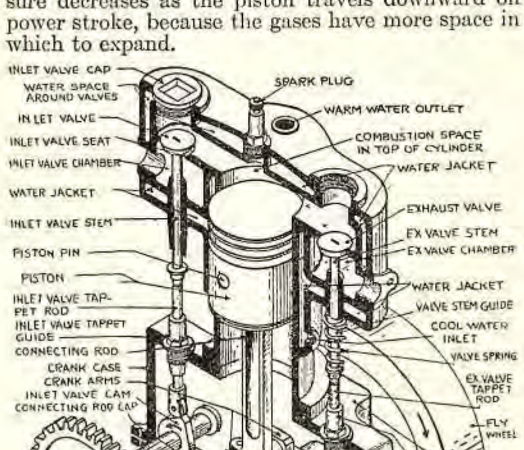


Fig. 4. Parts of a gasoline engine. Cylinder is a "T-head" type with inlet valves on one side and exhaust valves on the other. The inlet valves do not necessarily have to be on the right side. Some cars, which formerly used the T-head type of engine (for instance, an early-model Locomobile T-head six-cylinder engine), had the inlet valves on the left and the exhaust valves on the right; whereas an early model Pierce-Arrow T-head six-cylinder engine was the reverse. The T-head engine is now seldom used; the L-head type, with the valves all on one side, and the I-head type (see p. 47) are used most.

[1] On a **gasoline engine** (Fig. 1) the cams open the poppet valves at the correct time. On a **steam engine** (Fig. 2), the eccentric (E) causes the valve to slide back and forth to open and close the valve-ports to admit and exhaust the steam. In Fig. 2, steam is being admitted to the top of the piston; below the piston, steam is being exhausted through the exhaust port. On the return stroke the valve will move so that steam will be admitted through the bottom port and exhaust from the top port.

The difference is that an explosion is instantaneous, while the combustion of gasoline vapor and air, although very rapid, is not instantaneous. The combustion takes place within the cylinder of the engine.

One end of the cylinder is **closed,** and the other is **open,** the closed end being called the **cylinder head.** Within the cylinder is a **piston,** sliding back and forth.

The space between the piston and the cylinder head is called the **combustion chamber.**

The back-and-forth motion of the piston in the cylinder is called **reciprocating motion.** In order that it may turn the wheels, this reciprocating motion must be changed to the motion of a wheel revolving on its axle, which is called **rotary motion.** The reciprocating motion of the piston is changed to the rotary motion of the wheels by means of a crank shaft.

The **piston** is connected to the crank shaft by a connecting rod, so that it moves in and out as the crank shaft revolves. One complete turn of the crank shaft, by which the piston is moved from one end of the cylinder to the other, and back again, is called a "revolution." One-half of a revolution of the crank shaft moves the piston from one end of the cylinder to the other, and this is called a **stroke.**

It must be remembered that there are two strokes of the piston to every revolution of the crank shaft: one down-stroke and one up-stroke.

A steam engine is called **double-acting,** because the pressure of the steam acts on both sides of the piston.

A gasoline engine is called **single acting,** because the pressure acts on only one side of the piston: on the top or side nearest to the cylinder head.

The **combustion** that causes the pressure or expansion that operates the engine takes place between the cylinder head and the piston, in the **combustion chamber.** The combustion should be timed to occur so that the greatest pressure is exerted when the piston is nearest the cylinder head. The pressure causes the piston to slide the length of the cylinder, from the head toward the open end.

In a steam engine, the pressure of the steam forces the piston to slide first one way and then the other.

In a gasoline automobile engine the pressure from the combustion acts on only one side of the piston, forcing it to slide only one way. After being forced downward, the piston must be brought upward again, and this is done by a **fly wheel** attached to the crank shaft. With the downward motion of the piston, the fly wheel starts revolving. When once started, the fly wheel continues to revolve until friction or some other resistance stops it, but before this can happen the pressure from another combustion is again exerted, keeping it going.

The fly wheel being attached to the crank shaft, they revolve together, and because the piston is connected to the crank shaft by the connecting rod it moves with them. The piston, moved downward by the pressure, starts the crank shaft and fly wheel, and then the fly wheel in continuing to revolve moves the crank shaft and piston. Since a gasoline engine does not operate with continuous pressure during its action, the piston first moves the crank shaft and fly wheel, and then the fly wheel and crank shaft move the piston.

Note. Larger fly wheels are used on single-cylinder engines than on multiple-cylinder engines, because there are not as many firing impulses to two revolutions of the crank shaft on a single-cylinder engine. The fly wheel is usually fitted securely to the tapered end of the crank shaft and flange. It must be secure, otherwise a knock would occur.

The fact that the crank shaft of a gasoline engine must first be turned by hand or by an electric motor or mechanical device, in order to start the engine, is due to the fact that a charge of gas must first be drawn into the cylinder by the suction stroke, and then compressed. After the gas is once ignited, then the force of the power stroke, and momentum of the fly wheel will carry the crank shaft and piston through the other three strokes until the power stroke occurs again.

Before there can be a combustion of mixture in the cylinder, the mixture must be drawn into the cylinder, through the inlet valve.

When in the cylinder, the mixture must be prepared, so that it ignites, burns and expands with the greatest possible rapidity and heat.

After the mixture has been burned, the useless gases must be removed, or exhausted from the cylinder, to make room for a fresh charge of the mixture.

These successive events must occur in their proper order, for if any one of them fails, or it is not performed properly, the succeeding event cannot occur, and the engine will stop running. **These events are called a cycle.**

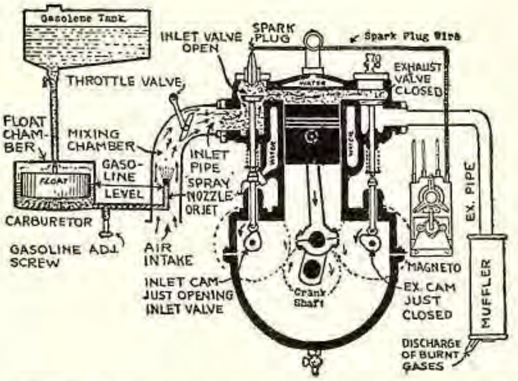


Fig. 5. In this view we are looking at the end of the engine. The illustration is exaggerated in order to simplify the explanation. Imagine the end cylinder cut in half. The object is to illustrate how the gasoline from the tank flows to the carburetor and fills the float chamber until the float needle cuts off the flow. The gas mixed with air, is then drawn into the cylinder by the suction of the piston on the **suction stroke.** During this suction the intake valve must be opened by a cam (the nose-shaped affair at the bottom of the valve lifter) to permit gas to enter the cylinder.

After the cylinder is filled with gas, which is the purpose of the suction stroke, the intake and exhaust valves are closed and the piston, on its up stroke **(compression stroke),** compresses the gas. At the highest point of compression, the gas is ignited by the spark at the points of the spark plug and the piston is forced down with considerable force; this is called the **explosion stroke.** As the piston travels up again the burnt gas is expelled through the exhaust valve which should open at this time and permit the burnt gas to pass out through the exhaust pipe and muffler. This fourth and last stroke, which completes the operation is called the **exhaust stroke.**

The Four-Cycle Principle

There are two distinct cycle principles; generally spoken of as "four-stroke cycle" and "two-stroke cycle" principles. The two-cycle engine will be dealt with farther on.

The four-cycle engine is the type used for automobile work. Therefore we still deal with this type throughout the automobile instruction.

The cycle is thus composed of: (1) the drawing into the cylinder of the mixture (Fig. 6) below; (2) the compression of the mixture (Fig. 7); (3) the burning or ignition of the mixture and the forcing downward of the piston by the pressure produced by the burning of the mixture (Fig. 8); (4) the removal of the burned and useless gases left after the combustion (Fig. 9). (See also page iv.)

The cycle is performed during two revolutions of the crank shaft, or, what is the same thing, four strokes of the piston.

The first event occurs while the piston makes a **downward stroke,** during which the cylinder is sucked full of the mixture, just as a similar stroke of a pump or syringe sucks in a liquid. This is called the **inlet stroke or suction stroke.**

The next stroke of the piston is an **upward stroke,** during which the mixture sucked into the cylinder is prepared by being compressed, and at the end or top of this stroke it is set on fire, or ignited. This is called the **compression stroke.**

When the compressed gas is ignited, the pressure from the combustion forces the piston to make a downward stroke. This is called the **power stroke.**

The next upward movement of the piston pushes the burned and useless gases out of the cylinder. This is called the **exhaust stroke.**

These four strokes occur in each cylinder during two revolutions of the crank shaft and are repeated over and over again in each cylinder as long as the engine continues to run.

On a six, eight, and twelve-cylinder engine, in order that the four events occur in each cylinder during the four strokes they "lap" one into the other. Thus we have two cylinders on power for certain periods of time.

In principle the gasoline engine is like a gun. In a gun the shot is fired by exploding powder behind it. In a gasoline engine we explode gasoline behind the piston in exactly the same way.

There are some differences, of course. The charge goes out of the gun, and that is the end of it. But in a gasoline engine, after the explosion drives the piston before it, in order to get any work out of the machine, this piston must come back and a new charge must be exploded behind it. The burned gases and heat must be disposed of, and all of these things must be done over and over again very quickly, at exactly the right time.

Explanation of the Four Strokes

Valves are arranged to open and close at the proper time to admit fresh gas and to let out the burned gas, and the positions of the piston, valves, and cams for each function are shown in Figs. 6 to 9. Note the direction in which the cams (1 and 2, Fig. 6) are turned by the cam gears, which are driven by the crank-shaft gear.

Cams on a gasoline engine are for the same purpose as an eccentric (**E**), (Fig. 2, page 30), on a steam engine—to open and close the valves.

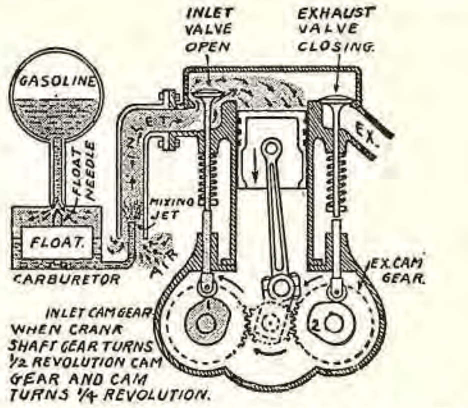


Fig. 6. Showing the suction stroke—down. The charge of gas is being taken into cylinder from the carburetor by the suction of the piston through the open inlet valve.

Note that the inlet valve is opened by inlet cam. Note direction of travel of cam. This stroke is also called "admission" or "inlet" stroke.

Note. The figures on the cams correspond to the figures on the cams in Fig. 10, which are intended to show the movement in degrees at each stroke of the piston.

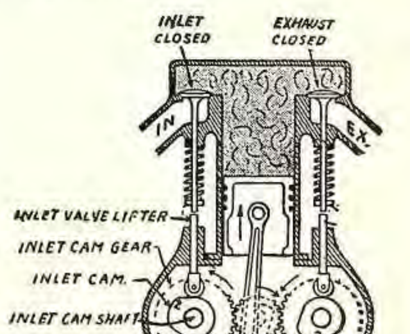


Fig. 7. Compression stroke—up. Both valves are closed because the nose of the cam is not raising either of the valves. Gas is being compressed as the piston travels up. Note the direction of travel of the cam.

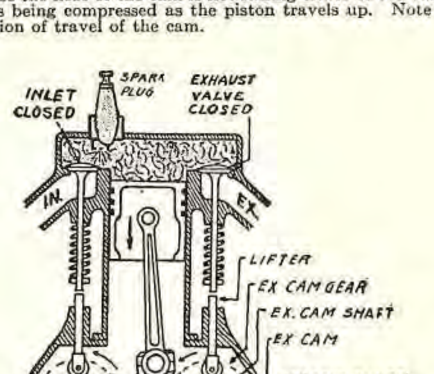


Fig. 8. Power stroke—down. The spark is now occurring, therefore the compressed gas is combusting and expansion force is being exerted against the piston head, thus forcing it down with great pressure. In actual practice, the spark occurs before combustion takes place. Both valves are closed. This stroke is also called the "explosion" or working" stroke.

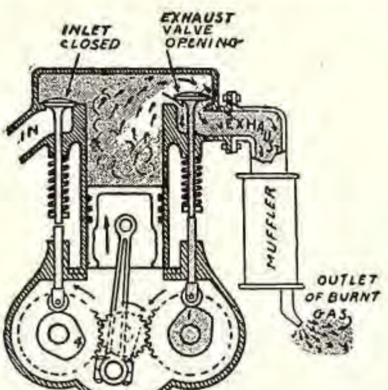


Fig. 9. Exhaust stroke—up. The exhaust-valve cam is now raising the exhaust valve which is open, thus permitting the burned gas to be forced out of the exhaust pipe through the muffler.

When the piston reaches the top of the exhaust stroke the piston will have completed the four strokes, or two crank-shaft revolutions, and the cam-shaft one revolution.

The next stroke is the suction stroke again. These four strokes are repeated over and over again as long as the engine runs.

The above explanation of the four strokes is based on a T-head type of engine, supposed to be cut in half.

The "L" head uses but one cam shaft. The view is from the front of the engine. Thus there is but one inlet and one exhaust cam for each cylinder, just the same as a T- or "round"-head cylinder or any type of four-cycle engine. The principle is identically the same.

Note. A "dual-valve" engine has four valves per cylinder. This is explained farther on.

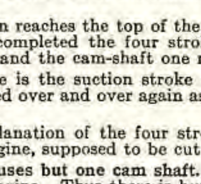


Fig. 10. Illustrates the movement of the cam. Note that the cam moves 90 degrees, or one-fourth revolution each time the crank moves 180 degrees, or one-half revolution.

When the crank shaft makes two revolutions, or 720 degrees to complete the four-cycle revolution, then the cam shaft and cam would be making one revolution, or 360 degrees, because the driven cam gears are twice the size of the driving crank-shaft gear.

The figures 1, 2, 3, 4 on the cams correspond to the cams in Figs. 6 to 9, and are intended to represent the movement in degrees at each stroke of the piston.

Control of Speed of Engine

After the engine is started with the starting crank (self-starters will be explained farther on), the speed of the engine is controlled by opening and closing the butterfly throttle valve of the carburetor which, when opened, admits gas to the cylinder. The more gas admitted, the stronger the compression, therefore the greater the explosive force, and hence more speed. Closing this valve reduces the speed. The gas, of course, is admitted through the inlet valve during the suction stroke.

The opening and closing of the throttle is regulated by hand (Fig. 11), by means of the throttle lever on the steering wheel, or by a foot pedal connected with the same throttle lever, and called an "accelerator."

The carburetor is connected to the inlet manifold by the inlet pipe, and the gasoline flows to the carburetor from the supply tank through a small brass or copper pipe, called the **fuel pipe.**

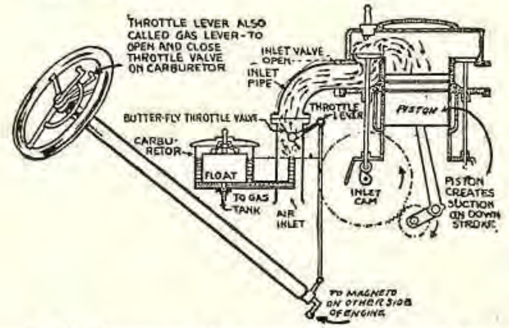


Fig. 11. Illustrating the principle of opening and closing the throttle valve in the carburetor by the throttle lever on the steering wheel.

Pure gasoline vapor will not burn, but must be mixed with air before it can be used to develop pressure. The mixing of gasoline vapor and air in the proper proportions is called "carburetion." To give the best results, the mixture of gasoline vapor and air must always be in correct proportion. (This is explained in the carburetor instruction.)

There is a passage through the carburetor into which the air is drawn as the piston makes the suction stroke. The liquid flows to the carburetor and is brought into contact with the current of air. The gasoline turns to vapor, and is absorbed by the air, the mixture being sucked into the cylinder on the suction stroke.

The quantity of mixture that is drawn into the cylinder during one suction stroke is called the **charge.**

If the speed of the engine is governed by the amount of gas drawn into the cylinder through the butterfly throttle valve of the carburetor and the inlet valve on the engine, it is clear that if high speed or more power is desired, it is necessary that all of the mixture possible be drawn into the cylinder through the inlet valve, and that the inlet valve must open at the exact time and open wide enough to permit a full charge being drawn in.

As the inlet valve is mechanically operated, the cam must be adjusted (by having the inlet cam gear properly meshed with the crank-shaft gear) so that it will open the valve promptly as soon as the sucking action of the piston commences, which it is just beginning to do in Fig. 6. Note that the cam is just starting to raise the inlet valve.

If the inlet valve does not open soon enough, the piston will have made part of its stroke before the charge begins to enter; if it opens too soon, part of the burned gases from the previous power stroke will be pushed into the carburetor. If it closes too soon, the cylinder will not get a full charge; if it closes too late, part of the mixture will be pushed out of the cylinder on the compression stroke.

The setting of the cam gear (which controls the position of the cams) with the crank-shaft drive gear, is termed **valve timing** and is treated more fully under the instruction on that subject.

If all the openings into the cylinder, such as the exhaust valve, the spark plug, piston rings, relief cock, etc., are not tight, air or gas will be sucked into the cylinder through them at the same time that the charge enters through the inlet valve, and this would destroy the proportions of the mixture

As the piston travels up on compression stroke, the gas is tightly compressed until it occupies only the space between the inside of the cylinder and the head of the piston, and it is the force or expansion from this compressed gas, when ignited, at the highest point of compression, that the power of a gasoline engine depends upon.

If the valves are not closed tight, or if there are any leaks by which this gas can escape, it is clear that the gas will not be compressed as much as if there were no leaks. The result is a weaker power stroke.

When an engine is running with the throttle wide open, as, for instance, on a steep hill, the compression is greater, because more gas is drawn into the cylinders.

If the engine is running on a level, with the throttle partially open, then the compression is less.

Thus it is clear that if the space between the cylinder and piston head is, say, one inch, the more gas that is compressed in this space, the greater the pressure.

The greatest power is obtained from a given volume of compressed gas when it is ignited at its highest point of compression, which is at the top of the compression stroke and just at the moment when the piston is over center in the direction of rotation.

It is the expansion force of the ignited gases, caused by the heat when combustion takes place, that produces the pressure against the head of the piston. It is, therefore, clear that as the piston travels down on the power stroke, this expansion force becomes less and less, because it has more space in which to expand. Hence the importance of having the spark occur at the correct time and also of having the valves open and close at the proper time.

Toward the end of the power stroke, and usually before the piston reaches the bottom of its power stroke, the **exhaust valve is set to open.** There is still pressure in the cylinder, and when the **exhaust valve is open**, this pressure will cause the gases to begin to escape.

As the exhaust stroke is an **upward stroke** of the piston, the piston will push out through the exhaust valve all of the burned gases that do not escape by their own pressure.

If all the burned gases are not pushed out of the cylinder, it will prevent a full charge of fresh gas from being drawn in, which will cause a weak mixture and a weak explosion.

The exhaust valve closes as the piston reaches its upmost point, or a little after, the inlet valve opening as the exhaust valve closes.

Back pressure, caused by the muffler or obstructions in the exhaust pipe, will prevent the burned gases from escaping as freely as they otherwise would, and all may not be pushed out by the time that the exhaust valve closes.

The exhaust valve and its seat are exposed to the full heat and flame of the burning mixture, and are more liable to warp or pit than the inlet valve. It must be watched, and if there does not seem to be perfect compression when the engine is cranked, the probability is that it needs grinding to seat it properly. The exhaust valve thus requires more grinding than the inlet valve.

A proper mixture will be entirely burned before the exhaust valve opens. An **improper mixture** that burns slowly may still be burning when the exhaust valve opens, and will heat the exhaust pipe and muffler so that the pipe may become red hot. Such a mixture wastes fuel, and may result in a fire. It may be corrected by making a correct adjustment of the carburetor and spark, which will be explained later on.

Ignition: When the throttle is being opened and the engine begins to speed up, it is necessary also to "advance" the time of ignition; in other words, to cause the spark to occur earlier than if engine is running slow.

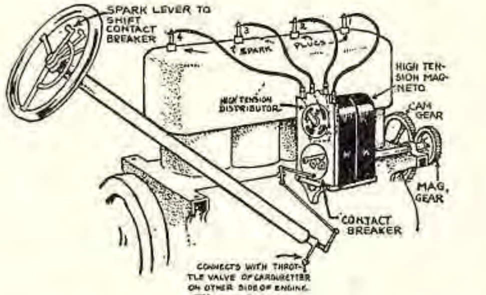


Fig. 12

A spark lever is usually placed on the steering wheel along side of the throttle lever, which is connected by a rod and bell crank to the contact-breaker box on the magneto, or, if a coil and timer is used, to the commutator or interrupter.

When the spark lever is moved, it also moves the contact-breaker box on magneto, or commutator, which causes the spark to occur "late" or "early," according to the movement of this lever.

The proper time for the ignition of the mixture is at the top of the **compression** stroke—when the gas is compressed to the highest point.

Up to this point we have supposed that the spark occurs exactly at the moment when the piston reaches the top of the compression stroke. Now, this would be, in fact, the correct time, were it not for the fact that the gas takes quite an appreciable time to combust and expand after being ignited, an interval, let us say of a fraction of a second. Thus before the gas has had time to burst into a full combustion and expansion, the piston, on account of its great speed (suppose it is traveling at 1,500 revolutions per minute), will have traveled part of the way down the cylinder before being affected by it. This means part of every power stroke wasted.

The advance of spark: The remedy for this is to make the spark occur earlier; that is, to make it occur just before the piston has completed, or reached the top of the compression stroke, so that the full burst of explosion and the piston arrive simultaneously at the top of the stroke, or just as the piston is slightly over the top of "dead center." This is called "advancing the spark."

The retard of spark: Suppose the engine is now running at only half the speed, say 700 revolutions per minute. During the exploding or igniting period, which we assumed to be a fraction of a second, and which remains the same, the piston, with its speed now reduced, has not time to travel so far, and the spark therefore need not be so much advanced.

Again, when the engine runs dead slow, say at 100 revolutions per minute, which is slow for an automobile engine, the spark requires hardly any advance at all. So that we see, at once, that the faster the engine runs the more the spark must be advanced, and that the slower the engine runs the less it need be advanced, or, to express it in a more usual way, the more the spark must be **retarded.**

To "advance" or "retard" the spark, means that the spark is made to occur earlier or later relative to the position of the piston. It does not mean that the spark is made to occur more frequently or less frequently. (This subject is treated more fully under "Ignition Timing.")

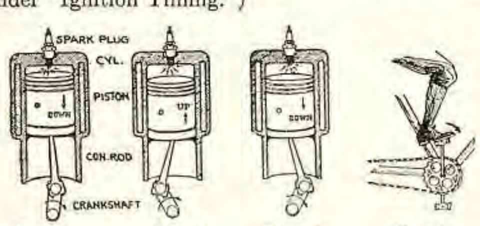


Fig. 13 Fig. 14 Fig. 15 Fig. 16

Fig. 13. Here the explosion is occurring at just the right time, at the moment when the piston starts downward, securing the full length of the power stroke.

Fig. 14. Here the explosion is occurring too early, causing the piston to push backward on the crank shaft, applying power in the wrong direction. While a single-cylinder engine would "kick back" and stop, in a four-cylinder engine the remaining three cylinders would have this resistance to overcome.

Fig. 15. Here the spark is occurring too late, wasting the top or best part of the power stroke.

Fig. 16. The piston is like the pedal of the bicycle. It should receive the push when it first starts downward. (Illustration through courtesy of K. W. Ignition Co.)

The point to bear in mind is that the spark must be made to occur so that the greatest expansion takes place just the moment the piston is over the top of dead center. In order to give the gas sufficient time to ignite, so that complete combustion will occur at this point, the spark is "advanced" or "retarded," according to the speed of the engine, as explained above.

Another factor to be considered is the electrical apparatus producing the spark. For instance, an ignition system using a vibrator coil would require more advance than a closed-circuit type of interrupter, because the action of the vibrator-coil system is slower. This condition is termed "electrical lag."

If the spark is advanced too much, all of the mixture will have been burned before the piston reaches its upmost point, so that it will be necessary for the fly wheel to force the piston upward against the pressure until it gets to its upmost point. This strains the engine, and causes a sound that is called an **"ignition knock"**; a hard, metallic sound.

The knocking is not always detected easily by the novice, who will probably confuse it with other sounds on the car, but when once it has made itself evident, the **spark should instantly be retarded** until the knocking ceases. The strains set up in an engine which is allowed to knock may seriously damage connecting rods and cranks.

It will be seen from the foregoing that in addition to controlling the speed of the engine through the gas throttle lever, it may also be controlled by advancing or retarding the spark, the speed of the car changing accordingly.

An engine should not be slowed by retarding the spark. If it has appeared to the reader in the last few paragraphs that it is possible to slow an engine by retarding the spark, let him at once understand that this is the last method by which it ought ever to be done. It is not only unscientific, but is also wasteful of fuel and produces extra heat, and causes rapid pitting of the exhaust valves, the gases passing through them in an incandescent form.

The correct method of slowing down or increasing the engine speed is to shut or open the throttle valve, which is situated between the carburetor and the inlet valve, by which the amount of fuel supplied to the engine may be regulated. Then as the engine varies its speed, slower or faster, the spark should be retarded or advanced accordingly.

The rule, therefore, is to let the engine speed follow the throttle and to make the spark follow the engine speed; or, to put it in another way, in order to drive economically, the throttle valve must be kept closed as much as possible and the spark advanced as far as possible, short of knocking or of a tendency to knock..

Such subjects as ignition, carburetion, cooling, fuel systems, lubrication, etc., will be taken up farther on under their respective headings. We are still dealing with engine construction, and must, for the present, adhere to this branch of the subject.

INSTRUCTION No. 8

ENGINE PARTS: Assembly; Types

ASSEMBLY OF PARTS

The stationary parts are: crank case, upper and lower half, bearings, cylinders, exhaust and inlet ports, valve caps, compression or relief cocks, water-cooling pipes, carburetion and part of the ignition systems, exhaust and inlet manifolds.

The moving parts are: crank shaft, connecting rods, pistons, piston rings, piston pin or wrist pins, cams, cam shaft, timing gears, crank-shaft gear, valves, valve plungers or tappets or lifters, fly wheel.

In order to enable the reader thoroughly to grasp the meaning and purpose of the parts, we will build up a four-cylinder T-head type of engine as shown below. *The illustrations are not drawn to scale, nor are they technically correct,* but will serve the purpose of explaining the location of the parts of an engine.

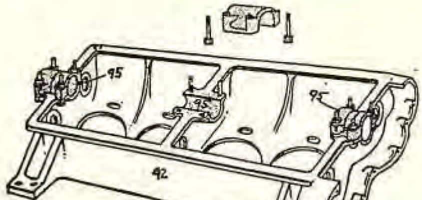


Fig. 1. Main bearings. Upper half of crank case upside down.

Crank case: A reference to Fig. 1 will show an aluminum crank case, upper-half part, which we lay on the floor, upside down, so that we can see the bearings (95).

Note. The S. A. E. designates the lower part of the crank case as the "oil pan" when containing no bearings. If it contains bearings, it is termed the lower crank case. The S. A. E. further designates crank cases as of the "split type" and the "barrel type." In the barrel type the crank shaft is removed from one end of the crank case, the bearing caps being removed through hand-hole plates. The type shown here, and most used, is the "split type" with the bearings in the upper half.

The main bearings are made in halves and are usually made of bronze or white metal and are termed bearings. They are fitted into bearing caps and the upper part of the bearing.

Shims are placed between the two halves of the bearing, so that when wear occurs, a "shim" can be taken out and the lost motion taken up. See Index, under "Shims."

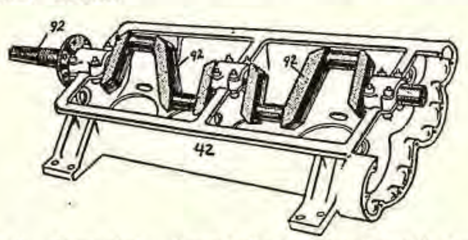


Fig. 2. Crank shaft. Upper half of crank case upside down.

The crank shaft (92) (Fig. 2) will now be fitted in the bearings. The bearing caps are placed over the bearing surface of the crank shaft, and the bearing cap nuts are tightened.

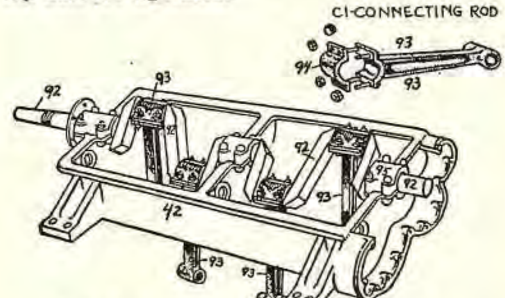


Fig. 3. Connecting rods fitted to crank shaft.

The connecting rods (93) (Fig. 3) are now fitted to the crank shaft. The lower half of the large end of the connecting rod, called the connecting-rod cap (94), is removed, so that it can be fitted to the crank shaft. Shims are inserted, so that it works free on the crank shaft. Then the nuts are drawn good and tight, so that there will be no lost motion. If there was lost motion a knock or pound, which would cause wear, would result.

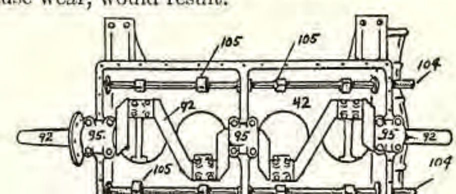


Fig. 4. Cam shafts.

The cam shaft (104) (Fig. 4) with the four cams (105, nose-shaped) is now fitted to its bearings. In this engine there are two cam shafts: one with four cams for raising the four inlet valves, and the other, with its four cams (105), to raise the four exhaust valves.

The cams are placed with their noses equi-distant, so that when they revolve they will raise the valves, by pushing them up with their nose, at a given time. The timing gears which operate the cam shafts will be explained farther on.

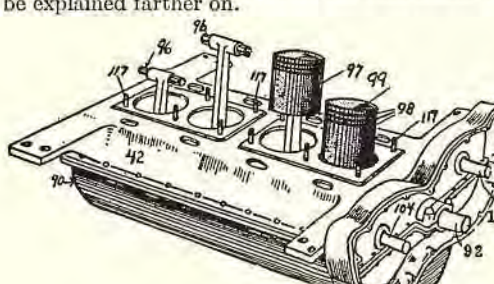


Fig. 5. Piston pins, pistons, cylinder studs.

Some of the changes in the modern high-speed, high-compression automotive gasoline engines: Cylinders: L-head and I-head; cast in block; detachable heads. Crankcase: Cast integral with cylinders; oil pan stamped out of heavy sheet steel. Bearings: Quoting excerpts from "*Federal-Mogul Engine Bearing Service Manual*": There are four types of crankshaft main and connecting-rod bearings in common use today: (1) those formed by applying the bearing metal directly to the connecting-rod forging, the bearing cap, or the crankcase saddle; (2) bronze or steel backed, babbitt lined, and with stock remaining in the bearing bore for align boring or reaming after assembly, etc.; (3) bronze backed, babbitt lined, and manufactured as a "precision type" to such fine tolerances that no align boring, sizing, or scraping operations are required during or after assembly, etc.; and (4) steel-backed "precision type" bearings, etc. A high-duty bearing alloy basically of cadmium, silver, and copper applied to a steel back and of the precision type is now available and is considered stronger than babbitt. (See page 786, footnote 6, and page 690 "*Engine Bear-*

The crank case is now turned right side up, after having fitted to it the lower half of the crank case (90). This lower half holds the oil, which the crank shaft splashes in and is called the oil pan (lubrication systems explained farther on).

The piston or wrist pin (96) (Fig. 5) in the small end of the connecting rod is shown here. This holds the piston to the end of the connecting rod (details of each part will be explained farther on).

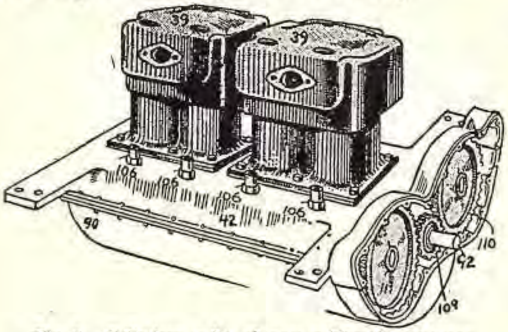


Fig. 6. Cylinders, valve-plunger guides, timing gears.

After the four pistons are fitted to the connecting rods, the cylinders (39) (Fig. 6) are fitted down over the pistons, care being taken not to break the piston rings.

The cylinders (39) are held to the crank case by nuts fastening to **studs** (117) (Fig. 5).

The valve-lifter guides (106) (Fig. 6) are fitted in holes in each side of the crank case so that they will come in line with the exhaust valves on one side of the cylinders, and with the inlet valves on the other side.

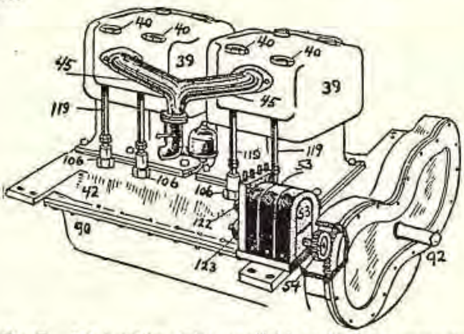


Fig. 7. Inlet valves, inlet manifold, carburetor, magneto.

Valve lifters, or tappets, are now fitted through these valve-lifter guides which raise the valves through the action of the cams.

The gear for driving the timing gears, called the **crank-shaft timing gear** (109) (Fig. 6), is keyed or threaded to the end of the crank shaft (92); this gear drives the two timing gears (110 and 111).

The cam-shaft timing gears are keyed to the cam shaft (104) (Fig. 4); one gear and shaft to operate the inlet valves (119) (Fig. 7), and the other gear and shaft to operate the exhaust valves (120) (Fig. 8). The gear-case cover is placed over gears.

The inlet valves (119) **and exhaust valves** (120) are placed in their seat by passing them through the inlet-valve cap holes (40) (Fig. 7) and exhaust-valve cap holes (41) (Fig. 8).

The inlet manifold (45) is now bolted to the inlet-valve side of the cylinders, and the carburetor is connected to it.

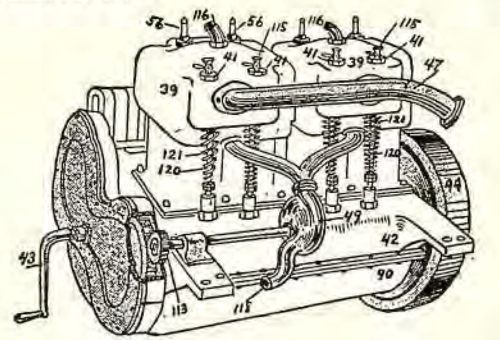


Fig. 8. Exhaust valves, manifold, fly wheel, pump, etc.

The exhaust manifold (47) (Fig. 8) is bolted to the exhaust side of the cylinders, and is connected with the muffler at the rear of the car, by the exhaust pipe (47).

The exhaust-valve caps (41) and the inlet-valve caps on the opposite side are now screwed in place.

The priming cups, also known as "compression" or "relief cocks" (115), are screwed into the exhaust-valve caps.

The spark plugs (56) are screwed into the inlet-valve caps or in the center of each cylinder.

The fly wheel (44) and **starting crank** (43) are fitted to opposite ends of the crank shaft. By referring to Fig. 3 (92), the reader will note that the end of the crank shaft tapers, and a flange is also turned on this crank shaft. The fly wheel fits to this taper and bolts to the flange, as there must positively be no lost motion.

The magneto (53) (Fig. 7) (a high-tension magneto is used for ignition in this example), is bolted in place on a brass base provided for it, on the side of the engine. An extra gear (which will be explained farther on) is operated by the cam shaft and drives the magneto, which generates electricity. The electricity is distributed to the four spark plugs (56) at certain periodical times by the distributor on the magneto (122) (Fig. 7).

Wires are now connected through a switch to the magneto. This switch is to control the ignition.

The circulating pump (49) is connected to the water jacket of the cylinders. The gear (113), driven by the cam gear, drives the pump, and keeps the water in constant circulation, which keeps the cylinders from getting too hot (not over 170 to 180 degrees Fahr.). We now connect rubber hose to metal pipes on the radiator and also to our pump (49), and belt up our fan, which is run from the same shaft. The radiator is filled with water.

The gasoline fuel pipe from the gasoline or fuel tank is now connected with the carburetor.

ings.") **Shims:** Some of the bearings mentioned above do not use shims. See page 784A for shims. **Lubrication:** Force-feed or full force-feed used most (see page 159). **Camshaft drive:** Silent chain, also gears. **Valve caps or "priming cups" not now used. Ignition:** Battery, coil, and distributor used most. The magneto is used considerably on aircraft, industrial power, tractor, and outboard engines, etc. Spark plugs are now located very close to the exhaust valves in several engines, because, it is claimed, in that position detonation is minimized, also better combustion is obtained when using leaner mixtures, all of which contribute to fuel economy. See footnote, page 233, for additional information on this subject. Spark plugs are smaller, a number being 14 mm. and 10 mm. (see page 1051, and footnote, page 236). **Carburetion:** Down-draft carburetion is the type most in use; the fuel pump is now generally employed to draw the fuel from the gasoline tank and deliver it to the carburetor (see Insert No. 2 at page 144, and Insert Nos. 6 and 7).

TYPES OF ENGINES

As previously mentioned, there are several types of engines, all of which work on the four-cycle principle. In order that the reader may more clearly understand, we will give an outline illustration of some of the different types of engines in general use.

The type of engine used more than any other for automobile work is the four and six, and the eight and twelve "V"-cylinder type of engine.

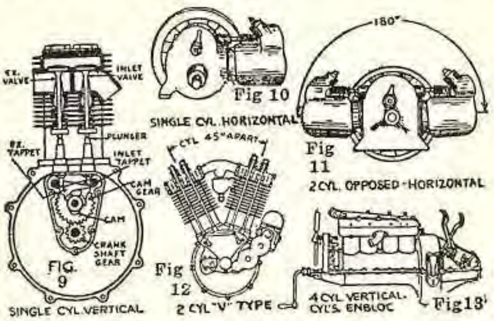


Fig. 9. A single-cylinder vertical type of engine, with air-cooled cylinder. Valves are both on the side and mechanically operated. There are two flywheels with a crank pin between them. The flywheels run inside of the aluminum crank case. This type of engine is used on motorcycles, cycle cars, and railroad light cars.

Fig. 10. A single-cylinder horizontal type of engine, with water-cooled cylinder. Formerly used on light-weight automobiles. Seldom used; valves mechanically operated.

Fig. 11. A double-cylinder opposed type of engine, with water-cooled cylinders and mechanically operated valves. Note that the cylinders are 180° apart. Cylinders are of the "L"-type. The crank shaft is also of the 180° type.

Fig. 12. A twin-cylinder "V"-type of engine, with cylinders placed 45° apart. Cylinders are air-cooled. Valves are mechanically operated from overhead. The cylinder is of the "round" type. This type of engine is used on motorcycles and cycle cars.

Fig. 13. A four-cylinder, vertical type of engine, with transmission and clutch in one housing joined to the engine—called a "unit power plant." This engine is suspended in a frame at three points; it would therefore be called a "three-point suspension" type of power plant. Valves are all on one side of the "L"-type cylinders.

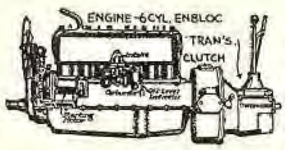


Fig. 14

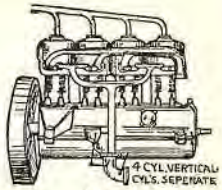


Fig. 15

Fig. 14. A six-cylinder "unit power plant." Transmission and clutch case join the engine. Cylinders are cast together, or "in block."

Fig. 15. A four-cylinder engine with cylinders cast separate. All valves are on one side; hence "L"-type cylinders.

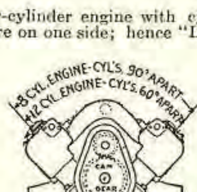


Fig. 16. Eight-cylinder "V"-type engine, with cylinders placed at an angle of 90° apart. One cam gear operates the valves on both sides of the "L"-shaped cylinders. There are four cylinders on each side, usually "in block." The crank shaft is a four-cylinder type (180°) between crank throws, with two connecting rods to each crank pin.

THE AUTOMOBILE, TRUCK, AND TRACTOR ENGINE[1]

The Automobile Engine

The 4, 6, 8, and 12-cylinder engine is used for automobile work. The "four" and "six" are used most.

Fig. 17

Valves are placed on the side or overhead. **Ignition** is usually coil and battery, using an interrupter and distributor. A **generator** supplies current for charging the battery, also for lights and ignition. A **battery** supplies current for lights, ignition, and starting the motor. **Speed** of automobile engines varies from 150 to 2,000 r. p. m. On some few engines the speed is as high as 3,000 r.p.m. The engine shown in Fig. 17 is a 6-cylinder engine with a 3⅞" bore by a 5" stroke, with valves on the side. **Control of speed** is by a hand-throttle lever and foot accelerator. A governor is never used.

The Truck Engine

Usually a 4-cylinder engine is used on trucks, for reasons stated in the instruction on "Trucks." **Valves** are usually on the side. **Ignition** is usually a high-tension magneto. On the Buda truck engine (Figs. 18, 19), the Eisemann magneto with automatic advance is used. The speed of the engine

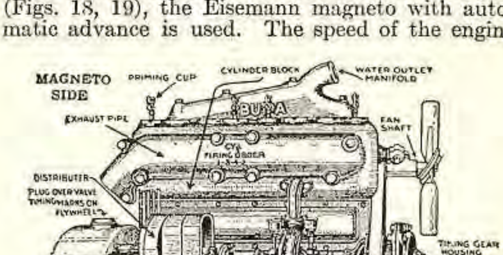


Fig. 18. Magneto side.

is comparatively slow (950 to 1,000 r.p.m.). Speed is governed by McCann or Pierce governor on this

[1] The truck and tractor engine is further explained under the "Truck and Tractor" Instruction.

engine (see Index under "Governors"). The **stroke of the piston** is usually long, and in this instance, the

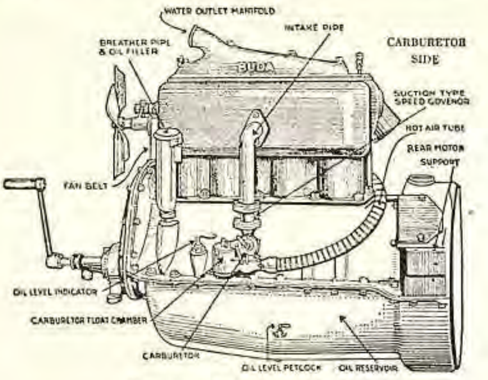


Fig. 19. Carburetor side.

bore is $4\frac{1}{2}''$ by $6''$ stroke or 32.4 H.P. (S.A.E.), or 52 actual H. P. **Truck speed** is from 9 to 17 m.p.h. **Starting** is usually by hand-crank in connection with an "impulse starter" (see Index). **Control of speed** is by hand throttle and accelerator.

Airplane Engine

Many airplane engines are 8 or 12-cylinder, "V"-type, and in most instances use the overhead type of valves. The "V"-type cylinders give a maximum of power at a minimum weight. **Ignition** is by means of a high-tension magneto or coil-and-battery ignition. The **speed of the engine** at flying speed is 1,400 to 1,700 r. p. m.

The Tractor Engine

Usually a 4-cylinder engine is used on tractors, for reasons stated in the instruction on "Tractors." **Valves** are overhead or on the side, and some use the overhead "dual" valve system. The **stroke** is usually long, the average being $6''$ stroke by $4\frac{1}{2}''$ bore. The speed of the engine is controlled by a **governor** (Fig. 20), which is a centrifugal ball-type, operating through levers to the carburetor throttle (T). The governor is used to maintain a uniform speed and to prevent the engine from "racing" if the load is suddenly released, or from "stalling," if the load is suddenly applied. **Speed of the engine**

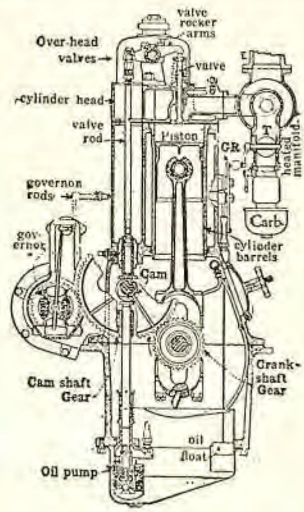


Fig. 20

is usually 950 r. p. m., which is usually maintained for long periods of time while working. The **speed of a tractor** is very slow, the average being about $2\frac{1}{2}$ or 3 miles per hour on high speed.

Ignition is usually provided by means of a high-tension magneto, in connection with an "impulse-starter," which is used to facilitate starting when cranking the engine.

Carburetion is secured by means of gasoline to start with and kerosene to run on after the engine is heated up. The heating of fuel around the intake manifold from exhaust gases is very important when using kerosene.

Cylinder sleeves, or barrels, are used on many tractor engines. They consist of removable sleeves or barrels (Fig. 20) placed in cylinder blocks, which, in case of wear or accident, can easily be replaced with new ones. See also, Index, under "Cylinder sleeves."

The reader can now compare the relative difference between the four engines and thus note, that while the construction may vary, the same underlying principles apply to each.

TWO EXAMPLES OF AUTOMOBILE ENGINES

An example of an engine with valves-on-the-side operated by one camshaft on the side is the Whippet "Four," model 96-A, four-cylinder in-line engine as shown in Fig. 21.

An example of an engine with valves-in-the-head operated by one camshaft on the side is to be seen in Fig. 22, showing a cross-sectional front view of the Nash "8–80" series, eight-cylinder in-line engine. The clutch and transmission (not shown) are mounted with the engine as a single-unit power plant.

Specifications of the Nash "8–80" series engine (Fig. 22) are as follows:

Engine: 8-cylinder, in-block, high-speed, valves-in-the-head type, operated by push rods on the side. **Cylinder** bore: 3 1/4", stroke 5".

Main bearings are die-cast babbitt, brass backed; nine in number; diameter and length: front $2\frac{1}{4}''\text{x}1\frac{3}{16}''$; No. 2–4–6–8, $2\frac{1}{4}''\text{x}1\frac{5}{16}''$; No. 3–7, $2\frac{1}{4}''\text{x}1\frac{3}{16}''$; rear, $2\frac{1}{4}''\text{x}2\frac{1}{4}''$. **Crankshaft:** forging steel, double-heat treated.

Lubrication: gear pump, driven by spiral gears from camshaft. Full force-feed to main bearings and connecting rods to wrist pins, also pressure to camshaft bearings. Oil filter return through valve rocker arm mechanism.

Valve adjustment: The clearance for valve adjustment is made between the valve stem and its point of contact with the rocker arm. The clearance is adjusted to .012" with engine at operating temperature. Loosen the push-rod lock nut and move the ball-adjusting nut either up or down until the correct clearance is obtained. Do this with engine running slowly.

Electrical system: Three unit, consisting of an Autolite generator, Autolite twin ignition timer-distributor and Autolite starting motor. There are two spark plugs per cylinder and two breaker-contact points on the timer-distributor. Spark plugs are metric thread with .020" gap. The firing order is: 1–6–2–5–8–3–7–4.

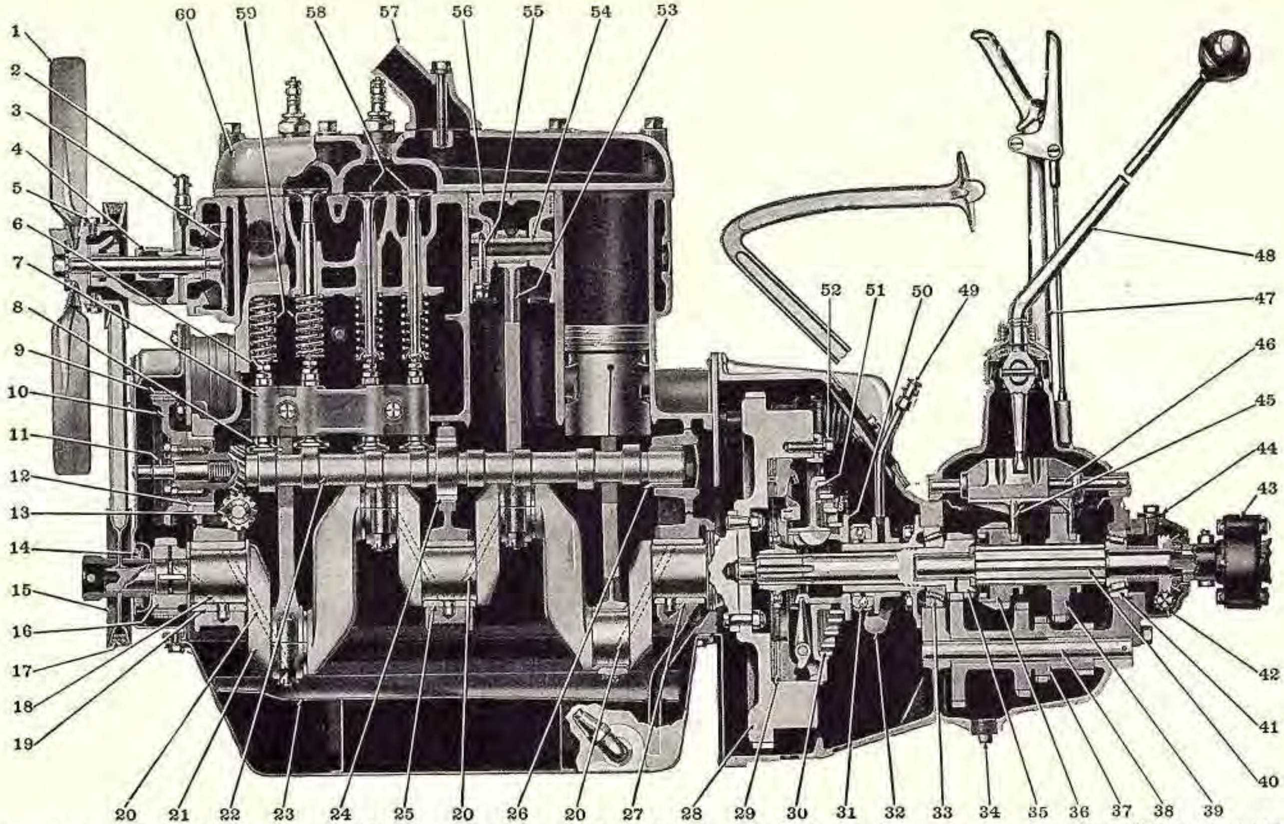


Fig. 21. Example of an engine with **valves-on-the-side** operated by one camshaft on the side. The illustration pictures a cross-section of the "Whippet" model 96-A four-cylinder, L-type, cast in block engine with clutch, transmission and universal joint, termed a unit-power-plant. See specifications of Whippet engines on pages 1055–1062. **Name of parts is given below.**

1—Fan
2—Water pump bearing grease nipple
3—Water pump
4—Water pump packing gland
5—Fan pulley adjusting screw
6—Valve tappet adjusting screw
7—Valve tappet guide
8—Valve tappet
9—Timing chain
10—Camshaft sprocket
11—Camshaft thrust plunger
12—Camshaft bearing—front
13—Oil pump driven gear
14—Timing chain cover-packing
15—Fan driving pulley
16—Crankshaft sprocket
17—Fan belt
18—Oil passage to timing chain
19—Crankshaft main bearing—front
20—Oil passage to connecting rod bearing
21—Crankshaft
22—Camshaft
23—Oil pan tray
24—Camshaft bearing—center
25—Crankshaft main bearing—center
26—Camshaft bearing—rear
27—Crankshaft main bearing—rear
28—Flywheel
29—Clutch facings
30—Clutch spring
31—Clutch release bearing
32—Clutch shifter yoke
33—Transmission front roller bearing
34—Transmission drain plug
35—Main drive gear and clutch shaft
36—Direct and second-speed sliding gear
37—Transmission countershaft gears
38—Transmission countershaft
39—Low and reverse speed sliding gear
40—Transmission main shaft
41—Transmission rear roller bearing
42—Speedometer drive
43—Universal joint
44—Transmission shaft bearing adjusting hole cover
45—Gear shifter forks
46—Gear shifter shaft
47—Emergency brake hand lever
48—Gear shift lever
49—Clutch release bearing grease nipple
50—Clutch release sleeve
51—Clutch cover
52—Clutch cover clamp screw
53—Connecting rod
54—Piston pin
55—Piston pin lock screw
56—Piston
57—Water outlet
58—Valves
59—Valve springs
60—Cylinder head

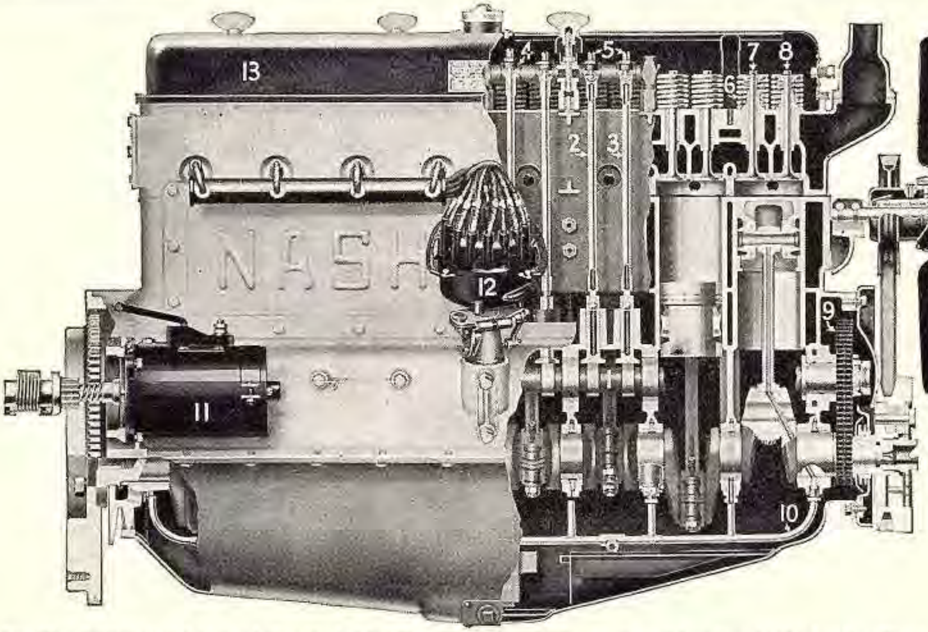


Fig. 22. Sectional end-view of the Nash "8-80" series eight-cylinder engine with valves-in-the-head. **Name of parts:** 1, camshaft; 2, inlet valve push-rod; 3, exhaust valve push-rod; 4, valve-rocker; 5, valve adjusting screws; 6, valve spring (note the inner and outer spring); 7, inlet valve; 8, exhaust valve; 9, timing chain; 10, oil distributing pipe; 11, starting motor; 12, timer-distributor; 13, valve cover.

ENGINE PARTS

Crank Case

The difference, or variation in construction of the various parts of an engine will now be taken up.

The adjustments and repairs of the various parts are treated farther on in the "Repair Section" of the book.

The cylinder is attached at its open end to the crank case, which forms a box around the crank shaft.

The crank case is of irregular shape, so that while there is plenty of room for the cranks and connecting rods to operate, there is little waste space. It contains the crank-shaft bearings, and forms the bed-plate, or foundation, for the engine.

It is often made in two parts: an upper part bolted to the cylinder and containing the crank-shaft bearings, and a lower part enclosing the crank shaft, and which is called the "oil pan."

As the lower crank-shaft case is intended to contain lubricating oil, it is tight so that there may be no leakage. Usually the lower part of the crank case can be removed for adjustment of bearings.

The crank case is usually made of aluminum alloy, or, if in two pieces, the upper may be made of iron, and the lower of aluminum and sometimes of cast iron.

The crank case is used to support the cylinders and the various parts of the mechanism, such as the pump, magneto, etc.

The S. A. E. designates two types of crank cases: the "split type," where the lower part is separate and contains no bearings. The lower part is then called the "oil pan." The "barrel type" is when the lower part is permanently attached and has a hand-hole plate for reaching the bearings, and the crank shaft is removed from the end of the crank case with the removal of the crank-case head

The arms for supporting the crank case on the chassis are sometimes made short to bolt to a sub-frame, while other manufacturers make longer arms to extend and bolt to the main frame.

A "three-point suspension" is where the power plant is suspended in the frame at three points of contact. **"Four-point suspension"** is where the power plant is suspended at four points.

A "unit power plant" is where the engine clutch and transmission are in one unit, as in Fig. 21.

Engine Bearings

The engine crank-shaft bearings are known as "main bearings." Most of the manufacturers make four-cylinder engines with three main bearings for the crank shaft. Some are made with 5 bearings, but these are usually very large engines. On six-cylinder engine crank shafts the majority use 7 or 4 main bearings, and some few use 3.

On eight-in-line engine crank shafts, either 5 or 9 main bearings are used.

On V-type engine crank shafts, for example, the Cadillac V-8, "355," LaSalle "345," Viking and Oakland use 3 main bearings; the Cadillac V-12, "370" use 4; the Cadillac V-16, "452" use 5; Lincoln and Peerless V-8 use 5. The "V-type" engine crank shaft is of course shorter than the "in-line" crank shaft with the same number of cylinders. For example a V-8 crank shaft has four "throws" or crankpins, whereas an eight-in-line crank shaft has eight "throws" or crankpins.

If ball bearings are used, there are usually two bearings unless the crank shaft is of the built-up type. See pages 931 and 46.

See Specifications, page 1060, giving the number of main bearings on the different engines.

Crank-shaft main bearings are usually in two parts: the upper and lower halves (Fig. 24). Both parts constitute the bearing.

The upper half is supported by the upper part of the crank case, and the lower half in a bearing cap.

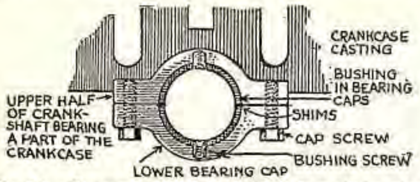


Fig. 24. Construction of a crank-shaft main bearing.

The bearing cap is fastened to the upper half of the bearing with cap screws.

On some engines, babbitt metal is cast into the bearing halves, and then dressed down, scraped and run-in.

On others, the upper half is cast and the lower half is in the form of a bushing which can be renewed when worn, by screwing a new bushing in place in the lower bearing cap.

Most of the wear is on the lower half of the bearing, because it supports the weight of the crank shaft and receives the thrust of the power impulses. Therefore it can be taken up by removing the lower bearing cap and the "shims," which are usually placed between the two halves, or by dressing the sides of the lower cap down to a proper fit, thus drawing the cap tighter around the shaft. After a long period of time and after the lower half has been taken up two or three times, the upper half will have to be cast again. On some engines the upper and lower half can be fitted with bushings, which are detachable and are held in place with a countersunk screw. Thus new bushings can be replaced and run-in.

A bearing bushing[1] is that part of a plain bearing that the shaft comes in contact with. They are usually made of babbitt, phosphor bronze, or white metal. The phosphor bronze is very hard and lasts a long time, but is somewhat liable to "seize," if run without oil.

A white metal bushing consists of a layer of white metal, run (when in a molten state) into a channel in the bearing. It then hardens and is scraped and polished. White metal has the virtue of not seizing or doing much damage if ill treated, but if it is run for a long time a knock will result. There are many different alloys used for bushings, some being faced with brass. Bushings can be purchased ready for application. **If a bushing is burned or cut** from lack of oil, it can be scraped and "spotted up" to a fit, if the cut is not too deep, or a new bushing may be put in place and burned and run-in. These subjects will be treated farther on under the subject of "Repairs."

All ordinary wear in engine bearings can be taken up by removing shims and drawing to a tighter fit, termed "taking-up-on-the-bearings." The rear main bearing is usually the bearing which wears first, because it supports the weight of the fly wheel.

Connecting-Rod Bearings

Probably the **first bearings to require renewal** are those of the connecting rod.

The big end of the **connecting rod** is attached to the crank pin, and a bushing of bronze or white metal or other metal (with a melting point lower than that of cast iron) in the form of a shell, surrounding the crank pin, is secured in it.

The bushing is split lengthways into two halves, like the bearing of the crank shaft, one part being

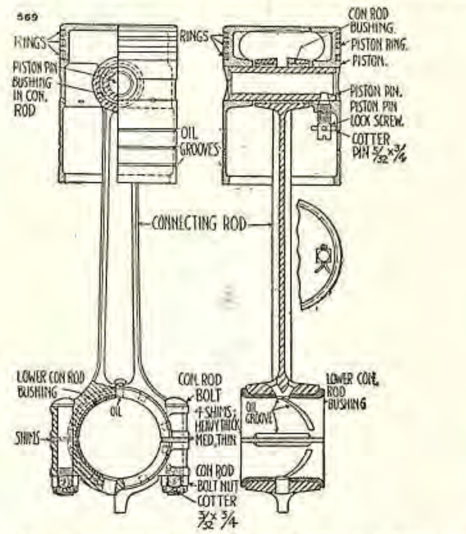


Fig. 25. A connecting rod showing piston-pin bushing and crank-pin bearing and cap. The bearing is in the small end of connecting rod for the piston pin. The piston pin is stationary.

set in the connecting rod and the other being held in place by the **connecting rod cap.**

The small or upper end of the connecting rod contains a solid bronze bushing (Fig. 25) that forms the **wrist or piston pin bearing.**[1]

Because of the small space in the piston, it is not possible to have this bushing split and held in place by a cap. The bushing is therefore set in the connecting rod, and the piston pin pushed through it. The wear of the piston-pin bushing is slight, and if it should wear loose, a new bronze bushing is driven into the connecting rod.

The **piston pin** is passed through the piston, and secured so that it cannot move. It is usually case hardened. This type is termed a "stationary piston pin."

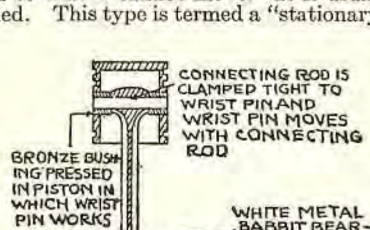


Fig. 26. Note that in this type the piston pin moves with the upper end of the connecting rod, and the bearings are in the piston bosses.

On (Fig. 26), the piston pin moves with the motion of the connecting rod, the small end of the connecting rod being clamped to it. The piston pin moves in bronze bushings fitted in the piston. This type is termed an "oscillating-type piston pin."

Through the connecting rod the piston transmits the pressure of the explosions to the crank shaft and fly wheel. In order that it may withstand the heavy shocks of the explosions, the connecting rod must have great strength. It is made of drop-forged carbon steel, heat treated, and, in rare instan-

[1] See page 781 for more modern nomenclature for bearings and bushings.

ces, is of bronze. A straight I-beam type is used almost universally.

Bronze is used extensively on large, slow-speed engines, but would be too heavy for automobile work, as the high-speed engine requires light-weight reciprocating parts. Each connecting rod should weigh the same.

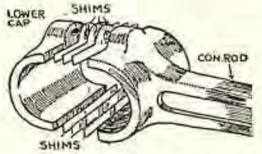


Fig. 27. Connecting-rod bearing end with cap removed to show shims.

Most connecting rods and main bearings are fitted with "shims" as in Fig. 27. When the bearing wears, a shim can be removed, thus drawing the lower cap tighter around the shaft. **Shims** are made of thin layers of metal .001″ to .005″ thick. The thinnest shim is usually placed at the bottom. Sometimes shims are made of paper.

Shims are used on the lower end of nearly all connecting rods, except in those engines using oil pressure in a hollow crank shaft which is cross-drilled to supply oil to the connecting-rod bearing. If shims were used with this type, they would allow oil to escape so rapidly that the oil gauge would show little or no pressure. The lower half of the connecting-rod bearing face is lapped off until an amount of metal representing the thickness of a shim has been removed.

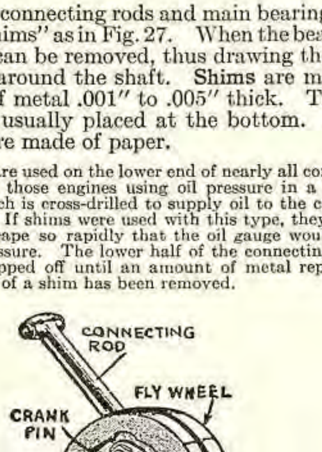


Fig. 28. Upper illustration shows a connecting rod, a crank pin, and a crank arm on a single-cylinder motorcycle or cyclecar engine. Note that a crank pin is between the two fly wheels which are placed in the crank case. The lower illustrations explain two methods of connecting two connecting rods to one crank pin on a "V"-type engine.

The connecting rod on a crank shaft of a "V"-type engine can be placed either "yoked" or "side by side," as shown in Fig. 28. When they are yoked, the cylinders would be "in line"; if side by side the cylinders would be "staggered," or slightly out of line.

The Piston

The piston of a gasoline engine is called a "trunk piston," to distinguish it from the "disk piston" of a steam engine.

A trunk piston is longer than its diameter, and is hollow, with one closed end. The closed end is toward the combustion space, and it is against the closed end that the force of the explosion acts.

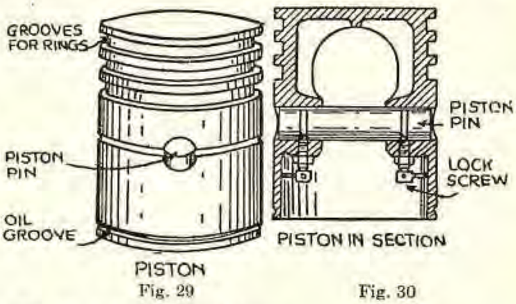


Fig. 29 Fig. 30

Fig. 29. A trunk type of piston.

Fig. 30. Sectional view of piston. Note piston pin is stationary, being secured in the piston boss by a lock screw.

The piston pin passes through the piston, usually about the middle or a little nearer the top (depending on the stroke).

The open end of the piston permits the connecting rod to swing from side to side.

The piston does not fit the cylinder tightly, for a tight fit would cause friction and wear. This space is called **piston clearance** (see Index). The piston is usually slightly smaller at the top than at the bottom, because the heat is more intense at the top and expansion must be allowed for.

A piston is usually measured at the skirt, or below the piston pin. Pistons are made of cast iron, and when heated they expand. The usual clearance between the cast-iron piston and cylinder wall is about .001″ to each inch of piston diameter.

Meaning of "piston clearance": Let us take, as an example, a Continental Model N engine which is 3¾″ bore. In decimals, therefore, its bore would be 3.750 (three inches and seven hundred and fifty thousandths of an inch).

Suppose the clearance of the piston was .003 (three thousandths of an inch), which would mean the piston diameter should be .003 less than the bore, then 3.750 (the bore) minus .003 (the clearance) would equal 3.747 (three inches and seven hundred and forty-seven thousandths), which would represent the diameter of the piston for a clearance of .003 for this engine.

Pistons are usually marked on top and in decimals. The diameter is that of the skirt. The **bore of a cylinder** is usually stamped on the lower machined face of the cylinder block.

Aluminum alloy pistons are used to a certain extent instead of cast iron.

Advantage: They are about one-third lighter; thus the inertia of the reciprocating piston is reduced considerably, and consequently the side-pressure or thrust on the walls of the cylinders is lessened. The great heat conductivity of aluminum alloy lessens the carbon deposit on the piston head and the deposit is more easily removed. In case of extreme heat, if the piston should "seize," the cylinder is not damaged by aluminum because it is softer than the cylinder.

Disadvantage: Aluminum alloy pistons expand twice as much as cast iron, and therefore when the engine is cold the clearance between the piston and cylinder wall being twice as great as normally, raw gasoline is drawn into the cylinder which passes down to the crank case and thins the lubricating oil and washes off all of the lubrication on the cylinder walls. A "piston-slap" is also produced, due to the great clearance, until the pistons are heated up, at which time they expand and the piston-slap noise should cease.

On one model of the Franklin, the shallow, square groove of screw-thread form was turned at the bottom of the skirt of the piston just beneath the lower ring. This held oil and permitted a smaller clearance.

Pistons and connecting rods for high-speed work should be made very light. In some instances, where cast iron is used, the piston is made lighter by making the skirts thinner and the piston pin-boss lighter. On some high-speed engines the piston skirt is sometimes drilled with large holes for the sake of lightness.

Piston Rings

The pressure from the explosion is prevented from escaping between the piston and the cylinder wall by **piston rings.**

The piston rings fit in the groove around the upper end of the piston, and there may be from two to five of them, usually three. The rings fit the groove snugly, but not so tight that they may not move freely.

They are cut crossways, so that they may be sprung open. When closed, so that ends touch, the rings are a trifle smaller than the diameter of the cylinder.

When sprung open, they are larger than the diameter, or bore of the cylinder. They are so made that they always stand a little open.

The rings are slipped into the grooves by springing them open, and sliding them over the piston.

When a piston is to be placed in a cylinder, the rings are drawn together, so that they will slide in easily. The piston with its rings fits the cylinder snugly, and the elasticity of the rings keeps them pressed against the cylinder wall, making a fit that keeps the pressure from escaping.

Since none of the pressure of the explosion is able to escape, it is all exerted against the closed end of the piston, or **piston head.**

The rings must be placed on the piston so that the ends are not one over the other, for if they were in line the pressure might escape through them (see Fig. 31).

Fig. 31

Fig. 32

Fig. 31. In order to prevent compression passing through the joints of rings they are placed as illustrated.

Fig. 32. Two standard types of piston-ring joints.

The rings are prevented from moving around the piston by **pins** placed between the ends (although this is not the case on all pistons). The only motion they have is the spring in and out.

The ends of the rings are beveled, or made with a joint (as in Fig. 32), so that the gas will not leak through the joint. Two of the usual types of piston rings are shown in Fig. 32. Piston rings are made of cast iron of a slightly softer grade than the cylinder.

There are many improved types of piston rings which the manufacturers claim will not leak; usually three rings are placed on a piston. Two rings are often used for high-speed work, whereas, for average automobile engines, three rings are generally used. This subject is fully treated in the "Repair Section" of this book.

Piston rings are measured according to the bore of the cylinder and the width of the ring groove.

The Crank Shaft

The crank-shaft-throw changes the reciprocating motion of the piston to the rotary motion necessary to turn the wheels. It rests in bearings that hold it in a fixed position, but permit it to revolve.

The crank pin must be rigidly attached to the crank shaft, and to secure this rigidity, it is usually made in one piece, solid as in Fig. 33, and is usually made of chrome nickel steel.

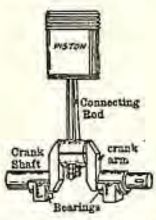


Fig. 33. A single-throw crank shaft. Crank is set at 360°.

The crank projects from the crank shaft, and when the shaft revolves, the crank makes circles around it. A crank is one of the most common mechanical devices. The crank pin is that part to which the connecting rod fits and is also called the **"throw"** of the crank. A windlass is turned with a crank; a bucket or chain pump is operated with a crank; the pedals of a bicycle form cranks.

In a bicycle, the crank arms are attached at their inner end to the crank shaft, and to their outer ends the pedals are attached. When riding a bicycle, the feet press on the pedals at the ends of the crank arms, and make the crank shaft revolve. The feet describe circles around the crank shaft. Each crank arm and pedal form a crank, and there is only one arm to a crank.

In a gasoline engine, two arms are necessary, for the reason that the cranks are not at the ends of the shaft. There are therefore **two arms** to each crank or "throw." (Fig. 33.)

The outer ends of the crank arms are connected by the **crank pin.** The crank pin corresponds to the pedal of a bicycle. A gasoline engine has as many cranks as it has cylinders.

Degrees as Used with a Crank Shaft

The position of a crank on a crank shaft in relation to other cranks on the same shaft is expressed in degrees of a circle.

A degree is designated with a small ° at the right of the figure. For instance, a crank shaft with throws of 360 degrees, would be designated as 360°. See Index, explaining the meaning of "degree."

If the cranks project from the same side of the shaft, as in Fig. 33, so that the crank pins are in line, it is called a 360-degree (360°) crank shaft.

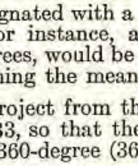


Fig. 34. A two-cylinder vertical engine with a 360-degree crank shaft; both connecting rods on one crank pin.

When the two crank pins on a crank shaft project in the same direction, as in Fig. 34, both connecting rods drive as one crank. This type of engine, however, is not used on account of its vibration. An engine with a crank shaft as shown in Fig. 36 would be more balanced. See Index under "Firing order" of cylinders.

If a crank shaft has two crank arms projecting in opposite directions, as in Figs. 35, 36, and 38, it is called a 180-degree (180°) crank shaft.

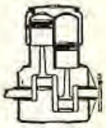


Fig. 35

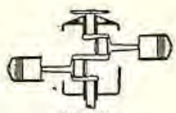


Fig. 36

Fig. 35. A two-throw crank shaft for a two-cylinder vertical engine; crank set 180 degrees.

Fig. 36. A two-cylinder opposed type of engine with crank shaft set 180 degrees. Cylinders are also 180 degrees apart.

The engine in Fig. 36 is **a two-cylinder opposed type of engine.** It was formerly used to a great extent on small cars, and is still used on trucks and tractors for heavy work. The cylinders are placed 180 degrees apart. The crank shaft is also 180 degrees.

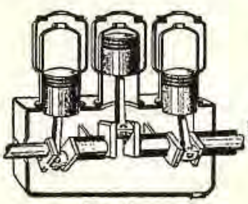


Fig. 37

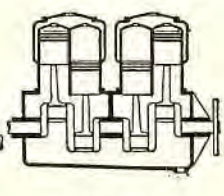


Fig. 38

Fig. 37. A three-cylinder vertical type of engine with cranks set at 120 degrees. Note No. 2 piston is up. No. 3 (right) would be 120 degrees or one-third of a revolution; No. 1 would be 120 degrees, or one-third revolution from No. 3, or two-thirds from No. 2.

Fig. 38. A four-cylinder vertical engine with crank shaft set 180 degrees. Note piston No. 1 and 4, and 2 and 3 are always in line.

The four-cylinder engine (Fig. 38) employs a 180-degree crank shaft. Note the "throws," or crank pins, of the crank shaft on cylinders 1 and 2 are 180 degrees apart and on 3 and 4 are 180 degrees apart. Therefore, pistons on cylinders 1 and 4 always move up or down together, and 2 and 3 move up or down together. In other words, these crank throws are in line.

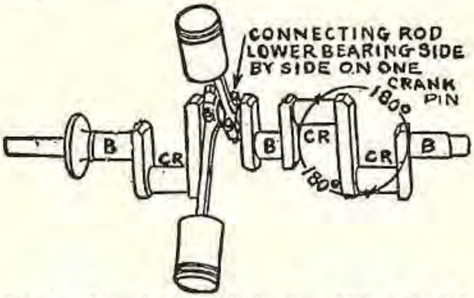


Fig. 39. A regular four-cylinder type, 180° crank shaft is used on the eight-cylinder "V" type of engine. Two connecting rods are placed on one crank pin, either side by side, or yoked (see Fig. 28).

The eight-cylinder "V"-type engine would in reality be nothing more than two four-cylinder engines with cylinders set "V" shape, the angle of the cylinders usually being 90 degrees, or one-half of the 180 degrees of the crank shaft. The same four-cylinder 180-degree crank shaft is employed. There are **two connecting rods to** each throw of the crank, which can be placed "side by side" (Fig. 39), or "yoked."

When connecting rods are placed side by side, as shown in Fig. 39, it is necessary to "stagger" the cylinders by setting them out of line with each other. If "yoked," the cylinders would be in line.

A three-cylinder engine must have a crank shaft with the three crank pins placed in three positions, or one-third of a revolution apart; this would be placing them 120 degrees apart (see Fig. 37).

A six-cylinder engine would have a crank shaft with six crank pins or crank "throws" placed in thirds, or 120 degrees apart. There would be three pairs in line (see Fig. 40).

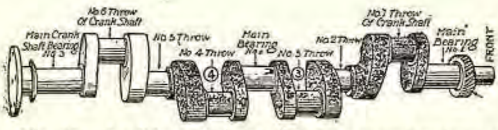


Fig. 40. A solid crank shaft, with three main bearings; six cylinder.

A twelve or twin-six-cylinder "V"-type engine would use the same type of six-cylinder crank shaft, but with two connecting rods to each crank pin. The cylinders would be placed 60 degrees apart, or one-half of the 120-degree crank shaft.

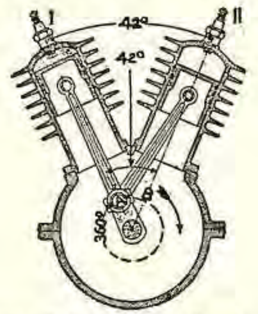


Fig. 41. A two-cylinder twin type of engine used on motorcycles and light cars. Note the 360-degree crank. Cylinders are at a 42° angle.

The twin-cylinder "V" type of engine used on a cycle car and motorcycle would use a 360-degree crank or one crank pin, with connecting rods "yoked." Cylinders on this type of engine are usually placed at an angle of from 42 to 45 degrees apart.

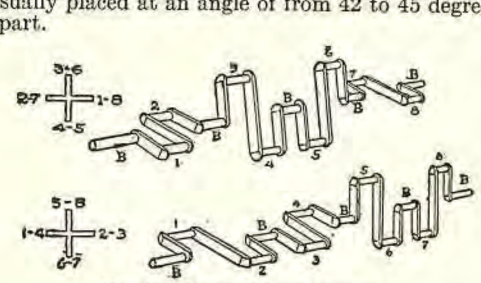
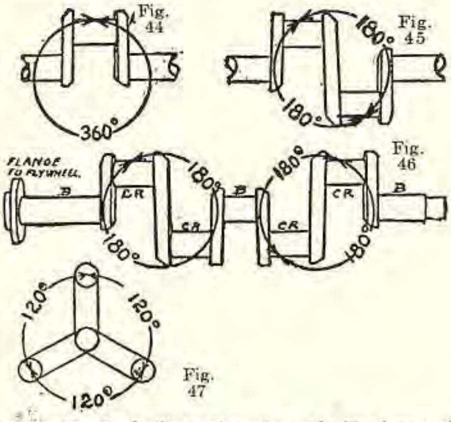


Fig. 42 (lower); Fig. 43 (upper).

Two methods of placing the crank throws on a "straight-eight" cylinder engine, where the eight cylinders are all in line are shown in Figs. 42 and 43. (B) are bearings and (1) to (8) are the crank pins.

The Duesenberg arrangement where two four-cylinder crank shafts are placed end to end, one of them being given a twist so that its "throws" are 90 degrees to the throws of the other is shown in Fig. 42. There are 3 main bearings on the Duesenberg. This crank shaft is made from a solid piece of steel. Counterweights not shown in the illustration are integral with the shaft. Fig. 43 shows another arrangement, which would give a different firing order. It is similar to the crank-shaft used on the **Packard straight-eight** engine. Note that crank pins 3, 4, 5, and 6 are at right angles to crank pins 1, 2, 7, and 8. There are 9 bearings to the Packard crank shaft. The firing order is 1, 3, 2, 5, 8, 6, 7, 4. The **advantage** claimed in using the "straight eight" is a better balance than any other eight-cylinder engine of the "V" type.



Figs. 44–47. In the illustrations above, the idea is to explain the term "degree" used in connection with crank shafts. Any perfect circle is 360°. If the circle is divided into quarters, each quarter would be 90°; half of the circle 180°; a third 120°

Fig. 44. Note one crank pin—hence 360° crank.

Fig. 45. From center of one crank pin to center of another is half a circle, or 180°.

Fig. 46. Here we have two pairs of crank pins as shown in Fig. 45. Each pair of crank pins is placed 180° to each other.

Fig. 47. End view of a three or six-cylinder crank shaft. Note that crank arms are one-third apart, or 120°.

Construction of Crank Shafts

There are two kinds of crank shafts, one known as the **"solid crank shaft"** and the other as the **"built-up crank shaft."**

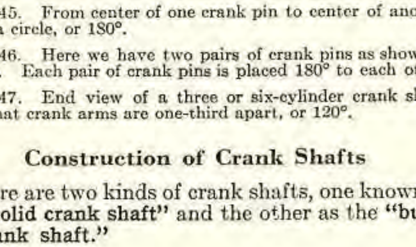


Fig. 48. A solid type of crank shaft—three-bearing type, four-cylinder.

The solid crank shaft is by far the most commonly used. It is made from one piece of steel, which is forged to shape and then turned up in a lathe, the workmanship in many cases being accurate to a ten-thousandth part of an inch.

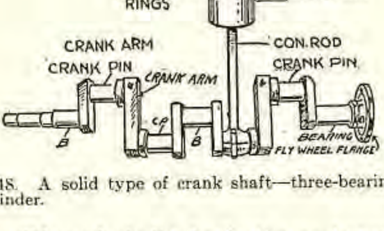


Fig. 49. A built-up type of crank shaft (seldom used). The above is a six-cylinder crank, with four bearings. Note that it is built-up to disks.

The built-up crank shaft (Fig. 49) has each of its parts made separately and then fixed strongly together, and quite often fitted with ball bearings. Ball bearings can be fitted only to a built-up type if there are more than two bearings.

An advantage of the built-up crank is that the crank-shaft bearings could be fitted with ball bearings, as shown in Fig. 50. However, built-up shafts of this kind are not usual, and in the case of

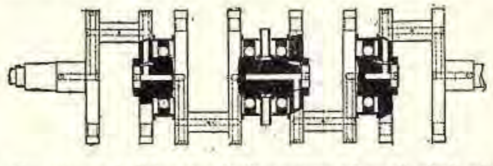


Fig. 50. A ball-bearing, built-up type of crank shaft with bearings for a four-cylinder racing engine. With three or more bearings it is necessary to have a built-up crank shaft in order to mount the ball bearings. On
engine there are two ball bearings placed on the outer bearing ends of the crank shaft. Thus a solid ball-bearing crank shaft can be used. See Index
under "White ¾-ton truck."

powerful engines, only the strongest solid crank shafts are ever used.

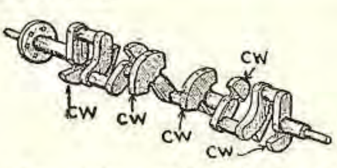


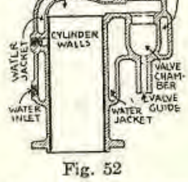
Fig. 51. Counterbalance weights applied to a six-cylinder crank shaft.

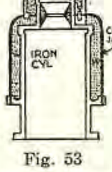
The counterbalanced crank shaft (Fig. 51), with counterweights (CW) electrically welded to the crank shaft and an integral part of the crank shaft, as illustrated, is becoming popular. It permits high speeds to be obtained without detrimental vibration, and relieves the tendency to "whipping" of the crank shaft and "slapping" of the pistons at high speeds.

Whipping of crank shaft is more pronounced where there are very long weak crank shafts with great distance between bearings. Vibration of an engine can also be due to forces being out of balance or unequal; for instance, engine loose on frame; uneven compression; weak explosion in one or more cylinders due to leaky rings or valves, or too much oil in that particular cylinder; defective spark or plug; sprung crank shaft; clutch out of balance; new full-size bearing and shims on one crank throw, and the old worn or lighter bearing with shims or liners removed on the other crank throw; different weight pistons; front wheels out of true, rim out of plane with spokes.

Cylinders

The cylinder of a gasoline engine is made of cast iron or twenty per cent semi-steel, and the water jackets are generally cast in one piece with it. The cylinder of a gasoline engine is cast with water jackets surrounding it and in one piece (Fig. 52).





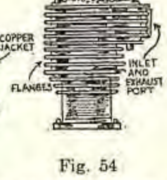


Fig. 52 Fig. 53 Fig. 54

Fig. 52. A single cylinder with water jacket cast around it.

Fig. 53. A single cylinder with a copper water jacket placed around it. An obsolete design.

Fig. 54. Air-cooled, flanged type cylinder.

On some of the early-model engines, such as the Pope Toledo and the 1914 Cadillac, the water jacket was formed by surrounding the upper part of the cylinder with sheet copper as in Fig. 53. This method is now obsolete.

The portion of the cylinder in which the piston moves should be a true circle, and as smooth as possible. In the better grade of cars the **cylinder walls** are ground to a smooth finish so that there may be as little friction as possible. Any roughness of the walls will cause wear, which comes in the form of cuts and scratches lengthways, and permit the pressure to escape around the piston.

Cylinder heads may be cast **solid** or with **detachable head** (see Fig. 62). The detachable head is very popular, especially where cylinders are cast "in-block." It permits easy access to the valves, and for removing carbon and removing pistons, and is also good manufacturing practice because it makes the grinding of cylinders easier. Where cylinders, on a **multiple-cylinder engine,** are cast singly or in pairs, the heads are usually solid and the entire cylinder is removed from the crank case when work is to be done inside.

Cylinders for **gasoline engines** are made in several **different shapes** and are usually made of cast iron. Some of the **airplane engines** have cylinders made of steel, and some of the engines used on trucks and tractors have **inner sleeves** which are removed and replaced with new sleeves when worn. The Marmon "34" passenger car automobile engine uses cylinder sleeves. See Index under "Cylinder sleeves." The type used most for automobile work is the **cast-iron cylinder** with a water jacket cast around it.

Cylinder Designs

The "T"-head type of cylinder is made so that the exhaust valves are on one side and the inlet valves are on the other side. Note the "T" shape in Fig. 55.

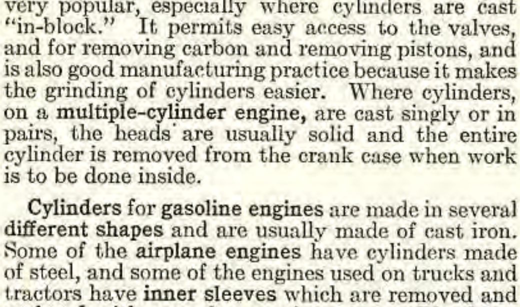


Fig. 55 Fig. 56 Fig. 57

The "L"-head type of cylinder is made so that the exhaust and inlet valves are all on one side of the cylinder. Note the "L" shape in Fig. 56 (if turned up-side-down).

The "I"-head type of cylinder is made so that the valves are placed in the top of the head of the cylinder (Fig. 57), and is termed the "valve-in-the-head" type.

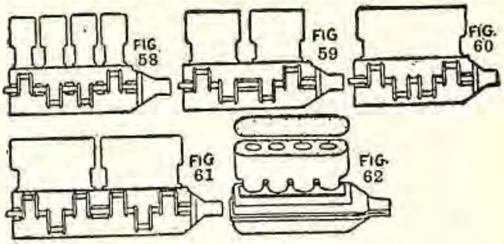
The "F"-head type of cylinder is made so that one valve is in the head, usually the inlet, and the exhaust is on the side.

How Cylinders Are Cast

When an engine has **more than one cylinder,** the cylinders can be cast singly, in pairs, or in-block, and can be of either the "T," "L," round or "I"-head type. Sometimes multiple cylinder engines have all cylinders cast singly. They can be of the "T," "L," or "I"-head type.

Cylinders cast singly, as applied to a four-cylinder engine, are shown in Fig. 58.

The term **Cylinders cast** in-block means that the multiple cylinders are all cast in one piece. They can also be of the "T" or "L"-head construction.



Note in Fig. 60 that the cylinders are in-block and the **head is solid,** whereas in Fig. 62, the **head is detachable.** The term **"mono-block"** is also often used where all cylinders are cast in one block. **Cylinders cast in pairs** are shown in Fig. 59. The engine is a four-cylinder type. **Cylinders cast in triplets** are shown in Fig. 61. The engine is a six-cylinder. The cylinders could be cast in-block, or in pairs, triplets, or singly. The Locomobile six-cylinder engines have the cylinders cast in pairs and the majority of other six-cylinder engines have cylinders cast in-block.

Cylinders on the **six-cylinder engines** are usually of the "L"-type, except the Pierce-Arrow and Locomobile, which are "T"-type.

Cylinders on **eight-cylinder "V"-type engines** are usually cast "in-block" and are placed 90 degrees[1] apart, and on a twin-six-cylinder engine, 60 degrees[2] apart (see Fig. 63). On a **twin "V"-cycle car or motorcycle engine,** the cylinders are usually 42° to 45° apart.

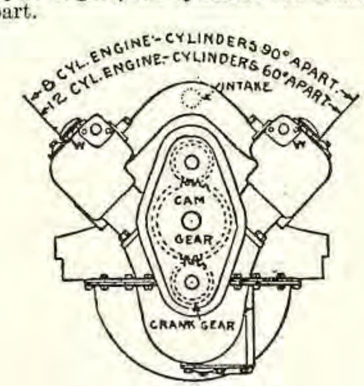


Fig. 63. A "V"-type eight-cylinder engine. A 180-degree four-cylinder type of crank shaft is used with two connecting rods on one crank pin.

Cylinders on a **two-cylinder engine with cylinders placed opposite** are shown in Fig. 64. Note that the cylinders are placed 180 degrees apart and are in a horizontal position. This is termed an "opposed-cylinder" engine.

The offset cylinder with an offset crank shaft or offset cylinders, or with Des Axe crank shaft setting, as you choose to say, is represented in Fig. 66. The line **A,** which passes through the center of the cylinder, is some distance to one side of the line **B,** which passes through the center of the crank shaft. Some of the advantages claimed for the

[1] Lincoln and Wills-Saint Claire eight-cylinder "V"-type of engines have cylinders set 60° apart.

[2] On the Liberty, twelve-cylinder "V"-type of engine, the cylinders are set 45° instead of 60° apart.

offset crank shaft are less liability of a back-kick, reduced wear on the bearing surface of the cylinder walls, connecting rods, and crank shaft,

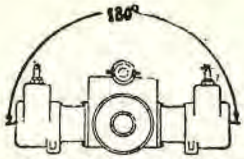
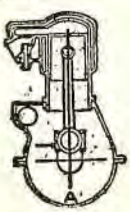
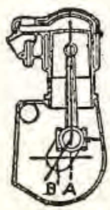


Fig. 64. Two-cylinder opposed type engines.

less liability of the engine to be stalled when the car is running slowly on a high gear, and other construction facilities. The cylinder **set central** over the crank shaft, as in Fig. 65, is the type in general use. See page 61; "Effect of offset cylinders."





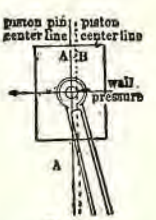


Fig. 65 Fig. 66 Fig. 67

An **offset piston** is shown in Fig. 67. Note that the piston center line is not in line with the wrist, or piston-pin center line. The reason for the offset of the piston is to compensate for the reaction of the side thrust of the piston during the power stroke. When the piston is part way down on its power stroke all of the power or pressure on the piston is transmitted to the connecting rod at an angle, which reacts against the piston wall in proportion to the angle at that moment, mounting to a maximum at 45 deg. The greater portion of this area is below the wrist pin, so by placing the largest area on the left side, the tendency is to tip the piston against the side-thrust pressure and thus give a better equalized pressure. The Buick engine has the piston slightly offset.

Meaning of Bore and Stroke

The stroke is the length or distance the piston travels up and down inside of cylinder. **The bore** of a cylinder is its inside diameter.

Square stroke. When the piston travel in a cylinder has the same length as the bore in diameter, it is called a square stroke and bore.

Long stroke. When the piston travel is much more than the bore diameter, then it is called a long stroke. For instance, an engine with a piston of 4" diameter, with a stroke of 4", is called "square-stroke" engine. The case of a cylinder whose bore is, say, 4" and the stroke 5½", would be called a "long stroke."

The valve chamber is that part surrounding the valve. The **valve port** is the opening for the intake or outlet of gas.

The combustion chamber is the inside upper portion of the cylinder, above piston, when the piston is at the top of its stroke.

Inlet and Exhaust Manifold

The **inlet manifold** is the part which connects to the inlet port openings in cylinders, from the carburetor. If there is only one connection to the cylinder, as on a single-cylinder engine, then it is called an **inlet pipe.**

When the valves are all placed on one side of the engine, as in the "L"-head type of cylinder, then the inlet and exhaust manifold are both on the same side of the cylinder.

When the inlet valves are on one side and the exhaust valves on the other side, as in a "T"-head cylinder, then the inlet manifold is generally on one side and the exhaust manifold on the other side.

The **exhaust pipe** leads from the exhaust manifold to the muffler. If the engine is an eight or twelve "V"-type, there are usually two exhaust pipes and two mufflers. In order that the exhaust manifold may be cooled as rapidly as possible, the exhaust manifold and pipe, connecting the exhaust valve chamber to the muffler, are exposed to the air.

The **connection from exhaust manifold to exhaust pipe** is usually made with a flange connection, with asbestos packing between.

The muffler and exhaust pipe should be made so that there is as little **back pressure** as possible. Back pressure is caused by anything that prevents the free escape of the gas. Therefore sharp bends should be avoided, otherwise the incoming fresh mixture becomes mixed with that part of the burned gas left from the previous charge, and the power of the engine is cut down accordingly.

The Muffler—also Called "Silencer"

Purpose: If the exhaust valve opened directly into the open air, the noise of the combusted gases escaping through the exhaust port during the exhaust stroke would sound like the firing of a gun.

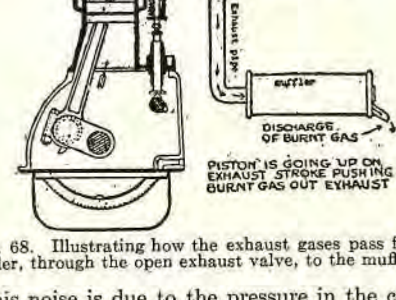


Fig. 68. Illustrating how the exhaust gases pass from the cylinder, through the open exhaust valve, to the muffler.

This noise is due to the pressure in the cylinder being much higher than the pressure of the air, and a sudden change from one to the other produces a loud report. The more sudden the change and the greater the difference in the pressure, the sharper will be the noise. For instance, the noise would be greater if climbing a hill with an open throttle, than if running on a level with a partially closed throttle.

To silence the noise, a muffler is connected to the end of the exhaust pipe, which is connected to the exhaust manifold (Fig. 68). The exhaust manifold is connected to the exhaust valve ports.

Construction: The muffler is usually made of iron pipe, like a stove pipe, with cast-iron heads, as in Fig. 69. The exhaust gases (when the exhaust valves are opened) pass through the exhaust pipe into the chamber (C), as shown by the arrow marks; then through openings in rear of (C), passing into chamber (B), then through openings in front of (B), into (A), then through (A) to the open air.

If the muffler is not designed properly and is too small, or if it becomes clogged with soot, then the burned gases cannot be expelled as rapidly as they

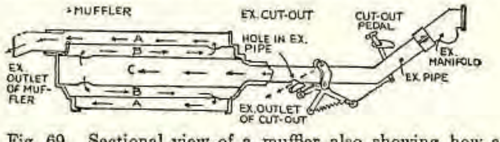


Fig. 69. Sectional view of a muffler also showing how a "cut-out" is placed on the exhaust pipe.

should be. The result is **back-pressure,** or a tendency for the gases to work back against the outcoming exhaust, and also a retention of heat, thus causing overheating of engine and a slight loss of power, due to the back-pressure.

The Exhaust Cut-Out

The exhaust cut-out is a device which can be placed on the exhaust pipe, between the engine and muffler (Fig. 69). It is arranged so that it can be opened by a foot pedal, thus permitting the exhaust gases to pass into the open air instead of the muffler.

The cut-out is now seldom used, except on speed cars or for hill climbing, because of the noise, and also because of the fact that mufflers are now designed so that there is only a slight back-pressure. The cut-out was used extensively during the early days, because engines were minus power and mufflers were not properly designed.

Inlet Manifold Construction

In the simplified illustrations below are shown different constructions, in order to give the reader an idea of the different methods which are and have been used.

With the **inlet manifold,** the design should be such that there may be as little resistance as possible to the flow of the mixture. This manifold should be as straight as the position of the carburetor will permit.[1] There should be no sharp angle-bends, the bends being as flat and easy as possible and the distance from carburetor to inlet ports as short as possible to prevent condensation.

When more than one cylinder is supplied from one carburetor, the distance from the carburetor to each valve should be the same. The inside of the inlet manifold must be smooth and clear so that there is no obstruction offered to the flow of gas.

In those illustrations marked "incorrect," the distance from the carburetor to the inlet valves is not equal, and consequently the valves nearest the carburetor will get more of the mixture than those farther away.

In the arrangement marked "good form," the distances are almost equal, and consequently the valves get equal quantities of mixture, and the engine will run more evenly than if the cylinders received different amounts.

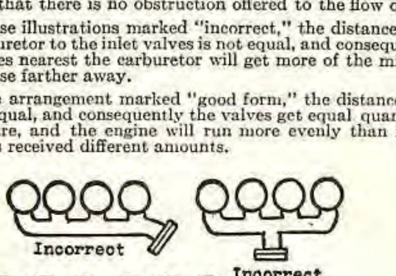


Fig. 70. Inlet manifolds.

Inlet manifolds are usually provided with **means for heating,** so that the gas mixture when passing through the manifold is vaporized. A hot-water jacketed manifold is shown in Fig. 71. The water connections are made with the circulating pump.

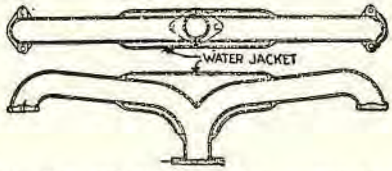


Fig. 71. Top and side view of a water-jacketed inlet manifold.

Most inlet manifolds are heated by a part of the exhaust gases passing through a jacket which surrounds part of the manifold.

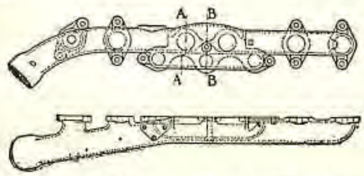


Fig. 72. Top and side view of an exhaust-heated intake manifold.

The "hot-spot" manifold is so arranged that the exhaust manifold surrounds part of the inlet manifold. Thus the exhaust gases pass over a portion of the inlet manifold which shortens the warming-up period with present-day fuel, and thus vaporizes the heavier particles of fuel more quickly. (See Fig. 72.)

This subject is also treated under the general subject, "Carburetion," in the discussion of "Heating the mixture."

Exhaust Manifold Construction

Sharp bends in the exhaust manifold or pipe cause back pressure, and should be avoided. Dirt in the pipe, or muffler, as well as soot in the muffler, has the same effect. In other words, the idea is to have the exhaust pipes offer the least resistance possible to the burned gases passing from the exhaust ports, otherwise part of the burned gases remain in the cylinder, mix with the fresh gases drawn in, and thus affect the mixture.

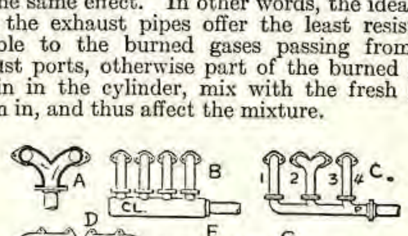


Fig. 73. Exhaust manifolds: A good method of exhaust outlet for a 2- or 4-cylinder vertical engine is shown in Fig. 73 at **A.**

B is a simple manifold in which an individual pipe from each cylinder exhausts directly into the large collector chamber **CL.** In this manifold the collector tube is made sufficiently large so that when the exhaust valve closes, the pressure in it is less than that in the cylinder at the valve, and thus there is no danger of back pressure.

C shows an arragement in which the pipes 2 and 3 for the middle chambers are formed in one, whereas they are separate for cylinders 1 and 4. This works satisfactorily in that cylinders 2 and 3 never fire consecutively, and the one pipe is capable of taking care of the exhaust of the two.

D is quite similar to the case shown in C, excepting that there are individual pipes for cylinders 1 and 2, and 3 and 4. This is bad construction, in that 4 fires immediately after 3, and 1 immediately after 2.

[1] Some engineers claim that an abrupt bend in the inlet manifold to produce **turbulence** is desirable. See page 115.

As the direction of the exhaust leaving the cylinders is the same it is very easy to make a manifold in which the exhaust pipes instead of having a tendency to obstruct one another, assist the other cylinders to exhaust.

In engines which have their inlet and exhaust valves opposite, frequently all four of the exhaust valves are connected through one manifold with a single orifice. F is one example of an arrangement where it is possible to make the two passages unite. This is suitable for engines with cylinders cast in pairs.

The defects of A and D can readily occur in this one; if makers were considering loss of power, they would not use this one, but they want only to save space.

For the best design, illustration G offers a reasonable solution. In this illustration there is an individual pipe from each cylinder to the large collector. At the end, each individual pipe projects into the collector tube and curves in the direction of the exit for this collector tube.

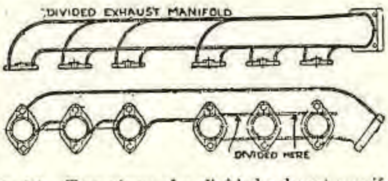


Fig. 74. Two views of a divided exhaust manifold.

The divided exhaust (Fig. 74) is used on several six-cylinder engines with cylinders cast in two blocks of three cylinders to a block. It is claimed for this design that it prevents overlapping and refilling of the cylinders with burned gases.

Valve Caps

Where valves are on the side and the head is cast integrally with the cylinders, **valve caps are screwed over the valves** in the cylinder. By removing these caps the valves can be lifted from their seat and ground. There are two valve caps to each cylinder; an **inlet-valve cap** and an **exhaust-valve cap.**

Compression or Relief Cocks, or Priming Cups

They consist of small **pet cocks** screwed into the exhaust valve caps. By opening them when the engine is running, it is possible to see if any of the cylinders are missing fire. A flame will shoot out if firing. They are also used for injecting gasoline when the engine is cold and hard to start. The S. A. E. term this a "priming cup."

Cams and Cam Shafts

A cam is a device that produces intermittent motion. When an object is in motion part of the time and at rest between motions, its action is said to be "intermittent." A cam may best be described as a wheel with a hump or nose on one side (Figs. 75 and 76); in other words, it is a piece of metal revolving with a shaft, part of its circumference being farther from the shaft than the rest. The part of the cam that projects is called the **nose.** Anything resting against the cam will be moved only when the nose comes around to it; otherwise it remains stationary.

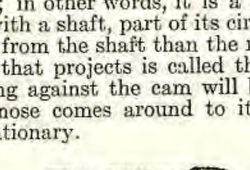


Fig. 75 Fig. 76

Fig. 75. Showing the nose of cam.

Fig. 76. Nose of cam raising valve plunger or tappet, which raises valve.

For a four-cylinder engine, four cams on the inlet cam shaft are shown in Fig. 77. Four more cams on an exhaust cam shaft are provided on the opposite side of this engine, because it has "T"-head cylinders. The cams are divided in four positions on the cam shafts, and are made in one piece or integral with the cam shaft. If the cylinder is the "L"-type, then all cams would be on the one cam shaft (see Fig. 79).

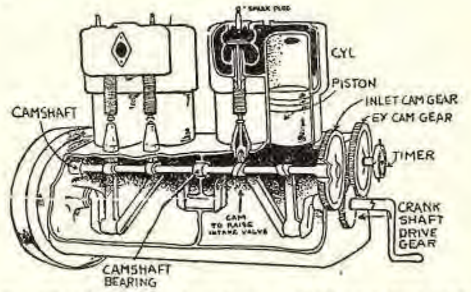


Fig. 77. Illustrating how the cam shaft on a four-cylinder engine is operated by timing gears; also how the nose of the cams raises the valves. There are two cam shafts placed opposite, therefore it is a "T"-head type.

For each cylinder there is one inlet cam and one exhaust cam. The **exhaust cam** usually has a **broader nose** because it must hold the valve open longer.

The **cam shaft,** also called the "secondary" or "half-time shaft," has a cog wheel or gear, called a "timing gear," on one end, which meshes with the **drive-shaft-gear** on the crank shaft. The cam shaft gear is also often driven by a **silent chain.**

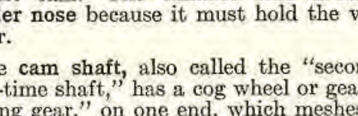


Fig. 78

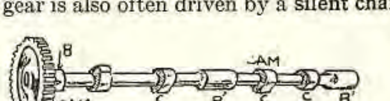


Fig. 79

Fig. 78. The cam shaft as used with a four-cylinder "T"-head type cylinder. There are two shafts, an intake cam shaft and an exhaust cam shaft—one on each side of the cylinder as shown in Fig. 80. There are four cams on each shaft. The noses of the cams are placed at different positions, so that the valves will be raised at a certain time. **C** are the cams. **B** are the bearings for the cam shaft.

Fig. 79. The cam shaft as used with a four-cylinder, "L"-head type of cylinder. There is but one cam shaft in this type because all of the inlet and all of the exhaust valves are on the "L"-side of the cylinder (see Fig. 81). There are eight cams on the cam shaft.

When the crank shaft revolves, the **drive gear on the crank shaft** drives the **timing gears,** which drive the cam shaft and thereby rotate the cams (see Figs. 80 and 81).

The **nose of the cam** raises a valve lifter or **tappet,** which plunges against the end of the valves and raises them from their seat. When the nose of the cam is under the roller or valve lifter, the valve is held open; the valve is closed after the nose passes, by the action of a strong spring.

The **valve stem,** being held in a **valve guide,** cannot move in any direction but up and down. Thus the steady **rotary** motion of the **cam** is changed to the **intermittent** motion of the **valve.**

NOTE: Valve caps and priming cups are now seldom used on the detachable cylinder heads of modern automotive gasoline engines. See footnote, page 37.

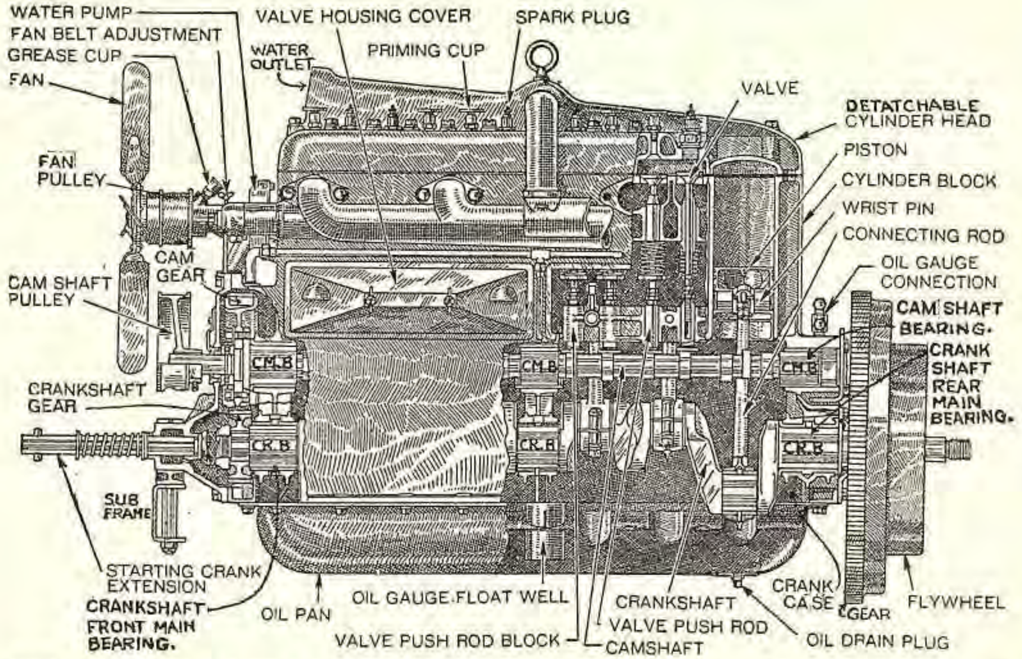


Fig. 83. Top view of the Mitchell model "F" six-cylinder engine. The illustration shows how the cam shaft is driven by gears. The crank-shaft gear drives the cam gear, which is attached to the cam shaft. The one cam shaft operates all valves (inlet and exhaust) from the one side of the engine.

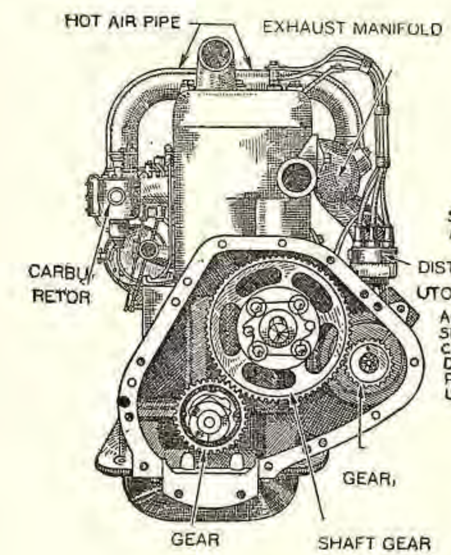


Fig. 83A

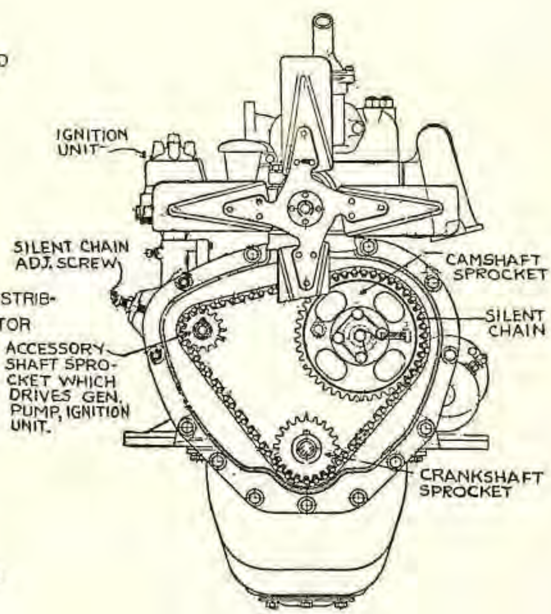


Fig. 84

Fig. 83A. End view of the Mitchell engine. Note that the crank-shaft gear (lower one) drives the cam-shaft gear (large one). The cam-shaft gear then drives the generator gear (on the right).

Fig. 84. Front view of the Studebaker model "EJ" six-cylinder engine. The cam shaft is driven by a **silent chain.**

As has been shown on four-cycle engines, each valve opens only once while the crank shaft makes two revolutions. Therefore the cam shaft should revolve only once while the crank shaft revolves twice.

The cams are an integral part of the cam shaft and one cam cannot be moved one way or the other unless all move together. There are **two types of cam shafts,** those operating from the **side** of the cylinder and those operating **overhead,** or above the cylinder.

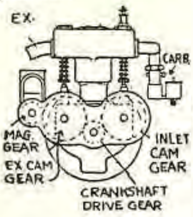


Fig. 80

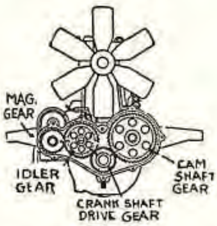


Fig. 81

Fig. 80. Showing method of driving the two cam shafts and magneto on a "T"-head engine. Note the two cam gears and shafts.

Fig. 81. Method of driving the one cam shaft. An idler gear is provided to drive the magneto gear. "L"-head type of cylinder engine. Note the one cam gear and shaft.

Gear-Driven Cam Shafts

The crank shaft drive gear and cam gears are called **timing gears.** If two gears running together

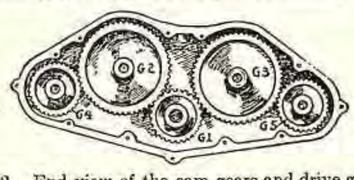


Fig. 82. End view of the cam gears and drive gear. The two cam gears (G2, G3) are called "half-time" gears, because they revolve just one-half the time, or revolutions, that the drive gear (G1) revolves. G1 is drive gear on crank shaft. G3 is cam gear for inlet cam shaft. G2 is cam gear for exhaust cam shaft. G4 and G5 are extra gears to drive the magneto and generator ("T"-head engine).

(or in other words, in "mesh"), have the same number of teeth they will make the same number of revolutions.

If the **driven gear** has twice as many teeth as the **drive gear,** it will revolve only once while the other revolves twice. This is called a "two-to-one" **or** "half-time" gear.

Because the cam shaft must revolve only once while the crank shaft revolves twice, the cam-shaft gear has twice as many teeth as the crank-shaft drive gear (see Fig. 82).

The **cam shaft revolves in the opposite direction to the crank shaft** when driven by gears without an idler and in the **same direction** when driven by a silent chain or an idler. The crank shaft and fly wheel of all gasoline engines revolve **clockwise,** or to the **right,** when facing the front of the engine. Thus gear (G1) (Fig. 82) would revolve clockwise.

The **wide-faced helical gear** is the popular type of gear for the timing gears because they make less noise than a straight-tooth spur gear. Special materials, such as fabroil, micarta, and other compressed materials, are used by many as material for making gears which are silent. Drop-forged gears are also used, so also is steel for the crank-shaft gear and cast iron for the cam gear.

Silent-Chain-Driven Cam Shaft

The **silent chain** for driving the generator is quite popular, and it is also being used to a great extent for driving the cam shaft. The object is to obtain quieter running. This type of chain must not be confused with the ordinary roller type as used on chain-driven trucks. The silent chain is more positive in action, otherwise the timing would be thrown out of adjustment. The **teeth on a sprocket** used for a silent chain are very close together and are accurately made. The **silent chain,** as its name indicates, is silent, but requires taking-up occasionally. After a certain period new links, or a new chain, is required. See Index under "Silent chains, adjusting of."

ENGINE VALVES

Purpose of valves: There are two valves to each cylinder of all four-cycle gasoline engines: an **inlet** valve and an **exhaust** valve.

Note. The "dual-valve" engine has four valves to each cylinder; two inlet and two exhaust valves. This subject will be treated later.

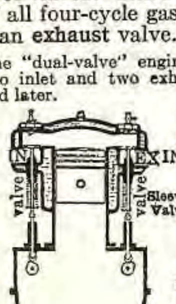


Fig. 85 Fig. 86

Fig. 85. Poppet type of valve: so named because the valve pops up and down. Poppet valves are used on "L," "T," "I" or "F"-head type of cylinders, and are always mechanically operated.

Fig. 86. The sleeve type of valve. There are two sleeves (S),—with openings at upper end. When these openings are together, the fresh gas is admitted or the burned gas is discharged. Mechanically operated. "IN" means inlet, and "EX," exhaust.

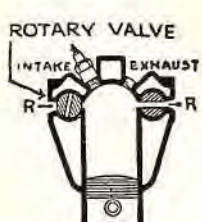


Fig. 87 Fig. 88

Fig. 87. The rotary valve.

Fig. 88. Automatic inlet valve. Suction of piston draws the valve open against the tension of spring. Exhaust valve mechanically operated.

Types of valves: There are three types in general use: the "poppet," the "sleeve," and the "rotary," (see Figs. 85 to 88), the poppet type being used almost exclusively.

The inlet valve admits fresh gas to the cylinder. As fresh gas is going into the cylinder during only one stroke in every four, the inlet valve is opened during only one stroke in every four, in other words, during one stroke in every two revolutions of the crank shaft.

The exhaust valve permits the burned and useless gas to escape. It is opened and held open by a cam on the cam shaft. It is thus described as "mechanically" operated.

Mechanically operated valves are opened and held open by means of cams and closed by means of a strong spring. The **exhaust valve** is always mechanically operated.

Inlet valves are generally mechanically operated, but some of the old and motorcycle type of engines have the inlet valves of the "automatic" type.

The **automatically operated inlet valve** is held against its seat by a light spring (see Fig. 88). During the suction stroke, the sucking action of the piston, as it travels downward in the cylinder, draws the valve open. At the end of the suction stroke, when the suction ceases, the spring forces the valve disk back to its seat, and the gas is prevented from escaping through the valve.

It must be understood that the valves of a gasoline engine always open in such a direction that the pressure from power and compression strokes tends to keep them firmly on their seats.

Valve Operation and Location

The "mechanically" operated "poppet" type valve is the type in general use, therefore we shall confine our attention to this type.

Valves are operated, or opened, by the intermittent motion of a cam and are closed by a strong spring.

The **location of the valves** may be overhead or on the side, or a combination of both.

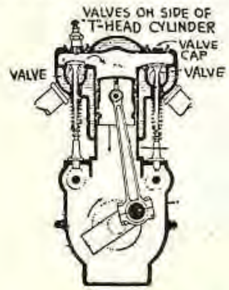


Fig. 89

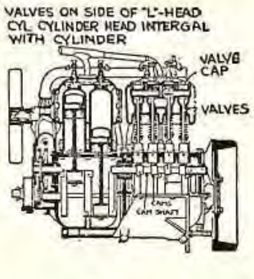


Fig. 90

Valves-on-the-side may be placed on opposite sides of the cylinder, as in the "T"-head cylinder type of engine (Fig. 89), or all on one side, as in the "L"-head cylinder type of engine (Fig. 90). Valves are operated by a cam shaft on the side.

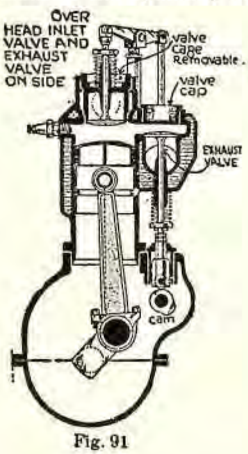


Fig. 91

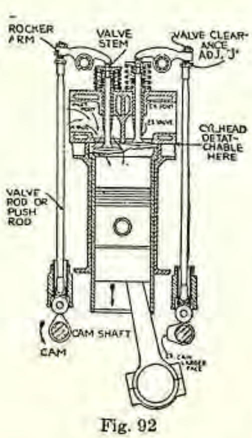


Fig. 92

Valves-in-the-head-and-side are illustrated in Fig. 91. In this instance, the overhead valve is always the inlet, and the valve on the side is the exhaust valve. Both valves in Fig. 91 are operated by one cam shaft on **the side**. The cylinder is of the "L"-type.

Valves-in-the-head (or both valves placed overhead) with a **detachable cylinder head** are shown in Fig. 92. The head is usually detachable from the valves. Thus valves are ground in the detachable cylinder head.

Note. Although Fig. 92 shows two cam shafts and valve rods on opposite sides of the cylinders, this is seldom found in actual practice. In most instances there is but one cam shaft, and the push rods are all on one side.

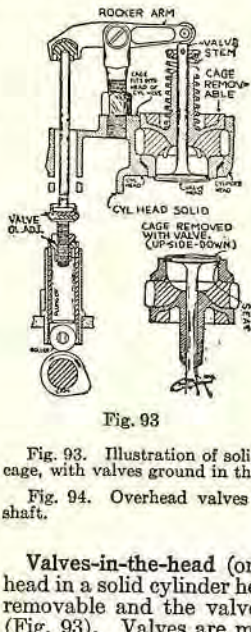


Fig. 93

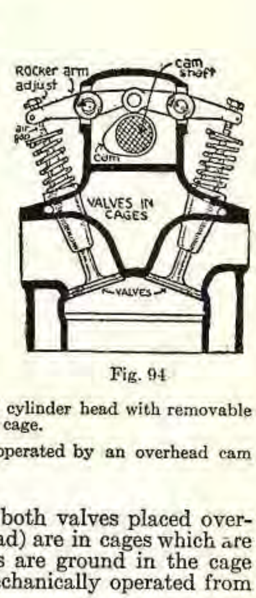


Fig. 94

Fig. 93. Illustration of solid cylinder head with removable cage, with valves ground in the cage.

Fig. 94. Overhead valves operated by an overhead cam shaft.

Valves-in-the-head (or both valves placed overhead in a solid cylinder head) are in cages which are removable and the valves are ground in the cage (Fig. 93). Valves are mechanically operated from the side by the cam shaft.

Valves-in-the-head operated by an overhead cam shaft are shown in Fig. 94. This principle is used on the Liberty Engine and on many other aviation engines.

The method of **driving the overhead cam shaft** is shown in Fig. 95. Note that the shaft (S) which drives the cam shaft is driven from the crankshaft gear. This principle is similar to that employed on the Stutz racing-car engine (Fig. 98).

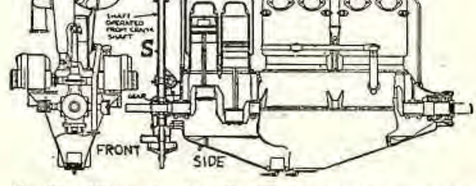


Fig. 95. Wisconsin six-cylinder aviation engine which has a valve action quite similar to that used on the Stutz racing cars. The cam shaft is carried overhead.

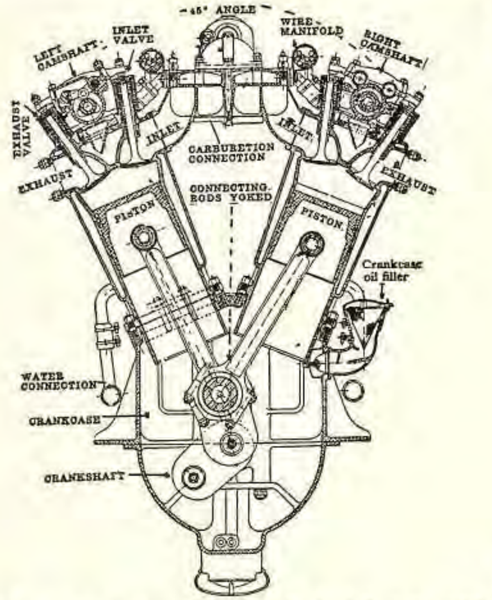


Fig. 96. A twelve-cylinder, or "twin-six" engine with valves-in-the-head operated by overhead cam shafts. This is the Liberty Airplane engine. The cam shaft is driven in a manner similar to that shown in Fig. 95.

The Dual Valve Engine

Dual valves are valves with two inlet and two exhaust valves to each cylinder. The Pierce-Arrow six-cylinder engine (Fig. 97) is an example of a dual-valve engine. The cylinders shown in the illustration are of the "T"-head type, with detachable head, cast in pairs, with a cam shaft on each side.

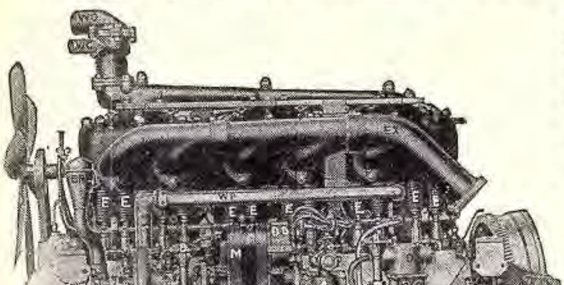


Fig. 97

Exhaust valves (**EE**) are on the left side of the engine and the inlet valves are on the right. This would be termed "valves-on-the-side." On the late model of Pierce-Arrow engines the cylinders are in-block.

Note. The left or right side of an engine or automobile is determined by being seated in the car, looking toward the front.

The Stutz engine (Fig. 98) is another example of dual valves, with both valves-in-the-head of the cylinder operated by an overhead cam shaft.

Advantage of dual valves: It is well known that greater power, especially at higher speeds, is obtained by using large valves. For instance, in standard practice, the rule is to have the valve diameter one-half that of the bore of the cylinder. For a 4½" bore, a 2¼" valve is used. In order, however, to get the maximum possible power, a 3" valve with a

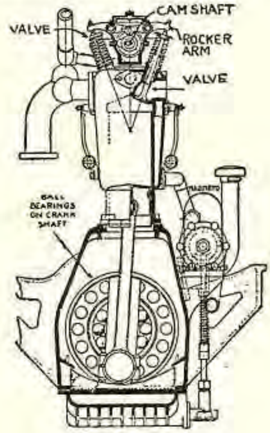


Fig. 98

⅜" lift would give greater power, but this would result in noisy valves, due to the heavy valve spring required to close them promptly, and also on account of the tendency of the exhaust-valve head to warp out of shape when heated.

Therefore, by using two smaller valves of about 2⅛" diameter with a ⅜" lift, the same opening area as the single 3" valve is obtained. This gives the maximum power and a very quiet valve action through the use of light valve springs.

Valve Arrangement

On the "L"-head type of cylinders, all inlet and exhaust valves are on one side, but they do not run consecutively. Owing to the fact that the exhaust manifold must connect with all exhaust valves and the inlet manifold must connect with all inlet valves, the valves are usually arranged as in the illustrations above. The exhaust is on the outside, next to the water jacket on most all engines, because of the greater heat at the exhaust valve. Fig. 99 shows a four-cylinder engine; Fig. 99**A** illustrates a six-cylinder engine. ("X" are exhaust valves).

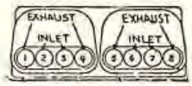


Fig. 99

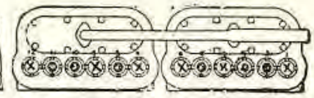


Fig. 99A

Fig. 99. Four-cylinder exhaust and inlet valves.

Fig. 99**A**. Six-cylinder exhaust and inlet valves. "X" are exhaust valves.

Although the valves vary in location and methods of operation, the principle or purpose remains the same; the inlet to admit fresh gas, and the exhaust valve opening at the correct time to expel the burned gas.

Valve Parts

Valve heads are made of cast iron, nickel steel, and tungsten steel. Cast iron is easily machined and works fairly well, but is heavy. Nickel steel does not heat as much as cast iron and does not expand as much as cast iron. Nickel steel heads are electrically welded to steel valve stems. Tungsten steel is hard and stands high temperature without heating. The **"poppet"-type valve** is the type in general use. We shall, therefore, confine our attention to this type. A "poppet"-type valve has **three parts:** a "head," a "stem," which forms the moving part, and a "valve face" which seats into a "valve

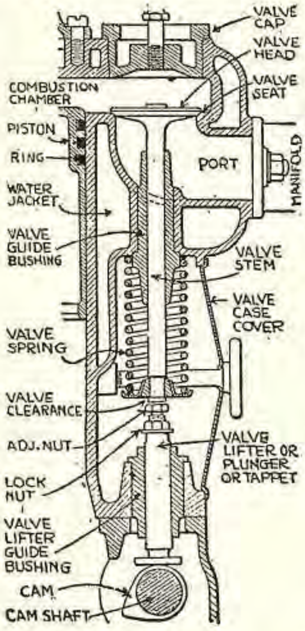


Fig. 100

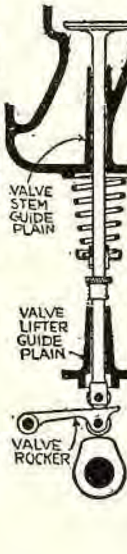


Fig. 101

Figs. 100 and 101. Two methods of operating the lift of the valve. Note in Fig. 100 that the lift is direct from the cam to the tappet, thence to valve stem, whereas in Fig. 101, a valve rocker arm takes the place of valve tappet. The method shown in Fig. 100 is the one in general use.

seat." This valve face is beveled and is perfectly round. When seated, it must fit the valve seat perfectly tight, otherwise during the compression stroke the gas would leak, and on the power stroke, a loss of power would result by the valve leaking at the seat. Therefore it is ground to this seat.

The expression **"valve-head diameter"** usually refers to the clear opening of the valve. The "valve-head" is the upper part of the valve and usually measures from one-third to one-half of the cylinder diameter. For instance, on the Continental model "7R" six-cylinder engine, which has a cylinder bore of 3¼", the diameter of the valve at the clear opening, or the small end of the bevel, is 1½", and at the head, or largest diameter, it is 1⅝". Both inlet and exhaust valves on this engine, as also on many others, are the same size.

The **valve lift** of this engine ("7R"), is 5/16". On the Pierce-Arrow, the valve lift is 11/32". "Valve lift" means the height the valve is raised from its seat by the cam. Therefore it is clear that if the valve stem clearance is not correct (the space between the end of the valve stem and the valve lifter), the lift would not be correct, and thus power would be lost, owing to the smaller valve opening. As a result of this, less gas would be drawn into the cylinder.

Valve seats are usually beveled at an angle of 45°. The diameter of the exhaust pipe should at least be equal to the diameter of the valve.

The valve spring holds the valve tight in its seat and must have sufficient tension at all times. If too strong, the valve will close with more noise. If too weak, the valve will not seat properly. The exhaust valve spring usually weakens first on account of being subjected to greater heat.

The valve-spring-retainer-and-lock, originally called the "valve spring washer," is placed at the bottom of the spring and held in place by a two-part lock. Formerly, a "key" was passed through a hole in the valve stem as in Fig. 104, but, as stated, a two-part lock is now placed in a groove in the valve stem under the retainer (washer).

The **valve face** is the beveled part of the valve head. The **valve seat** is the part of the cylinder head in which the valve face is placed. The valve face and seat can be conical or flat. It is usually conical, as in Figs. 100 and 102.

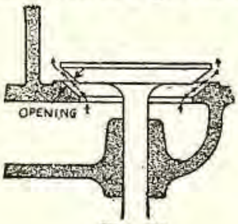


Fig. 102

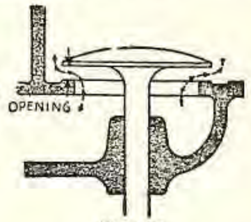


Fig. 103

Note the conical type of valve in Fig. 102 and the flat type in Fig. 103. It is said that the flat valve gives a greater opening for the same valve lift and has greater possibilities for high-speed work. Seldom used.

The **"tulip"-shaped valve** is another type, formerly used on the Cadillac for inlet valves. It is now seldom used (see Index).

The **valve stem** is the stem part of the valve head. The stem of a mechanically operated valve on the "L"- or "T"-head cylinder of the "side valve" principle usually extends about half-way down to the cam shaft. A valve lifter then lifts the valve stem by action of a nose on the cam as the cam revolves. To set this cam to raise the valve at the proper time, is called "valve timing."

On engines with overhead-valves, there is a rod, called the **"push rod,"** or **"valve rod,"** between the valve tappet and the rocker arm (see Fig. 92, page 53).

Note that a spring is placed between the valve tappet and the valve rod, which tends to keep the tension of the valve rod up and to reduce noise.

Valve-stem-clearance, also called "air-gap," is the distance between the lower part of the valve stem and the valve tappet. On the overhead, or valve-rod type, it is usually between the rocker arm and the end of the valve stem. This distance is regulated by an adjusting nut.

The **valve-lifter,** also called "valve plunger," "valve tappet," and other names, is the part placed between the valve stem and the cam. The top part has an adjustable screw which can be slightly raised or lowered to obtain correct valve clearance.

Exhaust cams usually have a broader nose than the inlet cam, because the exhaust valve remains open longer.

The bottom of the valve lifter is sometimes fitted with a "roller," (R), (Fig. 106). The "mushroom" type (Figs. 100, 104 and 105) is the type used most.

A **valve rocker**—upper—is used on all overhead valves, also called "rocker arm." A valve rocker—lower—is the principle shown in Fig. 101. It is also called a "side tappet lifter." The latter is seldom used.

A **valve-stem guide** holds the part through which the valve stem passes (Fig. 100). Sometimes it is bushed as shown in Fig. 100. Quite often it is plain, as in Fig. 101.

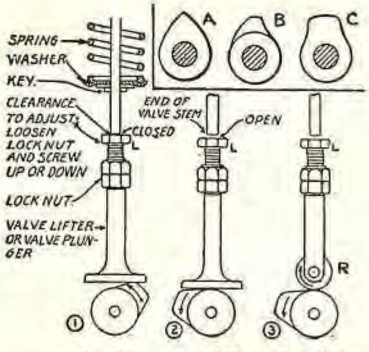


Fig. 104 Fig. 105 Fig. 106

Figs. 104, 105. Mushroom type of valve lifter.

Fig. 106. Roller type of valve lifter.

Note in Fig. 104 the valve just starting to lift. In Figs. 105 and 106, the valve is just closed.

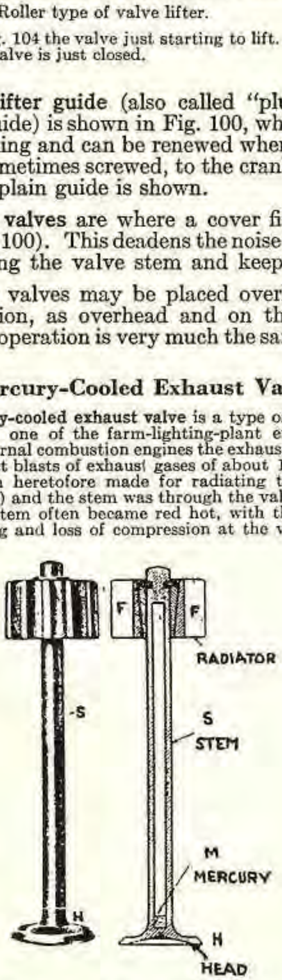
A **valve-lifter guide** (also called "plunger" and "tappet" guide) is shown in Fig. 100, which is fitted with a bushing and can be renewed when worn. It is bolted, sometimes screwed, to the crank case. In Fig. 101, a plain guide is shown.

Enclosed valves are where a cover fits over the valves (Fig. 100). This deadens the noise of the lifter when striking the valve stem and keeps out dust.

Although valves may be placed overhead, or in a combination, as overhead and on the side, the principle of operation is very much the same in either case.

Mercury-Cooled Exhaust Valve

The mercury-cooled exhaust valve is a type of valve at one time used on one of the farm-lighting-plant engines. With high-duty internal combustion engines the exhaust valve is subjected to direct blasts of exhaust gases of about 1,800°F. The only provision heretofore made for radiating the heat from valve head (H) and the stem was through the valve guide. As a result, the stem often became red hot, with the consequent result, warping and loss of compression at the valve seat.



Principle: The effect of the mercury contained within the valve is of course to transmit the heat from the hottest part of the valve up to the portion of the valve stem which is exposed to the atmosphere, and which has a series of aluminum radiating fins (F) connected therewith, to facilitate the cooling of the valve.

The mercury (M) under normal temperature is in liquid state and rests at the bottom of the valve stem. As heat is absorbed by the valve stem and transmitted to the mercury, the mercury is vaporized and immediately rises, until, coming into contact with the cooler part of the valve stem, it will undoubtedly condense and flow back to the bottom of the stem to be again vaporized and to repeat the previous operation.

Purpose of Valve Grinding

The purpose of valve grinding is to prevent the inlet and exhaust valve from leaking compression (see pages 765–770).

The **exhaust valve** is surrounded by a flame when open, and will become "pitted" in time, as shown in Fig. 107.

Fig. 107

The exhaust valve requires more grinding than the inlet valve because the hot gases pass out between the valve seat and the valve face when the valve is raised. When the valve is opened, there must be sufficient space to permit the burned gas to pass freely.

The **inlet valve,** admitting gas instead of ejecting a flame, does not pit as badly as the exhaust valve.

In a perfect seated valve, the valve face and seat are smooth and even, with dull-gray surface. **A pitted valve** is rough, uneven, and full of tiny holes, and cannot come to a tight seat. A valve in this condition, therefore, must be ground.

The process of grinding a valve is the placing of a grinding paste between the valve face and the seat, and revolving the valve until the roughness is worn down. See Index under "Valve grinding" and "Valve re-seating."

There are several prepared valve-grinding pastes on the market, but a very satisfactory abrasive may be had by mixing flour of emery, of the grade known as No. 120, with a little kerosene or thin lubricating oil, until it has the consistency of paste.

To grind valves in an engine where valves-are-on the-side, the usual plan is to remove the valve caps, if the cylinder head is solid, as in Figs. 108, 109 and 110, and to grind the valves in their seats.

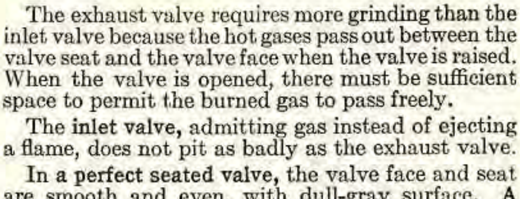


Fig. 108 Fig. 109 Fig. 110

Fig. 108. **To grind valves in a solid cylinder head,** remove the valve caps; remove the pin (or valve retainer) at bottom of the valve stem. A spring lifter is used to compress the spring.

Fig. 109. Lift valve out of cylinder.

Fig. 110. Smear valve grinding compound around edge of valve. Replace valve in its seat and grind, by turning valve back and forth on its seat until both the valve and seat show a bright ring about 1/32″ wide all the way around. Remove all abrasive matter carefully before replacing.

To grind valves in an engine with valves-on-the-side, with a detachable cylinder head, the cylinder head is removed as shown in Fig. 111, and the valves are ground in their seat on the cylinder block as in Figs. 108, 109, 110.

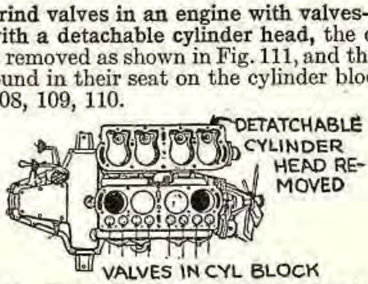


Fig. 111. To grind valves on an engine with valves on the side and detachable cylinder head (Ford engine).

To grind valves in an engine with valves-overhead and with a detachable head, the cylinder head is removed and valves are ground in the head as in Figs. 111 to 115. (The Chevrolet is shown as an example.)

To grind valves in an engine with valves-in-the-head and in cages, remove the valve cage and grind the valve in the seat of the cage. See Index under "Valve grinding, cage type."

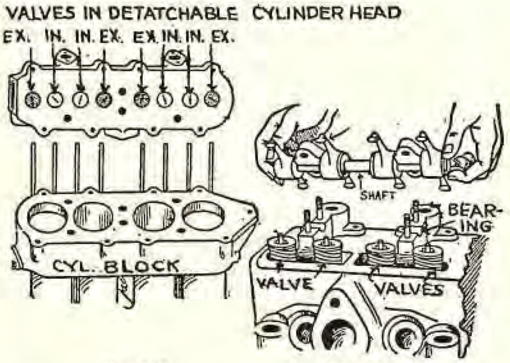


Fig. 112 Fig. 113

Fig. 112. Cylinder head removed.
Fig. 113. Remove shaft and rocker arms.

Procedure: Disconnect the upper radiator hose connection Remove each of the bolts holding the cylinder head to the cylinder casting and lift the head off. The valves, rocker arms, and bearings, being attached to the head, will remain with it as shown in Fig. 112. Next remove the rocker arms and shafts as shown in Fig. 113. Before removing, the bearing caps should be marked with a center punch, so that they will not become mixed when replacing. Next remove the small wire holding the valve-spring cap pin in place (Fig. 114). With a screwdriver and your fingers press down upon the valve spring cap until a spring has been compressed enough to admit pulling out the pin. Remove each valve separately, using care not to mix them in any way, as they must go back into the same valve holes.

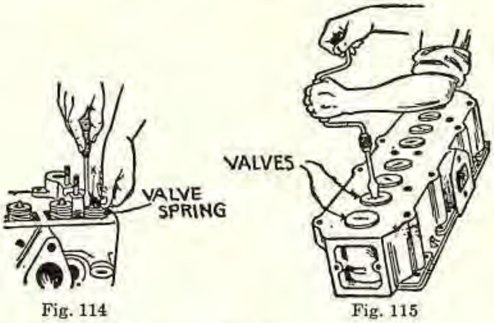


Fig. 114 Fig. 115

Fig. 114. Remove valve springs.
Fig. 115. Grinding the valves in the cylinder head.

Grinding: Secure a light coil spring and place it around the valve stem before replacing it for grinding. Smear the compound thinly on the beveled edge of the valve head and on the seat in the cylinder head. Place the valve in the up-turned cylinder head and grind as shown in Fig. 115.

Before replacing the valves it is a good plan to scrape off all carbon deposit from the combustion chamber and piston. Also examine the copper asbestos gasket before replacing the cylinder head. If not perfect, a new gasket should be used.

When replacing the cylinder head bolts, turn each one until the head just touches the cylinder head, then tighten each one evenly, a little at a time. None should be drawn tight until all are set snug.

Refacing Valves and Reseating Valve Seats

If valves leak compression and there are no ridges, or shoulders on the seats, or if not burned or warped, then they can be ground. If burned or warped, or shoulders or ridges are formed in the valve face or seat, then the valve face ought to be refaced and the valve seat be reseated. This work is usually done with refacing machines and reseating reamers. This subject is covered in the section devoted to "Repairs" (pages 769-776). Tungsten valves are hard, and when pitted or leaking it is advisable to regrind on a valve grinding machine.

INSTRUCTION No. 9

VALVE TIMING: Valve-Stem Clearance; Valve Lift; Setting the Valves; Meaning of Degrees.

VALVE-STEM CLEARANCE

If no space was left between the end of valve stem and tappet, even very slight wear of the valve and seat would prevent the valve from closing properly. Furthermore, there must be some cognizance taken of the **expansion due to heat.** As the stem expands, it gets longer, so if no clearance were provided the stem would rest against the tappet and valve would be unable to seat properly and would remain open.

This would cause **trouble,** such as missing, especially at low speeds, a loss of power, sluggish pick-up or acceleration, excessive fuel consumption, and, if the engine was run for a long period of time, the probabilities are the **valve would be burned and would warp,** which would necessitate refacing and trueing up both the valve head and seat, or installing a new valve.

Frequently, when complaints are made by the owner of a car that the valves are noisy, the mechanic proceeds to adjust them close for quietness, but in doing so he should never exceed the **minimum clearance** as given by the manufacturer.

If the car is to be run on a tour, or a continuous run for a long period of time, then the **maximum clearance** should be given. It is better to permit a little noise rather than to incur the above troubles.

Another point to bear in mind is that if the manufacturer gives instructions to set the valves at a certain clearance when cold, or when hot, the instructions should be followed. If set while warm and manufacturer specifies to set when cold, the resulting clearance will be too large and valves will be very noisy. If set while cold and manufacturer specifies to set while warm, the resulting clearance will be too small and valves may be held open when engine becomes hot, especially after a long continuous run. Some engines naturally run hotter than others, hence the variance in valve clearance.

If the clearance between valve stem and tappet is too great, it not only produces noise but **lessens the power of the engine,** owing to the **valve lift** being lessened to such an extent that the inlet valve does not open wide enough to take a full charge of gas, and that the exhaust valve does not fully discharge all of the burned gas.

To tell if any of the valves are open and if they leak compression (or if a cylinder leaks due to some other cause), test the compression of each cylinder and compare the pressures. They should show a uniform pressure in each cylinder, that is, within a close margin at least (see page 766).

Valve-stem clearance, also called "valve-tappet clearance" and "air-gap" space, is the space between the end of the valve stem and the valve tappet when tappet is at its lowest point and valve is seated. The width of this air gap varies, as will be noticed in the list of valve clearances of cars below.

Some manufacturers give about 1/1000" less space to the inlet than to the exhaust, because the exhaust valve stem lengthens more, owing to greater heat. For instance, Hudson and Essex give .003" valve-stem clearance on the inlet valve and .005" on the exhaust valve (maximum), with engine warm.

It is necessary to adjust the valve-stem clearance when valves become worn and thus lowered, or as a result of repeated grinding, or when the end of the valve stem, rocker arm, or push rod becomes worn, owing to the constant tapping, which causes natural wear in time.

When the distance is too great between the valve stem and the tappet, as a result of wear or improper adjustment, this will produce a **clicking noise** and can be overcome by proper adjustment.

Often a **noise** which sounds as if coming from the valve stem will be found in a **worn valve tappet in its guide.** The noise is caused by the cam shifting the valve tappet against its worn guide. In fact, this is a very common trouble. The remedy is to replace the tappet with a new one.

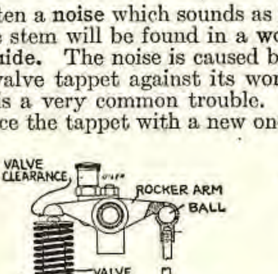


Fig. 1

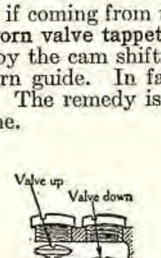


Fig. 2

Fig. 1. Valve clearance on valves-in-the-head is measured between the end of the rocker-arm and the top end of valve, as above.

Fig. 2. Type of valves on side of "L"-head engine. Clearance is adjusted as shown in illustration.

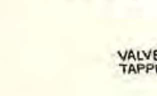


Fig. 3

Testing and adjusting valve clearance is usually done when engine is warm and not running, by inserting a thickness gauge between the end of the valve stem and tappet, as in Fig. 3. On some engines, where the valves are accessible, as on overhead-type valve engines, the test and adjustment can be made when engine is warm and running slowly.

Adjustment of valve clearance where the valves are on the side, as in Fig. 2, can be made by screwing up the adjusting screw if there is too much clearance, or screwing down the adjusting screw if clearance is not great enough. When the correct position is found, the valve-tappet adjusting screw is locked in position with the lock nut, and clearance is again tested.

Adjustment of valve clearance where the valves are in-the-head and rocker-arms over head can be made at the lower part of the valve push rod, if arranged as shown in Fig. 1, which adjusts the clearance between the end of the valve stem and the rocker arm when valve is fully seated.

On the valve-in-the-head type (Fig. 92, page 53), the adjustment is on the top of the valve push-rod (J). The clearance is between the end of the valve stem and the rocker-arm, when the valve rod is entirely free from the cam, or when it is not riding the cam. The adjustment is made when the engine is warm.

Buick (see page 71).

Chevrolet (superior model, Series K): Space between rocker arm and valve stem should be .008" on the intake valves and about .010" on the exhaust valves, when the valves are seated and engine warm.

Continental model "7R" engine (side-valve type), the inlet valve is given .004", and the exhaust valve .005" clearance. The exhaust valve is given slightly more clearance because it is subjected to a higher degree of heat than the inlet, and, when iron is heated, it expands. The instructions are to adjust when the engine is warm.

Dodge (see page 71).

Ford valve clearance should not be greater than 1/32" nor less than 1/64".

Franklin (Series 11): Both valves .010" with engine cold.

Hudson Super-Six and Essex Six: Adjust inlet valves .002" minimum and .003" maximum clearance. Adjust exhaust valves .004" minimum and .005" maximum, with engine warm.

Hupmobile (R) instructions call for .005" clearance for inlet and .006" for exhaust valve, when the engine is warm. **Hupmobile** (series E) .007" both valves, engine warm.

Lincoln: .003" to .004" to both valves; engine warm.

Locomobile instructions for Model "48" are to adjust the inlet valves .002" and the exhaust .005", when the engine is cold. (See "Note," page 70.)

Marmon (D74): Both valves .006" with engine warm.

Packard "eight and six" gives for the inlet and exhaust valves a clearance of .004" when warm.

Pierce-Arrow instructions are to adjust the inlet for .003" clearance and the exhaust for .005" clearance, when warm.

Star Models C–CC–F (3 1/8" bore) should have .008" clearance when engine is warm.

Studebaker "Standard Six" instructions are to adjust both valves for .005" clearance with the engine warm.

Studebaker "Big Six" and "Special Six" should have .005" clearance when the engine is warm.

Some manufacturers give instructions for certain clearances when the engine is warm, and others when the engine is cold. When the engine is warm,

Above refers to early models.

appears to be the logical time for adjusting clearance, because the expansion and length of the valve stem are greatest at this time, as the stem expands or lengthens when warm and contracts or shortens when cold.

While it is true that the valve stem expands when heated, it is also true that the cylinders and other metal parts of the engine expand at the same time. In extreme cold weather, the probabilities are that the cylinder contracts and expands to a greater extent than does the valve. This is a problem that has never been definitely settled. Thus the subject of valve clearance is one where expansion and contraction of the metals are factors governing the clearance. Accordingly, one should follow the manufacturers' instructions as to the exact clearance to be given on an engine, as they have no doubt learned the correct clearance from experience.

The usual clearance is from .003″ to .005″, and most of the adjustments are made when the engine is warm. Clearance varies according to size of the engine and also according to the temperature; an engine running unusually hot would require more clearance, as expansion would be greater. By referring to the Index, a table will be found giving the diameter of valves and the valve clearance of different makes of engines.

In the absence of explicit instructions, give an engine with valves-on-side a clearance of .004″ when warm, and an engine with valves-in-head, .008″ to .010″ when warm. In this way one will be safe. It is also advisable to **check the valves** to see if they open and close at the proper time. This can be done by observing the marks on the flywheel and noting if the valves close accordingly. (See page 58 for Ford.)

Valve-Clearance Adjustment

Adjustment should always be made after the valves of an engine have been ground, as the grinding may slightly lower the valve. When checking the adjustment of valve-stem clearance, turn the fly wheel of the engine over until the other tappet and valve in the same cylinder are up as far as they will go, or the valve is wide open. The first valve will then be closed. The clearance should then be measured between the end of the valve stem and the head of the tappet screw on the closed valve.

If it is found that the clearance is not right, loosen the lock nut on the tappet screw and turn the screw up or down, to obtain the correct clearance.

It is best to use a "thickness gauge," but if a gauge is not obtainable a piece of newspaper will serve as a gauge. A sheet of ordinary newspaper is between .002″ and .003″ thick. After the tappet screw is adjusted so that the clearance is correct, tighten the lock nut. "**Back lash**" or lost motion in the cam-shaft driving gears should be taken up in the direction of rotation (crank-shaft drive gear) when clearance is adjusted.

A noisy valve tappet, resulting from wear, and where no adjustment is provided, can be, in some instances, remedied by placing fibre or steel washers under or over the valve ends.

The opening and closing time of the valve is not when the lifter begins to rise, or comes to rest, but when it makes or leaves contact.

Valve-Clearance Pointers

If the engine has good compression when cold and lacks compression and power when hot, this may indicate a lack of sufficient clearance between the valve tappet and valve stem. When cold, the valve seats properly, but when hot, metal expands. Therefore lengthening of the valve stem by expansion causes the valve to seat improperly, with a loss of compression and power. Experienced auto mechanics are aware of the fact that **when an engine has good compression the force of the combustion during the power stroke is greater** than if the engine has poor compression. Thus, since the force is greater with high compression, if there are any parts even slightly loose, such as bearings, too much piston clearance, loose piston pin, etc., a hammer-knock sound will occur and be the more noticeable the higher the compression. Frequently an automobile owner will drive his car in and tell the repairman to "take out the knocks." The repairman immediately proceeds to give the valves less clearance, which quiets the valves and at the same time relieves the knocks in the engine to a certain extent. This results from the fact that when the valves are given less clearance than they should have, the valve opens early and closes late, which reduces the compression, thus reducing the combustion and expansion force on the piston. As a consequence the noise is reduced, but power is sacrificed. **This is bad practice. The proper procedure would be** to properly adjust the valve clearance in the manner designed for the particular engine, and then to take up on the parts inside of the engine that are loose. And if there is a piston slap, be careful to replace the piston with a larger one.

Valve Lift

The inlet cam has a sharp nose. The exhaust cam has a broader nose, because it must hold the valve open longer. The **height of the nose, less the air gap, regulates the lift.** The average lift of either the exhaust or inlet valve is approximately 11/32″ to ⅜″. It is thus evident that if the air gap between the valve stem and the tappet is too large, the valve will not open at all.

If the air gap is increased, the valve will lift very slightly and stay open but a few degrees. If the air gap is **decreased,** the valve will open sooner, rise higher, and close later. This process can be repeated until there is no air gap left.

Therefore, suppose an engine was designed to have 1/16″ air gap and there was no air gap at all; the valves would open possibly 50° too soon, rise 1/16″ higher than intended, and close 50° too late.

In case of **wear of the end of the valve stem or tappet,** it is apparent that as the wear increases, the space or air gap increases, and valves will have less lift, open late and close early, and become more noisy, all of which will affect the power of engine. The valve lift on the **Continental** Model "7R," six-cylinder engine, with 3¼″ bore, by 4½″ stroke, with 1½″ valves, is 5/16″. The **Pierce-Arrow** six-cylinder engine, with a bore of 4″ x 5½″ stroke and using 1⅝″ valves, has a lift of 11/32″. The **Locomobile** six-cylinder engine, model "38," has 5/16″ lift; model "48," a larger engine, has 13/32″ lift.

VALVE TIMING

Before the reader can thoroughly master the subject of valve timing he must first learn the **four-cycle principle** as explained on pages 31 and 32, as it is with this principle we shall deal. In addition, the **meaning of degrees** as explained below, and the **relation of the valve-cam speed to the engine crank-shaft** speed and the importance of **valve clearance** adjustment must be thoroughly understood.

Meaning of Degrees

Suppose we take a fly wheel and divide its circumference into 360 equal parts (Fig. 1); each part would be a degree—expressed with a small "°" as 360°. In fact, any perfect circle can be divided into degrees. The crank shaft revolves in a circle; therefore we will designate the travel of the crank shaft in degrees. Any circle, or, say, travel of the crank pin, would represent 360° when it made a complete circle or revolution. One-half of the circle would be 180°, which would represent a stroke of the piston, or a half-revolution of the crank. One-quarter of the circle would be 90°; one-third of the circle would be 120°.

Note. The fly-wheel movement in the illustrations below is to the left, or counter-clockwise. We are supposed to be looking at the rear, or fly-wheel end of the engine for this purpose.

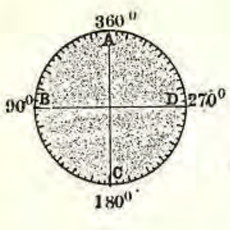


Fig. 1

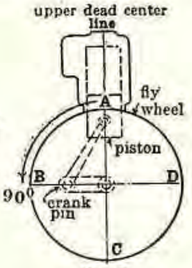


Fig. 2

In Fig. 2, the piston has traveled down from upper dead center, one-quarter of the circle, or one-half of a stroke; the crank pin and fly wheel have turned 90°.

Note. The piston in actual practice will have moved slightly more, depending upon the length of the connecting rod, as will be explained farther on.

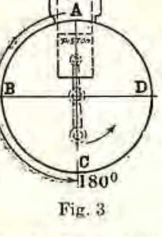


Fig. 3

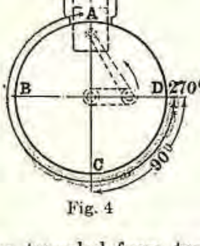


Fig. 4

In Fig. 3, the piston has traveled from top dead center to the bottom of the stroke; the fly wheel and crank pin have traveled 180°.

In Fig. 4, the piston has traveled up from bottom one-half of a stroke, the crank pin and fly wheel have traveled one-quarter of a circle from bottom, or 90° from **C** to **D**. In all, the crank pin and fly wheel have traveled from **A** to **D**, three-quarters of a revolution, or 270°.

In Fig. 5, the piston has made two strokes, one down and one up; therefore the crank pin and fly wheel have made a complete revolution, from **A** back to **A**, or 360° in all.

The idea is to learn that the crank pin travels in a circle and the fly wheel travels in a circle, and a revolution is a complete circle, and a complete circle is 360°. **The piston travels in strokes,** each stroke representing a half-revolution of the crank. If we spaced off 360 marks, equal distances apart, on any

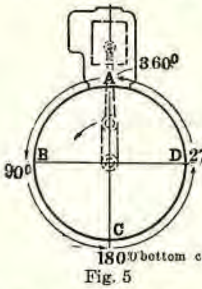


Fig. 5

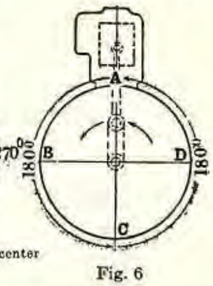


Fig. 6

circle, then each mark would be called a degree. In Fig. 1, we have spaced off the marks as 5 degrees each.

Meaning of Minutes and Seconds

Now we can divide each degree into, say, sixty equal distances, and call each part or mark a "minute." We could go still farther, and divide each minute into sixty equal distances, and call each part or mark, a "second."

A minute is usually expressed with a single mark after the figure, as, 25′. A second is expressed with two marks, as, 25″.

Note. An inch is also designated with two marks, thus ("), and a foot with one mark, thus (′).

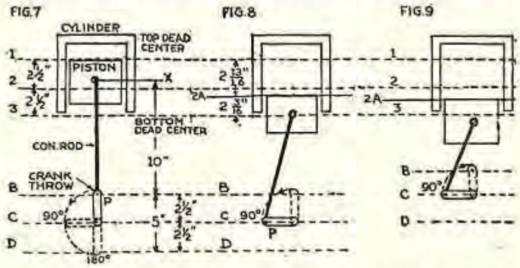
Example: Express ten degrees, six minutes, and five seconds. It would be as follows: 10° 6′ 5″.

To find the circumference of a fly wheel: Multiply the diameter in inches by 3.1416. If the circumference is then divided by 360, the distance or portion of the fly wheel circumference equivalent to one degree may be ascertained.

Uniformity of Piston Movement Governed by Length of Connecting Rod Relative to Crank Throw

From the foregoing explanations of the piston movement relative to that of the crank throw, it would appear to the reader that when the crank pin moved 90° or one-fourth of a revolution from top dead center, the piston would have moved down exactly one-half of its stroke. This is not correct.

For example, the crank throw is always one-half of the stroke of the piston, or the piston stroke is twice the crank throw; that is, where the cylinders are centrally located, or in line with the crank shaft.



Figs. 7, 8, and 9. Relative position of piston to crank on a centrally located cylinder.

As an illustration of this, see Fig. 7, in which is shown a connecting rod 10″ long from the center of the wrist pin in the piston (**X**) to the center (**B**). The crank throw is 2½″ from (**B**) to (**C**), therefore the stroke of the piston woud be 5″ when the crank pin (**P**) moves from position (**B**) to (**D**).

The foregoing applies to a full stroke, or one half-revolution (180°) movement of the crank pin (P).

In the illustration (Fig. 8) the crank pin (P) has moved from top dead center (B), down 90° to (C), which would appear to indicate that the piston would have moved down from top dead center (1) to (2), or one-half of its stroke, which however, is not the case, as will be seen by referring to Fig. 8.

Note that the piston has actually moved down 2½″ plus about 5/16″, or 2 13/16″ instead of 2½″, which is about 5/16″ **more** than one-half of its stroke. Therefore when the crank pin moves the next 90° (C) to (D), the piston will have to move only one-half of its stroke less 5/16″ (2½″−5/16″=2 3/16″), which will be **less** than half of a stroke.

The shorter the connecting rod relative to the crank throw, the greater the difference in movement there will be between the upper portion of the stroke and the lower portion of the stroke, as represented by the first 90° movement of the crank pin and the second 90° movement of the crank pin.

An exaggerated illustration is shown in Fig. 9, in which the connecting rod has been shortened, but not the crank throw. Note the difference in piston stroke from (1) to (2A) in Fig. 9, as compared with (1) to (2A) in Fig. 8, while it will be noticed the crank pin has moved exactly the same in each case, that is, 90°.

Effect of Offset Cylinders

In the foregoing, we have taken as an example an engine with a centrally located cylinder (in line with the center of the crank shaft). Many manufacturers build their engines with offset cylinders; that is, the cylinders are placed to the left (when looking from the fly wheel) of the center of the crank shaft. The most peculiar feature of an offset cylinder is that the piston stroke or travel is no longer equal to twice the crank throw, as in the case of a centrally located cylinder. With an offset cylinder, the stroke is slightly longer than twice the crank throw.

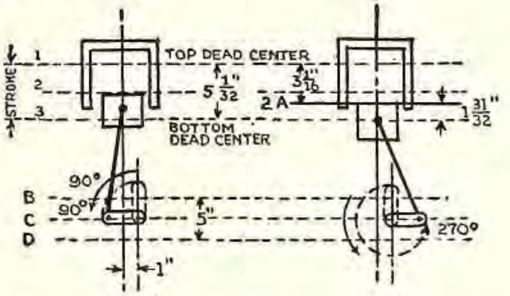


Fig. 10 Fig. 11

Figs. 10 and 11. Relative position of piston to crank on an offset cylinder.

In Fig. 10, we have the same crank throw and length of connecting rod as in Fig. 8, but it will be noticed that by offsetting the cylinder 1″, we have increased the stroke from 5″ to about 5 1/32″.

Another feature to be noticed is that when the crank has revolved 90°, the piston has descended just about one-half of the stroke. Contrast this result with that found in Fig. 8. **The offsetting decreased the effect of angularity during the downward stroke.**

In Fig. 11, when the crank has revolved 270°, it will be noticed that the piston rises only 1 31/32″ (approximately) from bottom dead center. This distance is still farther removed from one-half the stroke than was the case in Fig. 8, consequently **the offsetting increased the effect of angularity during the upward stroke.**

Remarks on Inlet-Valve Opening

It has been explained that the valves are raised by means of cams operated by a cam gear or sprocket placed on the front of the engine, in connection with a gear or sprocket driven from the crank shaft.

If one of the cams raises an inlet-valve just as the piston is starting down on the suction stroke, a charge of gas will be drawn into the cylinder as long as the piston is on the suction stroke and the valve is open. The valve should therefore open in time to give the piston a chance to draw in a cylinder full of gas.

If the valves were to open late in the stroke, a full cylinder of gas would not be drawn in and the power of the engine would be less than what it should be. If the inlet valve opens too early, it will cause back-firing; if too late, a sluggish engine and overheating will result. The inlet-valve timing gear is used for timing the inlet valve to open at the right time, this being done by meshing the gears or setting the sprockets at the right place.

The practice is to allow the piston to descend about an eighth of an inch in the cylinder on the suction stroke before the inlet valve opens, so as to reduce the pressure and create, if anything, a vacuum which causes a greater suction.

Inlet-Valve Closing

It is almost universal practice to leave the inlet valve open until the piston has not merely reached the bottom of the stroke, but has actually traveled slightly up again on the compression stroke. It would seem that under these circumstances part of the gas would be forced out of the cylinder, but this is not the case as the high speed at which the piston is traveling causes the suction to continue for a short time on the compression stroke. This will, of course, vary with the speed of the engine, so that a certain valve setting will not be correct for all speeds, since, if the inlet valve is closed at the correct time for slow speed, it will close too early for higher speeds and less gas will be drawn in than would be the case with correct setting.

However, there is an average speed for all engines, and the valves are set to it accordingly. This average speed on most engines is approximately 1,000 revolutions per minute.

Exhaust-Valve Opening

The exhaust valve must open considerably before the piston reaches the end of the expansion stroke, and although this may waste some of the force of the explosion, it is compensated for by the freedom afforded the piston in completing the exhaust stroke.

It would be wrong to keep the exhaust valve closed up to the very moment when the piston is about to move upward, for, on commencing the exhaust stroke, the piston would be confronted for an instant with the force that had just driven it down, and until the valve was wide open, it would be considerably impeded on its journey.

The exhaust valve is usually opened when the piston has moved through about seven-eighths of the power stroke; that is, before bottom of dead center. Exhaust valves opening too early, however, cause pounding and clatter.

Exhaust-Valve Closing

The exhaust valve must not close before the end of the exhaust stroke. Since the gas which remains in the cylinder head is slightly under pressure at the end of the stroke, the valve is often allowed to remain open until the piston has moved slightly down on the suction stroke, so as to give full opportunity for as much exhaust gas to escape as possible.

In order to understand just how important it really is to expel all of the burned or exhaust gas, it must be explained that one of its chief constituents is carbon dioxide—the most powerful anti-combustion agent known to science. Its presence, therefore, even in small quantities, retards considerably the speed of the combustion development.

It will now be obvious from the foregoing that, if the exhaust gases are to be entirely expelled from the cylinders, the valve must be made to close a little later than "top center," or—as it is technically described—must have a certain degree of "lag"; for it is evident that if we close it at the exact top of the stroke, the contents of the combustion head (which we wish to get rid of) will be imprisoned and will contaminate the incoming charge.

The amount of this "lag" will depend on several things—the shape of the combustion head, the weight of the valve, the strength of the springs, and design of the exhaust system.

Valve Effect of "Lag" or Bounce

Valve spring, strength, and weight have to be reckoned with on account of their influence on **inertia lag** as distinct from that which is **intentional,** for it is well known that as the speed of the engine increases the valve tends to "jump" the closing face of its cam and closes later and later as the speed increases. This is what we describe as "inertia lag." There is a point, however, past top center to which the exhaust extraction lasts, and pending this extracting effect the valve should remain open. But if carried beyond this point, a reverse of the exhaust gases may occur, for it must not be forgotten that the piston has now started down on its suction stroke. It becomes a question, therefore, of closing the valve when the scavenging is as complete as possible.

The best design of cylinder head for an **"overlap"** is the round or "I" head with overhead valves. The ordinary "L" head is not so good, and in certain kinds of heads in which the inlet and exhaust valves are small and close together in a small pocket an overlap is quite useless.

On the other hand, it has been found in racing practice, where the exhaust pipe is very long, straight, and open, and the combustion head suitable for scavenging, that a very considerable overlap can be allowed with advantage.

What Governs Valve Timing

The **size of cylinder,** especially in the stroke and in the type of ignition, shape of manifold, and the speed of engine, governs the valve timing.

Early **setting of valves** on an engine will cause irregular running at lower speeds, unless a very heavy fly wheel is used. It will also increase the gasoline consumption in short-stroke engines.

For high-speed work, the inlet may be opened and closed late. For slow-speed work, closing the exhaust and inlet on center gives the best control, and no blowing back.

The **time of opening and closing of valves** with reference to the engine speed of course has an important bearing on its performance. If the valves open too early it will cause **back-firing,** while if they open too late a sluggish engine and overheating will result.

High-speed (short-stroke) engines have a longer time of valve opening than medium or slow-speed engines. The slower-speed engines have the exhaust opening and the inlet closing nearer to bottom center, while some high-speed engines open the exhaust 65° before bottom center and close the intake 70° after bottom center.

Valve timing of different engines will vary according to the intended average speed and the length of stroke. Long strokes are for slower-speed engines than short strokes. Obviously high-speed engines are not efficient at slow speeds, because the inlet closes too late and the exhaust opens too soon, thus losing part of the charge and part of the power stroke. And slow-speed timing on a high-speed engine does not permit of receiving a full charge nor of getting rid of the back pressure during the exhaust stroke.

The value of the **design of the cam** may be, and nearly always is, lost through improper valve clearance or air-gap adjustment.

A point which suggests itself on the timing of the inlet opening, and which also holds true for other operations on the timing circle, is in the securing of a quiet cam. Quietness in the cams is generally secured at the sacrifice of power. A steep cam is as a rule more noisy and more powerful than one giving a slower opening.

To secure the full opening of the inlet valve at a point which will not be too late to permit a full charge to be taken into the cylinder, and yet at the same time to have a cam which will not be noisy, means that the inlet opening will have to be started fairly early. This is one of the points which often induces a maker to sacrifice the vacuum to some extent for the sake of quietness.

Meaning of Valve Lap

The word "lap" is often used in connection with valve-timing, as also in connection with the firing-order of cylinders.

In speaking of the **firing order** of cylinders we speak of one cylinder "lapping" another. For instance, on a certain eight-cylinder engine there are eight periods of 44 degrees travel of the crank when two cylinders are on power, or "lapping" at the same time.

The use of the word "lap" in connection with valve timing means the period of time that both valves are open at the same time, or + (plus lap).

Zero lap: If the exhaust valve closed just as the inlet valve started to open, we should term this, "zero lap" (no lap at all). "Zero lap" means that the exhaust closes at the same time the inlet valve opens. With zero lap there is no vacuum in the cylinder at time of the inlet valve opening.

Minus lap: If the exhaust valve closes before the inlet valve opens, we should term this "minus lap," designated with a (−) mark. The (−) "minus lap," which is the general condition in use on most engines, the exhaust closes an appreciable period before the inlet opens. This permits the piston to descend slightly on the suction stroke before the inlet valve opens, thus creating a vacuum in the combustion space. Therefore, the rush of gases into the cylinder is greater owing to this partial vacuum.

By referring to Fig. 6, page 32, the exhaust valve will be seen to be closed before the inlet starts to open; this would be termed (−) "minus lap."

Plus lap: If the inlet valve opens before the exhaust valve closes, it is termed "plus lap," designated with a (+) mark. The (+) "lap" means that both exhaust and inlet valve are open together for a period of the lap. In other words, the inlet opens before the exhaust closes. The theory is that the inertia or rush of exhaust gases passing out through the exhaust port is sufficiently great to create a partial vacuum, and causes a stronger inrush of fresh gas.

Owing to the fact that the exhaust and inlet gases should not conflict in their direction, the (+) plus lap is generally used on "T"-head engines.

Valve "Lag" and Valve "Lead"

If a **valve opens late or remains open** after it is supposed to close, it is said to "lag." For instance, the exhaust valve is usually allowed to "lag" about 10 degrees after leaving the top of its exhaust stroke before it closes.

The term **"valve lead"** usually applies to the valve opening before the piston reaches top or bottom center. This distance is called "lead"; and when it closes after center, this distance is termed "lag."

For instance, the setting of the spark is sometimes given a "lead," or the exhaust valve is usually given a "lead" of 46 degrees, meaning that it opens before bottom. The faster engines are designed to run, the greater the amount of "lead" or "advance" given the opening of the exhaust, and also the spark, when running.

Periods of Time Valves are Usually Open

Before taking up this subject in detail, we shall again review the relation of the speed of crank shaft to the cam shaft and get the names of the parts clearly in mind.

A stroke is the movement of the piston from the top to the bottom, or from the bottom to the top. This motion is called "reciprocating motion of the piston." When the piston goes either from top to bottom or from bottom to top, the crank shaft turns one-half of a revolution. (This does not hold true where the cylinders are offset.)

Therefore, four strokes of the piston would represent two revolutions of the crank shaft.

The **cam shaft** turns one-half as fast as the crank shaft, because the cam gear is twice the size of the crank-shaft gear which drives it.

The nose of the **inlet cam** is usually shorter on its length of face than the **exhaust cam**, because the exhaust cam holds the valve open a much longer period of time than the inlet cam holds the inlet valve open. The cams which operate the valves are steel forgings, turned and ground to correct shape. They are then case-hardened to decrease the wear, and are usually made as an integral part of the cam shaft.

The **shape of the cam** determines the actual lift of the valve and the time during which it shall stay open. The symbols, A, B, and C, over Figs. 104 to 106 (page 56) show several generally used shapes.

Cams which are pointed give a slow opening and slow closing, the greatest opening being at the middle of the valve-lift period.

Cams which are more nearly square open the valve rapidly, keep it nearly wide open until ready to close, and then allow it to close quickly.

It is customary to design the positioning of the cam shaft and valve tappets, so that the tappets are not directly over the center of the shaft, but are offset slightly on the lift side. This gives a more direct lift instead of a side thrust, as would be the case if they were centered.

In actual practice, **the inlet valve seldom opens on top,** usually after the top of stroke, varying from 5 to 15 degrees flywheel measurement as explained in Fig. 12, (page 64), which opening is 8 degrees after the top of the stroke.

The **inlet seldom closes when the piston reaches bottom,** but from 5 to 38 degrees after bottom. (Fig. 13, page 64.)

The **exhaust valve seldom opens on bottom,** but usually 40 to 50 degrees before bottom (Fig. 14, page 64).

The **exhaust valve seldom closes on top of stroke,** but usually 5 to 10 degrees after top. (In Fig. 15, page 64, the illustration shows the exhaust valve closing on top, in order that the reader may more clearly understand the illustration.)

The cam turns at the same speed as the cam shaft. The nose on the cam raises the valve. Therefore the inlet valve will be raised once during the four strokes, and the exhaust valve will be raised once during the four strokes.

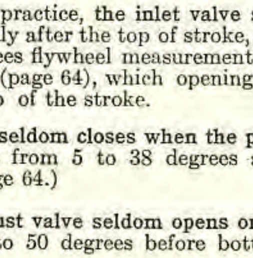


Fig. 11A. This illustration is supposed to represent the movement of the cams during a period of four strokes of the piston, as explained below and on page 33.

By referring to Fig. 11A, the inlet cam on the first stroke will be found to be in the position of (1), and will turn from 1 to 2, or 90 degrees during the first stroke.

The exhaust cam will then be in position (2), and will turn from 2 to 3, or 90 degrees, during the first stroke.

During each stroke the cam moves 90 degrees, whereas during the same period the crank moves 180 degrees.

Inasmuch as a stroke of the piston is from top to bottom, or 180 degrees travel of the crank, it will be necessary to distinguish the difference between the time of opening and closing of the valves and the period of travel of the crank shaft during the four actions of suction, compression, explosion, and exhaust periods, as explained in the discussion that follows.

Note. When speaking of "top," it refers to **top dead center** (or upper dead center), or when piston is at the top of its stroke, and "bottom," refers to **bottom dead center** (or lower dead center), or when piston is at the bottom of its stroke.

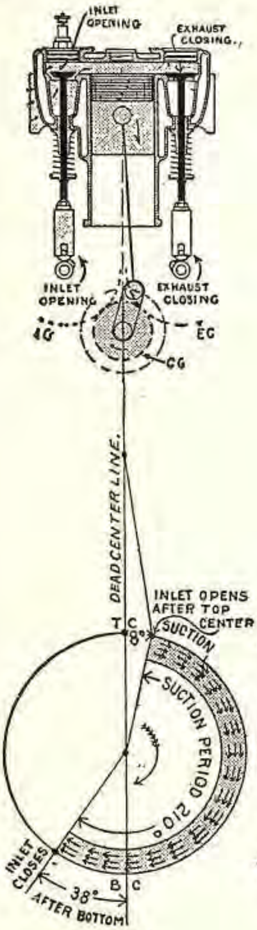


Fig. 12

Fig. 13

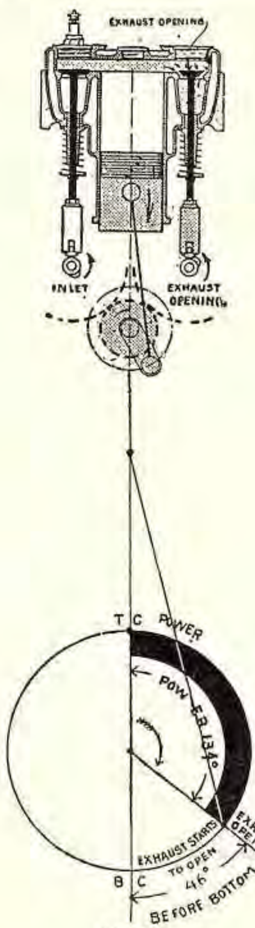


Fig. 14

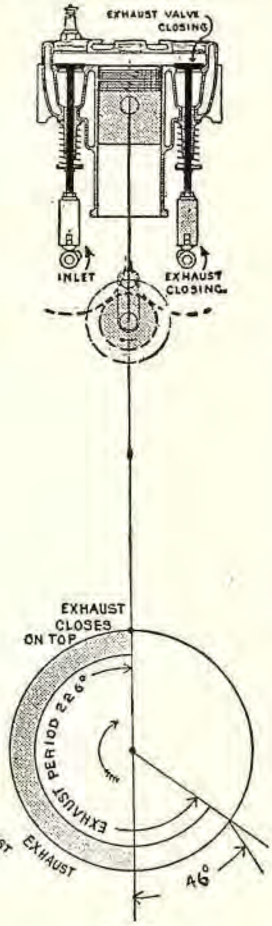


Fig. 15

Explanation of the Period of Suction, Compression Power, and Exhaust

Example: Inlet opens 8° after top, closes 38° after bottom. Exhaust opens 46° before bottom, and closes on top.

Fig. 12 shows the inlet valve starting to open 8° after top center ("TC") (viewing the engine from front); note that the inlet will remain open during the suction period until the crank is 38° after bottom center ("BC"). The period of travel of the crank during the suction period is 210°. The inlet valve is open during this period.

Fig. 13 shows the inlet valve closed. The piston will now travel up on compression to top center ("TC"). The period of travel of the crank during the compression period is 142°.

In Fig. 14, the spark occurs at top (in actual practice, just before the top), therefore, the next stroke down is a power stroke. Note that the period of travel of the crank pin during the power stroke is only 134°, as the exhaust valve starts to open at 46° before bottom. Note, too, that the exhaust cam is just starting to open the exhaust valve.

In Fig. 15, the exhaust opens 46° before the piston reaches bottom. The exhaust valve remains open during a period of 226°, the crank traveling from 46° before bottom, to bottom, thence to top ("TC"). In this instance the exhaust valve closes on top or dead center. In actual practice it usually closes a little after top dead center (about 5° to 10°).

Note. Fig. 15 shows shading of the exhaust period. This shading should extend to the right of the 46° mark.

Fig. 16. Illustrates all that is shown in Figs. 12 to 15, combined in one illustration.

Observe the position of the cams during the various periods. The cam turns at one-half the speed of the crank shaft. Therefore, if the crank shaft revolves twice to complete the four strokes, the cams will make one revolution.

Valve-Timing Position

The **position of the crank shaft** determines the position of the piston.

The **position of the piston** determines the point where the valve is set to open or close.

Therefore the cam shaft must be so placed that the cam will raise the valve when the piston is at a certain position.

This is accomplished by **meshing the cam gear with the crank-shaft gear** when the piston is in correct position.

Marks are usually placed by the manufacturer on the cam gears which will indicate just where to mesh gears. The flywheel is also used for timing, if there are marks on it, which is usually the case.

It is also important to secure the proper valve clearance when timing the valve.

Setting Valves on a Single-Cylinder Engine

Suppose the valves are to be set on a single-cylinder "T"-head engine, with exhaust to close on dead center, and inlet to open one-eighth inch after top on the suction stroke.

Setting the exhaust valve: First, place the piston (by turning the crank shaft) to top dead center; then mesh the exhaust cam gear with the crank-shaft gear, so that the exhaust valve is just seating.

Setting the inlet valve: Move piston down one-eighth of an inch from top; mesh inlet cam gear with crank-shaft gear, so that the inlet valve is just starting to rise.

It will be noted that the inlet opens and the suction stroke begins right after the exhaust closes. Therefore the **closing of the exhaust and opening of the intake** is the point to work from.

A matter of importance to remember, is **the spark.** When setting valves, be sure the contact on timer or magneto is set to occur when the piston is on top of compression stroke, a full revolution from where the inlet valve starts to open. (This will be treated under "Ignition timing.")

Setting the Valves on a Multiple-Cylinder Engine

Setting the valves on a multiple-cylinder engine is identically the same operation as timing a single-cylinder engine.

If there is a multiple of cylinders, say four, then there must be at least one inlet and one exhaust valve for each cylinder. Therefore, there must be four cams for the four inlet valves and four cams for the four exhaust valves. The usual plan is to place the piston of No. 1 cylinder at the top of its stroke, and to work from that point.

If the engine cylinders are "T"-head, then there are **two cam shafts:** one for the inlet valves and one for the exhaust valves, placed on opposite sides of the cylinders.

If the cylinders are "L" or "round" head, with cam shaft on the side, then there is usually but **one cam shaft.**

Timing the Valves on a "T"-Head Multiple-Cylinder Engine

On a "T"-head engine, all exhaust cams are on the exhaust cam shaft and all inlet cams are on the inlet cam shaft. Therefore when setting valves on a "T"-head cylinder engine (Fig. 17), there are two cam gears to set, the inlet and the exhaust. If the cylinder is a four or six, or any multiple of these, setting, or meshing the cam shaft gear with the crank-shaft drive gear so that one cylinder is correctly timed, is all that is necessary, as the other cams are fastened permanently on the cam shaft, and must open and close all other valves at the correct time.

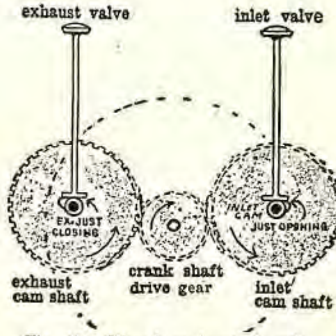


Fig. 17. View from front of engine

For example, suppose the inlet valve opened on top dead center and the exhaust closed on top dead center. The piston of No. 1 cylinder (front of engine) would be placed at the top dead center of its stroke and the cam gears would then be meshed at this position.

The **setting of the inlet cam gear** would be such that the nose of the inlet cam was just starting to raise the inlet valve in the direction of rotation (see Fig. 17).

The **setting of the exhaust cam gear** would be such that the nose of the exhaust cam was just permitting the tappet to leave the stem of the exhaust valve (Fig. 17).

Timing the Valves on an "L"-Head Multiple-Cylinder Engine

To set the cam for valve opening on an "L"-head cylinder, it is only necessary to set the one cam gear, which is the exhaust cam, at the closing point (see Fig. 18). If the engine has a multiple of cylinders all other cams will then operate as they should, as all exhaust and all inlet cams are on the one cam shaft and are set permanently when the cam shaft is made.

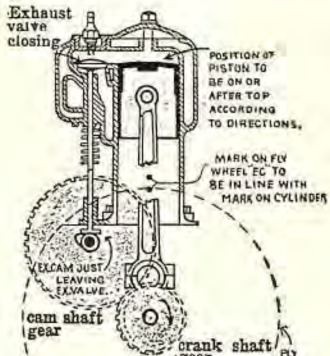


Fig. 18. View from front of engine.

The usual plan is to place No. 1 piston in the position where the exhaust valve is to be closed, and mesh the cam-shaft gear with the crank-shaft drive gear at this point. Although it is only necessary to set the exhaust cam so that the exhaust valve will close, on an "L"-type engine, there are marks on the fly wheel which are used for checking the timing. This is explained farther on.

Timing Valves on an "I" or Round-Head Type of Engine

The **overhead valves** are usually operated by push rods, all from one side of the engine and from one cam shaft. Therefore the timing would be the same as for an "L" head.

With an **overhead cam shaft,** the valves are usually operated by one cam shaft. Therefore the principle is the same.

Remarks

It is well to note that even though there are four, six, eight, or twelve cylinders, each of the pistons must pass through the four strokes during two revolutions of the crank shaft, even though two of the cylinders are firing at once during part of the time (which they are in a six, eight, and twelve cylinder engine).

Just how these four strokes are made by each piston during two revolutions of the crank, is explained under "Firing order," farther on.

In a **four-cylinder engine,** remember that, owing to the shape of the crank shaft, pistons 1 and 4 are always up or in line when 2 and 3 are down, or vice-versa. In a **six-cylinder engine,** pistons 1 and 6, 3 and 4, and 2 and 5 are in line.

Before timing the valves on No. 1 cylinder, adjust the valve clearance on this cylinder.

After completing the valve timing on No. 1 cylinder, adjust the valve clearance on the remaining cylinders.

Timing Marks on Flywheel

Usually marks also appear on the circumference surface of the fly wheel, which indicate the position in which the crank shaft is to be placed for correct setting of valves and meshing of cam gear and crank-shaft gear.

The mark on the flywheel is placed in line with a center mark (or a "trammel," also called an "indicator," or a "pointer") on the cylinder, or elsewhere.

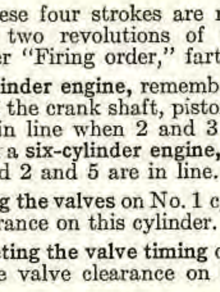


Fig. 19

Note. On engines with unit power plants, instead of the center line being on the cylinder, a small hole at the top of the fly-wheel case is provided, in order that the line and figures on the fly wheel can be seen through the hole.

Valve-Timing "Indicator" or "Trammel"

A trammel or indicator is a stationary starting point on which to base all work. It is sometimes attached to the base of a cylinder or other point, instead of a center line on the cylinder. It is usually directly over, or in front of, the fly wheel, as in Fig. 20 (flywheel indicator).

Example of timing the valves on an "L"-head six-cylinder engine by marks on the flywheel: The exhaust valve closes at 15° past top. It is not necessary to know this, however, as the marks are all that is necessary to follow.

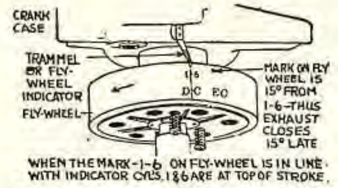


Fig. 20. Showing the purpose of an "indicator" or "trammel" as applied to a 6-cylinder engine.

Procedure: When the long mark 1-6 on the fly wheel is in line with "indicator" on the crank case, pistons Nos. 1 and 6 are at their highest points or upper dead center. After turning the fly wheel to this mark, then turn the fly wheel to the left (when behind it) until the small dot mark is under the indicator. This is the point (15°) at which to set the exhaust valve, just closing, and at which point the cam gear should mesh with the crank-shaft gear. Therefore it is plain that setting the exhaust valve just closing, on a 6-cylinder engine with valves on the side, is all that is necessary.

Variation of Valve-Timing Marks (on Fly Wheel)

Sometimes the **marks may vary.** For instance, instead of "1-4 UP" or "1-4 DC," it may appear as, "T C 1-4" (top center 1-4) or "U C 1-4" (meaning upper dead center), or some similar mark meaning the same thing.

Some manufacturers vary their marking on the rim of the fly wheel as follows: Inlet opens "IN-O" or "I. O." Inlet closes "IN-C" or "I. C."

Exhaust opens "EX-O" or "E.O." or "X.O." Exhaust closes "EX-C" or "E.C." or "X.C."

If the figures 1-4 or 2-3 appear after or before any of these marks, as "1-4-IO.," this means the number of the cylinders, as "1 and 4, inlet opens."

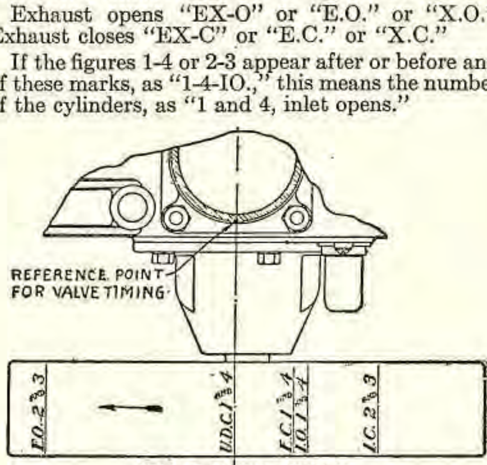


Fig. 20A. Valve-timing marks on the fly wheel of a Reo four-cylinder engine.

For an example of valve-timing marks on a four-cylinder engine fly wheel, see Fig. 20A. Here the engine fly wheel has upon its face the following marks:

I. O., meaning, inlet valve opens.
I. C., meaning, inlet valve closes.
E. O., meaning, exhaust valve opens.
E. C., meaning exhaust valve closes.
U.D.C., 1 and 4, upper dead center; cylinder 1 and 4.
U.D.C., 2 and 3, upper dead center; cylinder 2 and 3.

These points, marked upon the face of the wheel, show where the exhaust and inlet valves of each cylinder should open and close. A reference point (the small boss marked with a cross upon cylinder No. 4, next to dash), is used in this instance, instead of an indicator.

The engine cylinders are numbered 1, 2, 3, and 4, No. 1 being next to the radiator, and No. 4 next to the dash. By referring to Fig. 38, page 45 of crank shafts, previously given, it will be seen that cranks 2 and 3, and 1 and 4 are exactly 180 degrees apart. Therefore the same marking on the flywheel that serves for No. 2 also serves for No. 3, and the marking for No. 1 serves for No. 4, these points being exactly one-half revolution, or 180 degrees, apart, as before mentioned.

Checking the Valve Timing

Although it is only necessary to set the exhaust cam so that the exhaust valve will just close, on an "L"-type of cylinder engine there are usually marks on the flywheel which are used for checking the timing. See note below:

As an example, a four-cylinder "L"-type engine is used (Fig. 21), with timing as follows:

Dead center of cylinders 1 and 4; mark on flywheel, "1-4."

Dead center of cylinders 3 and 2; mark on flywheel, "3-2."

Inlet valve opens 10° past top center, mark on flywheel, "IN. O. 1-4."

Inlet valve closes 20° past bottom center, mark on flywheel, "IN. C. 1-4."

Exhaust valve opens 35° before bottom center, mark on flywheel, "EX. O. 1-4."

Exhaust valve closes 5° past top center, mark on flywheel, "EX. C. 1-4."

The same marks appear for cylinders 3 and 2. (**Note:** In most instances only two marks appear on flywheel, namely, "upper dead center" and "ex. closes cyl. 1." In this example we will assume there are marks for all cylinders.)

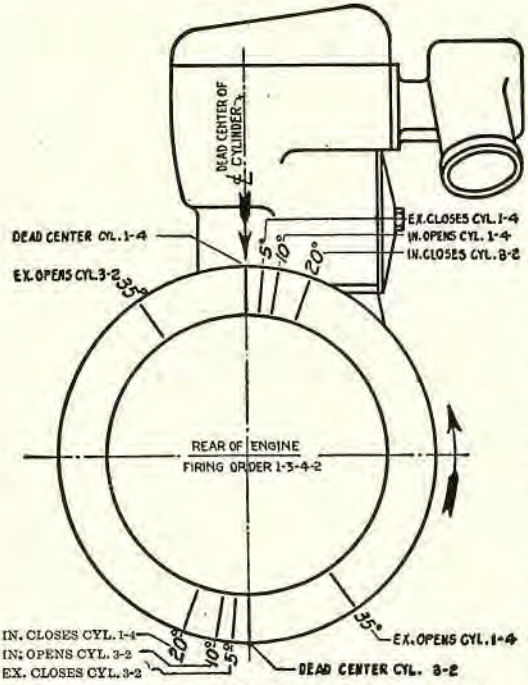


Fig. 21. **An example of valve-timing marks on the flywheel of a four-cylinder engine.** See text for checking valve timing from these marks. View from rear of engine. Note that the flywheel turns to the left. This is the valve timing of the Continental "J4" four-cylinder truck engine with 3¾" bore and 5" stroke with firing order 1, 3, 4, 2. **This engine actually bears only two marks on flywheel, namely "upper dead center" and "exhaust closes cyl. 1."**

The purpose of checking the valves is to see that they open and close as marked on flywheel.

To determine whether or not the valves are properly timed, first open the relief cocks on top of the cylinders, then have someone crank the engine over slowly until the line marked "1-4" is opposite the center line of the cylinders. At this point the exhaust valve in either No. 1 or No. 4 cylinder should just commence to close. It will be the case in one or the other.

If you find that the exhaust valve in No. 4 cylinder is beginning to close and you wish to check up the valve timing in No. 1 cylinder, turn the flywheel around to the left (standing in rear of engine) one complete revolution, until line "1-4" is again brought opposite the center line of the cylinder; then continue slowly turning the flywheel about one-half of an inch farther to the left until the line marked "5° (EX. C. 1–4)" coincides with the center line of the cylinders. This is the point at which the exhaust valve in the No. 1 cylinder should just seat or close.

To determine whether or not the valve is seated, see if the tappet or push rod underneath the valve can be turned with the fingers. If the tappet turns freely, the valve is seated; but if the tappet is hard to turn, that will show that the valve is still being held slightly open. If this is the case, loosen the lock nut on the tappet screw, and turn the screw down until the valve has the proper clearance, then turn the lock nut down tight against the tappet.

When the valves are closed there should be a clearance between the end of the valve stem and the tappet screw of from .003 to .005 of an inch. This amount of clearance is necessary to allow the valve to seat tightly.

Note. The opening and closing time of a valve is not when the lifter begins to rise or comes to rest, but when it makes or leaves contact.

To check the timing of the inlet valve in No. 1 cylinder, turn the flywheel slightly to the right until the line "1-4" is in line with the center of the cylinders, and then turn the flywheel about one inch to the left until the line marked "10° (IN. O. 1–4)" coincides with the center line of the cylinder. At this point the inlet valve should just begin to open.

Continue turning the flywheel half a turn to the left, stopping when the line marked "20° (IN. C. 1–4)" comes in line with the center of the cylinders. At this point the inlet valve should just close.

To see if the exhaust valve in No. 1 cylinder opens at the proper time, revolve the flywheel still farther to the left, and stop when the line "35° (EX. O. 1–4)" comes up in line with the center of the cylinders. This is the point where the exhaust valve in No. 1 cylinder should just begin to open. This operation completes the checking of cylinder No. 1, with the exception of the **exhaust closing,** which can be checked by the 5° mark "(EX. C. 1–4)" being in line with the dead center line of the cylinder.

To check the timing of cylinder No. 2, turn the flywheel until the line marked "3–2" is in line with the center line of the cylinders. If the exhaust valve in the No. 2 cylinder is closed, turn the fly wheel through one complete revolution, until the line "3–2" is up again; the exhaust valve in No. 2 cylinder should then be just starting to close. Proceed now the same as in timing the No. 1 cylinder. The valves in cylinders No. 3 and No. 4 are timed in the same manner.

Cylinders Nos. 1 and 4 are timed from the center line "1–4"; 10° to the left for inlet opening, and 5° for exhaust closing, and cylinders No. 2 and 3 from the line "3–2"; 10° to the left for inlet opening and 5° for exhaust closing.

It is advisable, when checking the opening and closing points of the valves with the marks on the flywheel, to make a note of the variation of each of the valves from the marks on flywheel.

Then, after all the valves have been checked, you can compare the variations for the different valves and in this way determine whether the variations are due to the large time gear on the end of the cam shaft not being properly set with relation to the timing gear on the end of the crank shaft, or to wear in any particular cam or valve tappet. A variation, not to exceed one-half of an inch either way from the lines on the flywheel, is permissible, and will not make any material difference in the timing of the valves. If the variations exceed this and are uniform for the different valves, the correction should be made by resetting the cam-shaft gear.

Note. If one person feels the tappet head of the valve which is being checked, while another slowly pulls the flywheel round in its proper direction of motion, **the precise moment at which the valve commences to lift can readily be determined by the binding of the tappet head against the stem of the valve.**

HOW TO CONVERT DEGREES ON THE RIM OF THE FLYWHEEL TO INCHES[1]

The following table is provided for converting degrees into fractions of an inch. For example, if a certain engine is to be timed when the inlet opens, say 10° after top of stroke, and there are no marks on the fly wheel to indicate this position, by referring to this table the distance in inches to measure on the fly wheel from upper dead center mark can be found.

It will be necessary however, to know the diameter of the fly wheel. Suppose the fly wheel is 17 inches; refer to first column and find 17, then go out to column under 10° and you have 1.48 (one and forty-eight one-hundredths of an inch). This would represent the distance to measure for the inlet opening mark on the fly wheel. Forty-eight one-hundredths (.48) is not so easy to measure on the rule. Therefore refer in the conversion table below, to .48 and note it is equal to 31/64 of an inch. Therefore we would have 1 34/64".

Another example: What would 2½° represent in inches on a 17-inch fly wheel? Procedure: find 17, go out to column under 2°, and we find .30. Put this down. Refer to the conversion table and note .30 = 19/64. Now refer back to the column headed 1°, and we find .15, which is equal (below), to 5/32" or 10/64." One-half of 10/64" = 5/64". Therefore 2°, or 19/64" + 5/64" = 24/64" = ⅜".

Diam. WHEEL	Circum.	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	20°	30°	40°	50°
12	37.699	10	.21	31	.42	.52	63	73	84	94	1 05	2 09	3 14	4.19	5.24
1/4	38.485	.11	.21	32	43	.53	.64	75	86	96	1 07	2 14	3 20	4.27	5.34
1/2	39.270	.11	.22	.33	44	.55	66	77	87	98	1 09	2.18	3 27	4.36	5 46
3/4	40.055	.11	.22	.33	45	.56	.67	78	89	1.00	1 11	2.22	3 33	4 45	5 56
13	40.841	.11	.23	.34	45	.57	.68	79	91	1.02	1 13	2.26	3 40	4.54	5.67
1/4	41.626	.12	.23	.35	.46	.58	.69	81	93	1.04	1.16	2.31	3.47	4.63	5.78
1/2	42.412	.12	24	.35	47	.59	.71	82	94	1.06	1.18	2.35	3.53	4 71	5.89
3/4	43.197	.12	.24	.36	48	.60	.72	84	96	1 08	1 20	2 40	3 60	4 80	6.00
14	43.982	.12	24	.37	.49	.61	73	86	.98	1.10	1.22	2.44	3.66	4.89	6.10
1/4	44.768	12	.25	.37	.50	62	75	87	.99	1 12	1.24	2.48	3.73	4.98	6.21
1/2	45.553	13	.25	.38	.51	63	76	89	1.01	1 14	1.27	2.53	3.80	5.07	6.84
3/4	46.338	13	.26	39	51	64	.77	90	1 03	1.16	1.29	2.57	3.86	5 15	6.44
15	47.124	13	.26	39	52	65	79	92	1.05	1.18	1.31	2 62	3.93	5.25	6.55
1/4	47.909	.13	.27	.40	53	66	.80	93	1.06	1.20	1.33	2.66	3.99	5.31	6.65
1/2	48.695	.14	27	41	.54	.68	.81	95	1.08	1.22	1 35	2.70	4.05	5.40	6.76
3/4	49.480	.14	27	41	.55	.69	.82	96	1 10	1.24	1.37	2.75	4.12	5.49	6.87
16	50.265	.14	.28	.42	.56	70	84	98	1 11	1 26	1.40	2.79	4.19	5.59	6.98
1/4	51.051	.14	28	.43	.57	71	85	99	1.13	1 28	1.42	2.84	4.25	5.68	7.10
1/2	51.836	.14	.29	43	.58	72	86	1 01	1.15	1.29	1.44	2.88	4.31	5.76	7.20
3/4	52.622	15	.29	44	.59	73	88	1 02	1 17	1.31	1.46	2.92	4.38	5.85	7.30
17	53.407	.15	30	44	59	74	.89	1.04	1 18	1.33	1.48	2.96	4.44	5.93	7.40
1/4	54.192	15	.30	.45	.60	.75	.90	1.05	1.20	1.35	1.50	3.00	4.51	6.02	7.53
1/2	54.978	.15	31	.46	.61	.76	.92	1.07	1.22	1.37	1.53	3.05	4.58	6.11	7.65
3/4	55.763	15	.31	.46	.62	.77	.93	1.08	1.24	1.39	1.55	3.10	4.65	6.20	7.75
18	56.549	16	31	.47	.63	.79	94	1.10	1.25	1.41	1.57	3.14	4.71	6.29	7.85
1/4	57.334	.16	.32	.48	64	.80	.95	1.11	1.27	1.43	1.59	3.18	4.77	6.37	7.95
1/2	58.119	.16	.32	.48	.65	.81	.97	1.13	1.29	1.45	1.61	3.23	4.84	6.45	8.07
3/4	58.905	16	.33	49	.65	.82	.98	1.14	1.31	1.47	1.63	3 26	4.90	6.54	8.18
19	59.690	.17	.33	.50	.66	.83	.99	1.16	1.32	1.49	1.66	3.32	4.97	6.63	8.30
1/4	60.476	.17	.34	.50	.67	.84	1.01	1.17	1.34	1.51	1.68	3.36	5.04	6.71	8.40
1/2	61.261	.17	.34	.51	.68	.85	1.02	1.19	1.36	1.53	1.70	3.40	5.10	6.80	8.51
3/4	62.046	.17	.34	.52	.69	.86	1.03	1.21	1.38	1.55	1.72	3.45	5.17	6.90	8.62
20	62.832	.17	.35	.52	.70	.88	1.05	1.22	1.39	1.57	1.74	3.48	5.24	6.98	8.73
1/4	63.617	.18	.35	.53	.71	.89	1.06	1.24	1.41	1.59	1.77	3.54	5.31	7.07	8.85
1/2	64.403	.18	.36	.54	.72	.90	1.07	1.25	1.43	1.61	1.79	3.56	5.37	7.15	8.95
3/4	65.188	.18	36	.54	72	.91	1.09	1.27	1.45	1.63	1.81	3.62	5.44	7.25	9.05
21	65.973	.18	.37	.55	.73	.92	1.10	1.28	1.47	1.65	1.83	3.66	5.50	7.33	9.15
1/4	66.759	.19	.37	.56	.74	.93	1.11	1.30	1.48	1.67	1.85	3.70	5.56	7.41	9.26
1/2	67.544	.19	.38	.56	.75	.94	1.12	1.31	1.50	1.69	1.88	3.75	5.63	7.50	9.38
3/4	68.330	.19	.38	.57	.76	.95	1.14	1.33	1.52	1.71	1.90	3.79	5.69	7.59	9.49
22	69.115	.19	.38	.58	.77	.96	1.15	1.34	1.53	1.73	1.92	3.84	5.75	7.68	9.60
1/4	69.900	.19	.39	.58	.78	.97	1.16	1.36	1.55	1.75	1.94	3.88	5.82	7.76	9.70
1/2	70.686	.20	.39	.59	.79	.98	1.18	1.37	1.57	1.77	1.96	3.93	5.88	7.85	9.82
3/4	71.471	.20	40	.60	.79	.99	1.19	1.39	1.59	1.79	1.98	3.96	5.95	7.94	9.92
23	72.257	.20	.40	.60	.80	1.00	1.20	1.40	1.61	1.81	2.01	4.02	6.02	8.03	10.03
1/4	73.042	.20	.41	.61	.81	1.01	1.22	1.42	1.62	1.82	2.03	4.06	6.09	8.13	10.13
1/2	73.827	.20	.41	.61	.82	1.02	1.23	1.43	1.64	1.84	2.05	4.10	6.15	8.21	10.23
3/4	74.613	21	.41	.62	.83	1.04	1.24	1.45	1.66	1.86	2.07	4.15	6.22	8.30	10.35
24	75.398	.21	.42	.63	.84	1.05	1.26	1.46	1.67	1.88	2.09	4.19	6.28	8.38	10 45

Conversion Table, Hundredths of an Inch to Sixty-Fourths

01, .02.. 1/64	.14.... 9/64	.26, .27 17/64	.39......25/64	.51, .52..33/64	.64......41/64	.76, .77..49/64	.89......57/64
03...... 1/32	.15, .16 5/32	.28...... 9/32	.40, .41..13/32	.53......17/32	.65, .66..21/32	.78......25/32	.90, .91..29/32
04, .05.. 3/64	.17.... .11/64	.29, .30 .19/64	.42......27/64	.54, .55..35/64	.67......43/64	.79, .80..51/64	.92......59/64
.06, .07.. 1/16	.18, .19.. 3/16	.31, .32...5/16	.43, .44.. 7/16	.56, .57.. 9/16	.68, .69..11/16	.81, .82..13/16	.93, .94..15/16
.08...... 5/64	.20, .21..13/64	.33......21/64	.45, .46..29/64	.58......37/64	.70, .71..45/64	.83......53/64	.95, .96..61/64
.09, .10.. 3/32	.22...... 7/32	.34, .35..11/32	.47.... .15/32	.59, .60..19/32	.72......23/32	.84, .85..27/32	.97......31/32
.11.... 7/64	.23, .24 15/64	.36.... .23/64	.48, .49..31/64	.61......39/64	.73, .74..47/64	.86......55/64	.98, .99. 63/64
.12, .13.. 1/8	.25. . 1/4	.37, .38.. 3/8	.50...... 1/2	.62, .63.. 5/8	.75. .... 3/4	.87, .88.. 7/8	1.00...... 1

[1] By courtesy of the *Horseless Age*, New York.

HOW TO MARK A FLY WHEEL IN DEGREES AND INCHES

Most fly wheels of engines are marked in some manner. If, however, you know in degrees what timing to give an engine, and if the flywheel is not marked, then with the assistance of the table on page 68, the markings can be punched on the cylinder with a center punch.

The first procedure would be to make a punch mark, or place an "indicator" at the base of the rear cylinder (A), Fig. 23. Be sure it is exactly in the center of the cylinder (see Fig. 20A, page 66); however, when the piston is on top dead center when the indicator is being located, it could be placed to one side, as on the Reo.

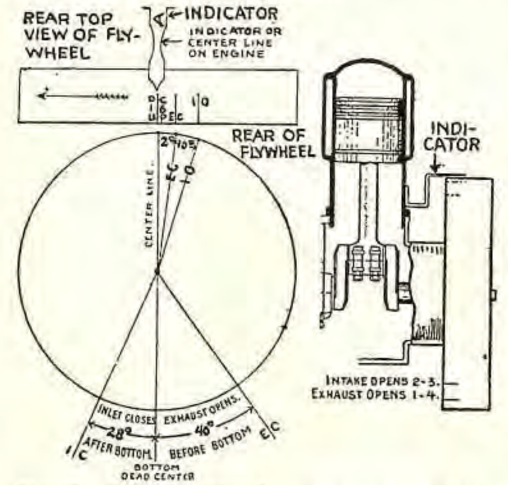


Fig. 22. (Left.) Looking down on top of the flywheel when standing in rear of it.

Fig. 22. (Right.) Side view.

Next, place the piston of No. 1 cylinder at the top dead center of its stroke.

Next, punch a mark or line on the flywheel directly in line with the indicator. Mark this line "DC-1-6," meaning that the pistons of cylinders 1 and 6 are at the top, or dead center. (We shall assume that it is a six-cylinder engine. If a four-cylinder, mark "DC-1-4".)

Suppose the **valve timing** is as follows: Exhaust valve closes 2° past top and opens 40° before bottom, and inlet valve opens 10° after top and closes 28° after bottom, as measured on the fly wheel, which is the usual method of following degree marks (Fig. 22).

The next procedure is to measure the diameter of the fly wheel. Suppose it measures 14″. Refer to the table (page 68) and find 14 in the first column under "Diam. Wheel." Note that 2° measured on the circumference of the fly wheel would be .24 (twenty-four one-hundredths of an inch). Refer to the conversion table in the same table, lower down on the page, and note that .24 is equal to 15/64 of an inch. Now, make another mark 15/64 of an inch to the right of the mark "DC-1-6," and mark it "EC" (exhaust closes).

Note. Looked at from the front of an engine, the fly wheel revolves clockwise, or to the right. Looked at from the rear of engine, which is the position from which we are looking at the engine in Fig. 22, the flywheel revolves counter-clockwise, or to the left.

When the flywheel is moved to the left so that the mark "EC" comes in line with the indicator, the "EC" represents a 2° movement of the flywheel, and the piston would be slightly down on its stroke from the piston dead-center position and the exhaust valve would just close.

If the engine was an "L"-head cylinder type, this marking would suffice, as the cam-shaft gear is usually meshed with the crank-shaft gear at the position where the exhaust closes.

If the engine was a "T"-head cylinder type, the inlet cam shaft would have to be timed as well as the exhaust. In our example (Fig. 22) the inlet valve opens 10° past top. Refer to the table and note 10° on a 14″ flywheel is 1.22 (one inch and twenty-two one-hundredths of an inch). Refer to the conversion table and note that .22 is equal to 7/32 of an inch. Now make another mark on the fly wheel 1 7/32 of an inch to the right of the mark "DC-1-6," and mark it "IO" (inlet opens).

When the flywheel is moved to the left so that the mark "IO" comes in line with the indicator, the "IO" represents a 10° movement of the fly wheel, and the piston would be slightly down on its stroke from piston dead-center position and the inlet valve would just begin to open.

The inlet cam-shaft gear is meshed with the crank-shaft drive gear at this position.

Marking of the position of other pistons on the fly wheel can be made in the same manner. This is not necessary for timing, but it is necessary for checking the timing.

Another Method of Marking a Flywheel in Degrees

Although the table on page 68 shows how to find in inches or a fraction thereof just where to mark a flywheel in degrees, another method is given below. Suppose there are no timing marks on the flywheel and you desire to mark it so that the exhaust valve closes 10° after top dead-center (see Fig. 23).

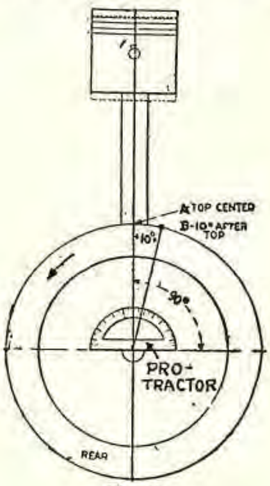


Fig. 23

Set the engine so that the piston in No. 1 cylinder, namely the cylinder nearest the radiator, is at the top of its stroke. With the use of the protractor or with a square, make a mark at **A** on the rim of the flywheel, on the inner edge, which mark will be directly above the center of the crank shaft when the piston is at top of its stroke.

Then, with the protractor placed against the flywheel so that the 90° mark points directly toward mark **A**, go 10° to the right on the protractor (standing in rear of engine), and then make a mark at **B** on the flywheel. This mark will be 10° to the right of mark **A**. Now turn the fly wheel until mark **B** is at top center.

With the engine in this position mesh the timing gears so that the exhaust valve of No. 1 cylinder is just closing.

It is understood that when standing behind the fly wheel it would turn to the left, as shown by the arrow point. Therefore, the piston must first reach top center (A) with the exhaust valve still open, and travel 10° farther to (B) before it closes.

This method is inaccurate. The method described under Fig. 22 is preferable.

To Locate Position of Piston for Timing Valves or Ignition

In the previous matter we have considered placing the piston on top dead center of its stroke. This refers to the top of exhaust stroke, or the top of compression stroke, because the **valve timing** is usually done with No. 1 piston on top (or slightly after top) of d.c. **exhaust stroke,** and the **ignition timing** is usually done with No. 1 piston on top (or slightly before) d.c. of **compression stroke. How to tell when the piston is on top of the exhaust or compression stroke** is explained below.

Usually a mark is placed on the flywheel to indicate when the piston is at top of compression or exhaust stroke. For instance, in a four-cylinder engine, a mark will probably be on the flywheel, such as "DC 1-4," meaning "dead center up 1 and 4," or pistons 1 and 4 are at top of stroke. In a six-cylinder the mark would probably appear as "DC 1-6 up," meaning pistons 1 and 6 are on top. Or the mark may be "1-4 up," or "1-6 up," meaning the same. These marks on flywheel are placed in line with the center mark on the cylinder, or in line with an indicator. After finding the top, by moving the flywheel to the right, the piston is placed before top; if moved to the left, it is placed after top.

On a four-cylinder engine, when No. 1 piston is on top, No. 4 is on top also. On a six-cylinder engine, when No. 1 is on top, No. 6 piston is also on top.

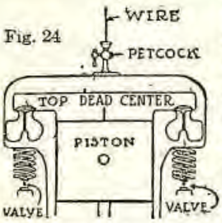
To find just what stroke pistons 1 and 4, or 1 and 6, are up on, that is, if up on **compression stroke,** or up on **exhaust stroke,** watch the valves.

When No. 1 piston is at top of compression stroke, both valves of No. 1 cylinder will be closed.

When No. 1 piston is at top of exhaust stroke, No. 1 exhaust valve will have just about closed and No. 1 inlet valve will just be starting to open. Piston No. 4 will then be at top of compression stroke, because, when No. 1 comes up on exhaust stroke, No. 4 (or No. 6 in a six-cylinder engine) comes up on compression stroke. See tables on pages 78 and 81.

If the engine happens to be a "T"-head engine with a compression cock in the center and there are no marks on the flywheel, it is easy to find when the piston is on top by placing a wire or bicycle spoke through the pet cock and turning the engine over; when the wire rises to its highest point the piston is on top of dead center (Fig. 24). The next point is to find if it is on top of exhaust or compression stroke, which position will be indicated by the position of the valves and cams, as explained above.

Fig. 24



If a cylinder is of the "L"-head type, and the flywheel is not marked, it may not be possible to get a wire into the cylinder. In this case open the compression cock and place your finger over it; have someone crank the engine slowly until you feel compression; let this escape gradually. When the gas has ceased escaping, the piston is at or near top dead center. The exhaust or compression stroke is then found by watching the position of the valves, as explained.

Example of Valve Timing with Position of Piston

The illustrations below represent the valve timing of the **Locomobile "48"** (series 19000) six-cylinder **"T"-head engine.** The figures below are expressed in inches of piston travel from dead centers. Degrees are also mentioned.

To speak of timing an engine in inches of piston travel means that we set the valves to open or close when the piston is in a certain position with respect to the cylinder. For example: to set the exhaust valve to close 1/64" past top dead center, bring the piston to top dead center of the exhaust stroke; turn the engine in the normal direction of rotation until the piston has descended 1/64" on its stroke; set the valve to close at this point. These measurements may be made by means of a wire inserted through the pet cock, as shown in Fig. 24.

Speaking of timing an engine where the timing is expressed in degrees refers to the degrees motion of the crank shaft or flywheel. For example: to set the exhaust valve to close 5° past top dead center, bring the piston to top dead center of the exhaust stroke; turn the engine in the normal direction of rotation 5°, as measured on the flywheel, and set the valve to close at this point.

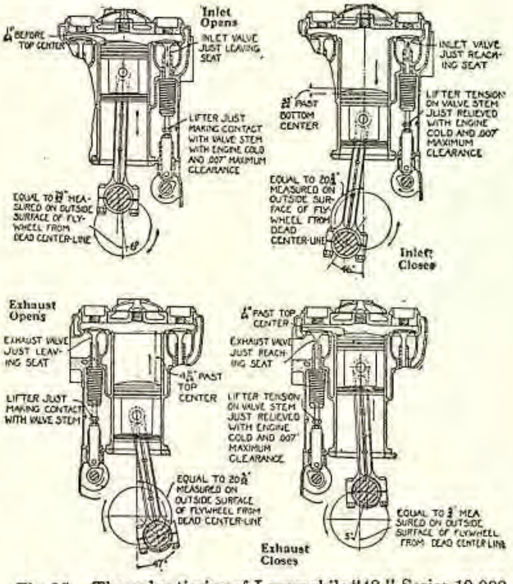


Fig. 25. The valve timing of Locomobile "48," Series 19,000, showing the relative position of piston to the opening and closing of valves.

The inlet valves are on the left of the engine and the exhaust valves on the right side when seated in the car. View above is from the front of engine.

Inlet opens 1/64" before top center (piston measurement), or 6° before top (flywheel measurement). **Inlet closes** 43/64" past bottom center (piston measurement), or 46° after bottom (flywheel measurement).

Exhaust opens 4 51/64" past top center, or 45/64" before bottom center (piston measurement), or 47° before bottom (flywheel measurement). **Exhaust closes** 1/64" past top center (piston measurement), or 5° after top (flywheel measurement).

Note: This timing is with engine cold and valve lifter clearance first set accurately to .007" on both intake and exhaust side. After the valves have been set at .007" and engine properly timed, the valve clearance must be again adjusted to .002" on the inlet and .005" on the exhaust when engine is cold for maximum power and quietness.

Hudson Valve Timing in Inches

The timing of the **Hudson "Super-Six" six-cylinder "L"-head engine, measured according to piston travel:**

Fig. 26—inlet opens 1/64" after top dead center.
Fig. 27—inlet closes 17/32" after bottom d.c.
Fig. 28—exhaust opens 57/64" before bottom d.c.
Fig. 29—exhaust closes 1/32" after top d.c.

Wire for measurements should bo 5 [illegible]/16" long.

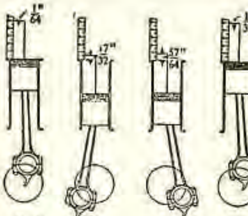


Fig. 26 Fig. 27 Fig. 28 Fig. 29

The timing of the Hudson in degrees relative to the movement of the flywheel: Intake opens 7° after top dead center; closes approximately 42° after lower dead center; exhaust opens about 55° before dead center; closes 8° after top dead center.

Adjusting Dodge Valve Clearance[1,2]

Valve clearance adjustment of the Dodge Bros. four-cylinder "L"-head engine[1] is .003" to .004" for engines below No. A265,496, and .006" to .007" for engines above this number; check with engine warm and usually while running. Measure clearance with .006" thickness gauge, which should pass through easily, while one of .007" should not pass.

The foregoing adjustments can be made while the engine is running and the clearance can be measured by using two feelers or thickness gauges, passing them between the end of the valve stem and valve lifter as they rise and fall.

Timing Dodge Valves

Retiming the valves and assembling the timing gears is necessary only when the engine has been disassembled, or when replacing timing gears.

To assemble timing gears: Follow factory marks on gears. Place mark on crankshaft gear in line with and on same side of crankshaft as No. 1 crank throw. Assemble cam gear to camshaft so that the arrow on camshaft points directly towards the pumpshaft. The pumpshaft gear is positively located by key and keyway. Mesh camshaft gear with crankshaft gear so that mark on crankshaft gear is between punch marks on camshaft gear. Mesh pumpshaft gear so that the marks on camshaft gear are between punch marks on pumpshaft gear. On cars with battery ignition, meshing of pumpshaft gear is not important but is important if magneto ignition is used.

In case the marks on the gears are not plain, the following procedure should be followed: Turn crankshaft clockwise until No. 1 crank is 8° beyond upper dead center.

On engine having the ignition timing opening in the housing of the flywheel, this position corresponds to the timing mark on the flywheel marked I.

On engines not having this opening, it will be necessary to remove the cylinder head and turn the crankshaft clockwise until the piston of No. 1 cylinder is .022 inches below the upper dead center on firing stroke. At this position the exhaust valve of No. 4 cylinder has just closed.

Very carefully adjust the valve lifter of the exhaust valve of No. 4 cylinder to the proper **valve clearance** as given above.

Turn camshaft (with cam gear removed) counter-clockwise until exhaust valve of No. 4 cylinder just closes. Crankshaft and camshaft gear can be correctly meshed at this point.

The camshaft gear should then be fitted to the camshaft, being careful not to turn the camshaft or crankshaft. An error of one tooth on the camshaft gear makes an error of about 16° in crankshaft travel. At this position of valve timing the **ignition** can be set for No. 1 cylinder, as explained on page 379.

Timing the Valves of the 1921 to 1926 Buick Six-Cylinder Engine

The exact point in the cycle at which the valves are opened and closed is determined by the shape of the cams which operate them and by the angular relation between the camshaft and the crankshaft. If it should ever become necessary to remove one of these shafts or the gears which drive them, they must be replaced in proper relation to one another or the valves will be "out of time." To obtain this relation, the punch-marked tooth on the crankshaft gear (Fig. 30) should be set to match with the punch-marked space on the camshaft gear.

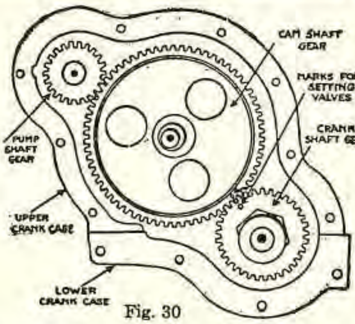


Fig. 30

Adjusting Buick-Six Valve-Stem Clearance

In making this adjustment, turn the engine by hand, in a clockwise direction, until the line marked "1 and 6" on the flywheel, comes into line with the line on the rim of the inspection hole. This is the firing position for cylinders Nos. 1 or 6, numbering from the radiator back, and one or the other of these cylinders will be found to have both valves closed.

Note: In setting the marks on the flywheel be careful to turn the engine only in a clockwise direction, otherwise the backlash in the timing gears will affect the result.

The push rods for the rocker arms should then be adjusted while engine is warm (see instruction plate on side of engine), so as to give .010" clearance[3] between the ends of the valve stems and rocker arms.

Push rods for the other cylinders may be adjusted in the same manner. Best results will be obtained if these adjustments are made while the engine is idle.

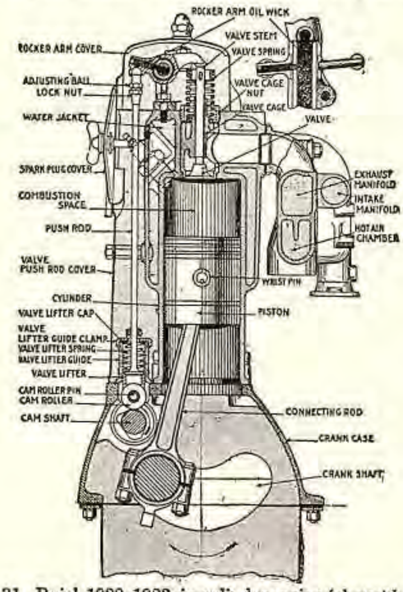


Fig. 31. Buick 1920–1923 six-cylinder engine (above) has both inlet and exhaust valves placed in-the-head of the cylinder and is a typical type of engine with valves-in-the-head. The valves are in cages which can be removed for grinding. On models 1924 and later, cages are not used. The cylinder head is detachable and valves are ground to seats in head. See Specifications, pages 1055–1062, for specifications of later engine.

One half-teaspoonful of kerosene inserted around the **valve** stem at least once a week while the engine is running will keep the valve free from carbon and prevent it from sticking **in the** valve cage (refers to early model as shown above).

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[1] Also applies to Dodge Bros. engine on Graham Bros. trucks, except, where engines have cast-iron head and carbon steel valve stems, it is recommended that a clearance of .008" to .010" be allowed on the **exhaust** valves of engines. Where silicrome valves are used, use valve clearance as mentioned in text (.006" to .007").

[2] When engine is timed by marks on the front end or timing gears, valve clearance is set **after** the gears are meshed; when timed without using the marks on the gears, the valve clearance **should be adjusted first.**

[3] On models 1924 to 1926, the clearance is .006" to .008", preferably the latter. Adjustment to be made when engine is hot. If made when engine is cold, or if too close an adjustment is made, the expansion of the valve stem and push rod when engine gets hot may cause valves to be held open, which would prevent proper seating of valves, thus causing trouble, such as loss of power, burned or warped valves, etc.

Grinding Buick-Six Valves[1]

When valves leak compression, they should be ground as follows: Compress valve spring and lift push rod out of socket in valve lifter. Loosen valve cage nuts with the special drift furnished in the tool kit and remove by unscrewing. A light tap with a hammer on the end of the valve stem will loosen the cage so that it may be withdrawn. Be careful not to injure the small bronze packing ring on top. Remove the valve spring and after cleaning with gasoline or kerosene, smear the valve and its seat with fine emery flour and oil or with one of the grinding pastes now on the market. **Grind** by turning the valve back and forth on its seat until both valve and seat show a bright ring 1/32" wide all the way around.

Be careful to clean out all traces of abrasive material before replacing valve. After grinding valves, it will usually be found necessary to readjust the push rods to compensate for the wear. For Buick ignition timing see the Index.

THE TIMING GEARS; FRONT END DRIVE SYSTEM BY GEARS

The camshaft can be driven by **gears** or **a silent chain.** This subject relates to a gear driven front end system.

Since the position of the camshaft is always the same with reference to the pistons (because the camshaft is always in mesh with the crankshaft gear), and since the cams are all integral parts of the shaft, the valve timing cannot change. If the gears are ever removed, they may be put back in the proper position by seeing that the marks on the edges of the teeth "dovetail" together.

If you find that the marked teeth do not come together, do not jump at the conclusion that the gears are improperly set, but first verify the setting by checking the timing of the valves with the marks on the flywheel.

If the timing of the valves of an engine is not correct, it is then necessary to re-mesh or re-set the timing gears. It will be necessary to place the piston of No. 1 cylinder at top of its stroke. Then remove the gear cover and turn the crank until the "EX. C" (exhaust closing mark of cylinder No. 1) is in line with the center mark on the cylinder (in rear).

Note. On engines with unit power plants instead of the center line being on the cylinder, a small hole at the top of the flywheel case is provided so that the line and figures on the flywheel can be seen through the hole. See Index for Continental engine, showing location.

Now remove the cam gear from its shaft and turn the camshaft in its direction of rotation (it is the opposite of the direction of rotation of the crankshaft), until the exhaust valve on cylinder No. 1 is just closing; keep the cam shaft in this position; replace the large cam gear on the end of the camshaft, properly meshing it with the gear on the crankshaft.

There are usually punch marks stamped on the gear teeth, as shown in Fig. 32. On some engines, figures are stamped on the gear teeth, as in Fig. 33, and, in some instances, a letter "O" or "C." These

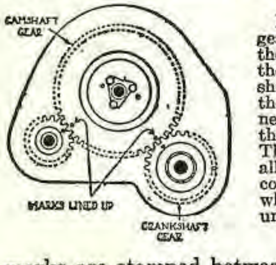


Fig. 32. Note the crankshaft gear mark which meshes with the camshaft gear mark. On the left side a mark on the camshaft is meshed with a mark on the gear which drives a magneto and which must be timed the same as the camshaft. The magneto, however, is usually timed or set by loosening its coupling from the shaft with which it connects. See Index under "Setting the magneto."

marks are stamped between the two teeth of one gear and in the center of a tooth in the other gear, both of which should be carefully noted when meshing the gears. At this point the valves are supposed to be correctly timed.

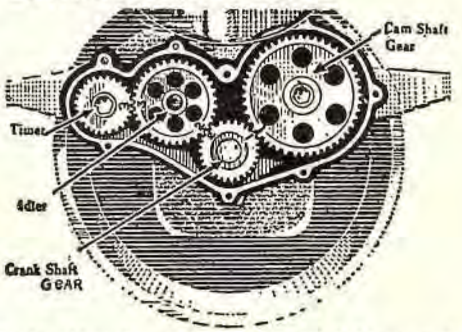


Fig. 33. Note the meshing of the crankshaft gear mark (1) between the two teeth on the camshaft gear mark (1). Also observe that in this instance (Overland model 85), there is an idler gear interposed between the crankshaft gear and the gear which drives the ignition timer. This idler gear runs free and is used to obtain a correct ratio and to drive the timer shaft. It must be meshed as shown when the ignition timer is in proper position, as will be explained under "Ignition timing."

Example of Setting the Cam Gear on the Reo Models "T 6" and "U 6"

The illustration (Fig. 34) **shows the timing gears** (with cover removed) and the relation which they bear to one another.

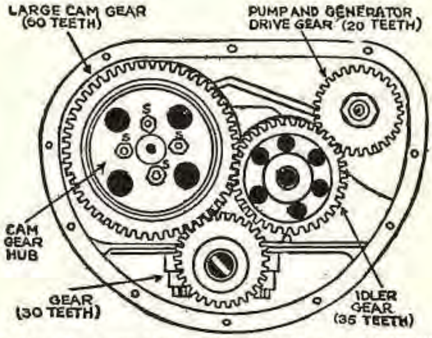


Fig. 34. Gears on the front of the Reo model "T6" and "U6" engine.

The crankshaft gear is keyed to the crankshaft and revolves with it. This gear has 30 teeth.

The large cam gear is fastened rigidly to the camshaft by four studs (S) and lock nuts. This gear has 60 teeth and, therefore, revolves half as fast as crankshaft gear and in opposite direction.

The pump and generator-drive gear has 20 teeth, and is driven through the idler gear at the crankshaft speed, but in the opposite direction to that of the crankshaft gear. One of the studs is marked with a center punch so as to insure correct replacement, should the gear for any reason be removed.

The teeth of the large cam gear and the one on the crankshaft are also given center punch marks for meshing reference. These markings should dovetail.

[1] Applies to early models using cages. On later models the valves are ground to seats in detachable cylinder head.

The teeth of the idler gear and the one driving the water pump and generator are not marked, and can be meshed at any point.

If the timing gears are assembled as described above, the timing must be correct.

In case a new gear is assembled on the engine, the following may be of some assistance in obtaining the correct timing or setting:

Cam gear setting: The fly wheel on this engine is of such diameter as to require its turning through an angle of approximately seven degrees to produce a one-inch movement of its face with respect to some fixed point.

Now, since the error in cam setting must not exceed one half-inch, this movement is equivalent to 3½° movement of the flywheel or crank shaft.

If, for any reason, the valve closing is not within this limit, the setting may be corrected in the following manner:

The large or 60-tooth cam gear (and with it, of course, the cam shaft) would move 6°, or 360 divided by 60, if shifted one tooth; this is the equivalent of 12° on the fly wheel or crank shaft, since, it will be remembered, the gear on the crank shaft has but 30 teeth.

If one inch on the flywheel is equivalent to 7°, 12° would represent approximately a 1¾″ movement of the flywheel.

If the cam openings were off two inches on the fly wheel, it would be a simple matter to change the meshing of the cam gear one tooth in the direction required, and to have an error of ¼″, which would be within the ½″ limit.

If, however, the error of the cam shaft was but 1″, it would be impossible to get nearer than ¾″ by shifting this gear one tooth, which is ¼″ in excess of the limit desired. Means must, therefore, be provided for shifting the gear a fraction of a tooth, or, in other words, a fraction of 6°.

For example, if the gear had 54 teeth instead of 60 teeth, this could be accomplished by removing the gear from the shaft and shifting the former one quarter-turn; 54/4 equals 13½, which would, in effect, be the same as shifting one half-tooth. In order to obtain a shift of one half-tooth (3°) with a gear of 60 teeth, two of the four studs which hold the cam gear to the cam shaft are placed 3° off of the 90° center lines and three of the holes in the cam-gear flange are slotted, the fourth being a tight fit over the stud.

Therefore, if the gear is taken off and shifted 87° or 93°, the effect is the same as changing the meshing of the gear one half-tooth. We shall have changed the relative position of the gear teeth to the cam shaft just 3°, this being equivalent to 6° on the flywheel, or approximately ⅞″. This arrangement gives this engine a means whereby the greatest variation in cam-shaft setting may never exceed ½″.

Valve Timing of Reo

The fly wheel of the engine has upon its face the marks: "U.D.C.1 & 6," meaning upper dead center, cylinders 1 and 6; "INTAKE OPEN 1 & 6," meaning that the intake valve in No. 1 or No. 6 cylinder commences to open; "SPARK," meaning that a spark should take place in No. 1 or No. 6 cylinder with the spark fully retarded.

These markings on the face of the fly wheel register with the top of the right-hand motor support. The spark occurs 1½″ late at full retard. The intake valve opens at the upper dead-center point. Since the cranks for cylinders Nos. 1 and 6 are on the same side of the center, it will be understood that the marks which serve for cylinder No. 1 also apply to No. 6.

To check valve setting: First screw out the spark plug from each cylinder, thereby relieving compression and permitting the engine to be turned over easily. Selecting No. 1 cylinder (it being the most convenient), crank the engine slowly with the hand crank until the inlet valve for this particular cylinder just commences to open. This can be determined by placing a piece of fine tissue paper between the inlet valve stem and its lever. When there is just sufficient pressure of the lever on the valve stem to prevent withdrawal of the paper, the inlet valve is commencing to open. At this moment the marking "INLET OPENS 1 & 6" on the face of the flywheel should not be more than ⅛″ either way from the top of the right-hand engine support. Before checking the valve setting, it is important that all backlash of the valve tappets be removed.

If one cylinder checks, it will not be necessary to check the valves in the other cylinders, as the cam shaft is accurately ground and the cams are in correct relation to one another.

Relation of Valve Clearance and Valve Timing, and Meshing of the Timing Gears

After your engine has been overhauled a few times the cam-shaft gear will have developed a dozen or more meshing marks. Each workman will have added a few marks that may or may not be right and changed a few that were right, until finally it is hopeless to match any of them.

This need not seriously inconvenience you, for if you understand valve timing, you can forget the gear marks and work entirely from the fly-wheel marks.

A "trammel" is a stationary starting point from which to base all your work (see Fig. 20, page 66). The trammel generally is directly over or in front of the flywheel, but may be located elsewhere if some careless workman has removed your flywheel and replaced it in a different position (flange connection, or a new flywheel with the key in the wrong place). The trammel should be shifted until it registers properly when the cylinder indicated is at top center.

Check up the top center mark by making sure that the piston in the cylinder indicated is exactly at top center and that the trammel registers exactly in line.

Now that you are certain of the trammel, move the flywheel in the direction in which it should travel (generally counter-clockwise, if flywheel is between you and the cylinders) until the marks I. O. (intake opening) No. 1 and No. 4 register with the trammel. Leave the flywheel alone now, and turn the cam shaft until the nose of the inlet cam on No. 1 cylinder is down. Adjust the air-gap (valve-stem clearance) for post-card distance. Turn the cam shaft in the direction of its travel until the air-gap is gone and any further movement would start to lift the valves. Put on the cam-shaft gear, being careful not to move either the cam shaft or the crank shaft. Have the gear key in place, but do not permanently fasten the gear yet.

Turn the fly wheel in its proper direction and **check up the intake closing.** If both opening and closing of this valve are right, it means that the cam shaft and air gap are correct, and the gear can be permanently fastened.

If the valve opens on time but closes at the wrong time, it means that both the cam shaft and air gap are wrong. **If the valve closes too soon,** the air gap is too large and does not hold the valve open long enough. **If the valve closes late,** the air gap is too small and holds the valve open too long.

Make a mark with a lead pencil or with chalk on the fly wheel, midway between the actual closing and the proper closing. Turn the flywheel to this new mark and adjust the tappet to correspond. The tappet must be just barely in contact with the valve stem. The air gap is now O. K., but the cam shaft is still out of time.

Turn the fly wheel back to the opening mark and remove the gear. Turn the cam shaft until the air gap is gone, replace the gear and check up the closing. The cam shaft and air gap are now correct and the remaining tappets are adjusted after registering each mark with the trammel. Do not use a sheet of paper or post card to measure with. Turn the fly wheel and adjust each tappet by the flywheel marks.

If the valve opens a certain number of degrees early and closes the same number of degrees late, the cam shaft is right but the air gap is wrong.

If a valve opens a certain number of degrees early and closes the same number of degrees early, the air gap is right but the cam shaft is wrong.

Make a habit of checking up this air gap occasionally with the flywheel marks.

After the valves have been ground or new valves put in—check up. Don't let your engine overheat or lose power through the fault of the air gap.

It will be observed that valve clearance, referred to above as "air-gap," is a very important adjustment.

SILENT CHAIN FRONT END DRIVE SYSTEM

Where silent chains and sprockets are used instead of gears, the procedure is similar. Note, however, that the cam shaft revolves in the same direction as the crank shaft.

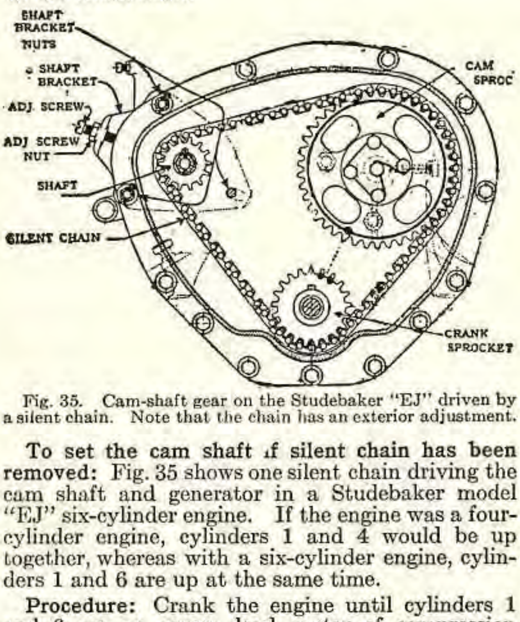


Fig. 35. Cam-shaft gear on the Studebaker "EJ" driven by a silent chain. Note that the chain has an exterior adjustment.

To set the cam shaft if silent chain has been removed: Fig. 35 shows one silent chain driving the cam shaft and generator in a Studebaker model "EJ" six-cylinder engine. If the engine was a four-cylinder engine, cylinders 1 and 4 would be up together, whereas with a six-cylinder engine, cylinders 1 and 6 are up at the same time.

Procedure: Crank the engine until cylinders 1 and 6 are on upper dead center of compression stroke by getting marks "UP-D-C 1-6" on the fly wheel opposite pointer, on the rear of the starter housing. With the crank shaft in this position turn the cam-shaft sprocket until the punch mark on the cam gear will be directly between the two punch marks on the teeth of the crank-shaft gear (Fig. 35). Replace the chain, being careful to see that the cam shaft or crank shaft are not moved.

It is not necessary to set the accessory shaft sprocket which drives the pump, generator, and ignition unit (the sprocket on the left side marked "shaft"). The ignition unit can be set by moving it on its own shaft. See Index under "Ignition timing."

Silent chains will stretch, especially when new, or after a few thousand miles or so of running, and will likely cause a **noise** by striking the bottom of the chain housing.

Adjustment can be made by moving the generator. There are three bolts holding the generator. They are to be loosened and the chain-adjusting screw given a turn or so, moving generator out, thus tightening chain. This movement usually allows about 1/16″ movement of the generator sprocket. Be sure and tighten all bolts and nuts.

Too tight a chain adjustment will cause "singing" as well as undue wear on one side of the bearing.

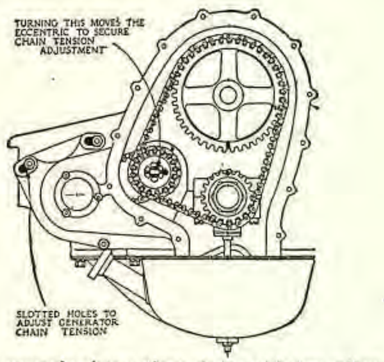


Fig. 36. An example of two silent chains with two adjustments for slack. (King.)

To set the cam shaft on an engine using two silent chains (Fig. 36) the procedure is similar, except that the chain driving the generator is not considered.

Note in Fig. 36 that the crank-shaft gear (lower) drives the large cam-shaft gear and also a double sprocket from which another chain drives the generator.

To adjust the cam-shaft chain an eccentric shaft is provided.

To adjust the generator chain, the generator is moved as shown in Fig. 36. If a chain is adjusted too tight, it will hum or sing at high speeds. If the chain should stretch to such an extent that no more adjustment is available, then either install a hunting or off-set link section, or a new chain, if badly worn. See Index under "Silent chains."

In re-timing, or any other operation requiring the removal of the chain, be sure that the chain is replaced so that it runs in the direction indicated by the arrows on the sides of the links.

Note. In order to reach the silent chain and cam sprockets, it is usually necessary to remove the radiator, starting crank stud, fan, fan pulley, and gear-housing cover. When replacing, be sure the gasket of the housing is in good condition.

Should it be necessary to remove the cam-shaft sprocket from the shaft, see that it is replaced in the exact position in which it was when it came off. On most gears and sprockets there are holes provided for a **"gear puller"** which is used to draw gears off.

Hupmobile Valve Timing

When timing this engine, reference to the marks on the gears should not be made, because they have no bearing on the engine timing. The appearance of the chain with the front cover removed is shown in Fig. 37.

There are two timing methods. The first is as follows: turn the engine over until the marks "Intake Opening" on the fly wheel line up correctly with the line on the housing; turn the cam-shaft gear until the intake cam is just beginning to lift the intake valve of No. 1 cylinder; place the chain in proper position and allow just a little slack.

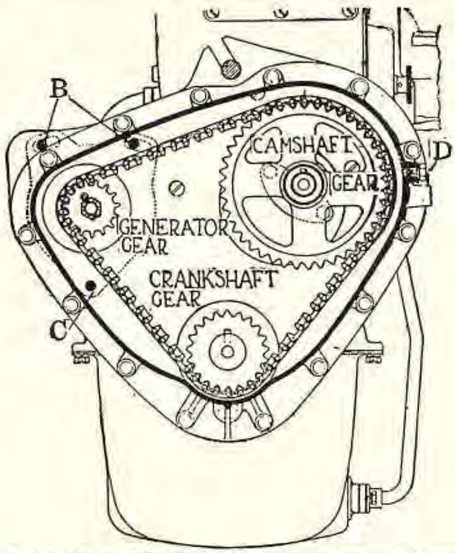


Fig. 37. Hupmobile front end drive system. Adjustment of slack in chain is taken up by loosening bolts (B) and (C) and sliding the generator to one side, at the top (B).

The second method is: remove cylinder head so that you can measure the distance of the piston travel from top of cylinder block to piston. Turn piston of No. 1 cylinder 3/64″ past top d.c. on the intake stroke (piston traveling downward). Turn camshaft so that intake valve is just opening and exhaust closing (.006″ valve clearance); then place chain in its proper position.

In order to place the chain on the gears it may be necessary to loosen the rear engine bolt. Place a jack under the bottom of the oil pan near the front and raise the engine slightly.

Remarks on Front-End Drive Methods

Cars using silent chain front-end drive are the Ambassador, Ace, Ogren, Revere, Haynes, Jordan, Moon, Saxon, Brewster, Cadillac, Chalmers, Chandler, Cleveland, Hupmobile, King, LaFayette, Lincoln, Meteor, Mercer, National, Packard, R & V Knight, Stearns-Knight, Studebaker (one model), Templar, Willys-Knight, Winton.

Virtually all the other cars use the helical-gear front-end drive. Where the gear-type front-end drive is used, alternate gears are of different metals, such as iron and steel, and also of compressed cotton. The majority of gears are steel against cast iron, as this has been found to reduce "resonance."

Where both gears are of cast iron, or both of steel, the gears are prone to "sing."

Duralumin, which can be forged, is used for gears in the Continental and Marmon engines.

A Fabroil gear, which is a specially compressed, spirally wound cotton type of gear, made by the General Electric Co., is used on Buick, Paige, Wills-Saint Claire, and DuPont cars.

Where silent chains are used, it must be possible to reduce the length of the chain by degrees one full link, after which a link can be removed from the chain and the adjustment let out again. This gives unlimited adjustment. On those cars not provided with chain adjustments, it is, however, always best to renew a chain entirely if it is worn. The adjustment must also be accessible, so that it can be easily made when required.

There are several types of chains used and different methods of securing adjustment, as follows:

1. Movable idler.
2. Movable sprocket (Figs. 35, 36, 37).
3. Eccentric adjustment (Fig. 36).
4. Double adjustment.
5. Automatic idlers (Fig. 38).

The movable idler is used for adjustment or to take up chain whip.

The movable sprocket for adjustment is used on one of the shafts where it can be moved in or out without destroying any alignments or adjustments.

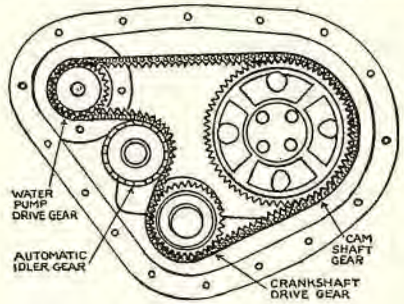


Fig. 38. A front-end drive system used on the model "75" Haynes. An automatic take-up for slack in the chain is provided. The cam gear operates the cam shaft, which operates the inclined valves.

The subject of silent chains is also dealt with elsewhere; see Index under "Silent chains."

Average Valve Timing

There is very little difference between the average timing of the four and the six-cylinder engine.

On the six, the average inlet opening is 10.7° past top center and the closing point 37.6° past bottom center.

On the four, the average for the inlet opening is 11.1° after top center, and the closing point is 36.8° after bottom center. The small difference would hardly be noticeable.

The exhaust on the average six **opens** 46° before bottom center and on the **four** at 46.3°. The **closing point of sixes** averages 7° after top, and on the **four,** 7.7°.

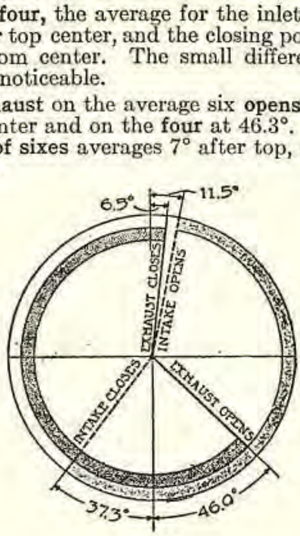


Fig. 39

On an average engine, therefore, the inlet would open 11.5° after top and close 37.3° after bottom. The exhaust would open 46° before bottom and close 6.5° after top.

The illustration (Fig. 39) is a **typical diagram of valve timing** with the timing designated in degrees. When reading such diagrams, imagine the circle being the rear of a fly wheel, which revolves to the left. The light shading represents the period of travel when the inlet valve is open, or 205.8°. The dark shading represents the period of travel when the exhaust valve is open, or 232.5°.

See also Index under "Valve timing" for the valve timing of engines on leading makes of cars; and under "Valve clearance" and "Diameter of valves."

INSTRUCTION No. 10

FIRING ORDERS: One, Two, Three, and Four-Cylinder Engines

Firing Order of One and Two-Cylinder Engines

There are four strokes to two revolutions of the crank shaft to complete a cycle operation, as explained on page 32.

A stroke of the piston means a travel from top to bottom, or from bottom to top, or 180° movement, or one-half of a revolution of the crank shaft. (This is not strictly true when offset cylinders are used.)

There are four strokes of 180° on all four-cycle engines; therefore there would be two revolutions of 360° each, or 720° travel of the crank.

There is but one power stroke (firing impulse) during the four strokes, or two revolutions of the crank shaft. Note, also, that the power stroke is a very short one, owing to the fact that the exhaust valve starts to open a considerable time before the piston reaches the bottom of its stroke. If the exhaust valve should open 46° before bottom, then the travel on the power stroke would be but 134° instead of 180°.

Therefore, if there is but one power stroke to two revolutions of the crank shaft (720° travel of crank shaft), we should have only 134° out of the two revolutions, or 720° on which there is power.

Fig. 1

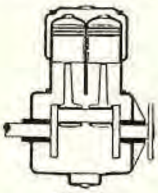


Fig. 2

Fig. 1. One-cylinder engine with a 360° crank shaft. Firing impulse every two revolutions; see diagram below.

Fig. 2. Two-cylinder vertical engine with a 360° crank shaft. Firing impulse every revolution.

Cylinder No.	1
1st Revolution	S
	C
2nd Revolution	P
	E

1	2	Cylinder No.
P	S	1st Revolution
E	C	
S	P	2nd Revolution
C	E	

Fig. 1 shows a single-cylinder engine. There is **one explosion during every two revolutions of the crank shaft,** or, in other words, there is one stroke of the piston when power is being developed, and three when there is no power, the piston then being moved by the momentum of the fly wheel.

As the piston must be carried through the three dead strokes, it is necessary to use a heavy fly wheel, so that when it is started, it will continue to revolve for a sufficient time to move the piston until the next power stroke.

There is vibration from a one-cylinder engine on this account, for the weight of the piston sliding first one way and then the other has nothing to balance it.

It can be balanced to some extent by attaching a weight called a "counter-balance," to the crank shaft opposite to the crank pin, in the same manner that the wheels of a locomotive are balanced, but even then there is vibration owing to the power stroke at uneven intervals.

Note. In the two small diagrams under the illustrations, **P** means power stroke; **S**, suction; **C**, compression; **E**, exhaust. The "firing impulse," is the time at which combustion takes place at the beginning of the power stroke.

Fig. 2 shows a two-cylinder vertical engine with a 360° crank shaft. If the piston of No. 1 cylinder is on power (P), No. 2 would be on suction (S)—see diagram. Therefore we should get an even firing impulse, or **one during each revolution.** But as both pistons are moving together, there would be considerable vibration, as both are on top or bottom at the same time. Counter-weights are also used on the crank shaft of this type of engine in order to counter-balance. (Seldom used.)

Fig. 3 shows a two-cylinder vertical engine with a 180° crank shaft. There are **two firing orders** of this engine, each of which would cause vibration. Refer to diagrams. In the first, if No. 1 is on power (P), No. 2 would be coming up on compression (C), and would fire next. Therefore, there would be **two firing or power impulses during one revolution,** and on the second revolution there would be no firing impulse at all. With the other order of firing, if No. 1 was on power (P), No. 2 would be coming up on exhaust (E). The crank would therefore travel 540°, or 1½ revolutions with but one firing impulse.

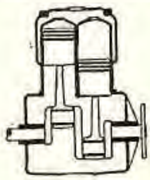


Fig. 3

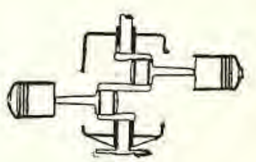


Fig. 4

Fig. 3. Two-cylinder vertical engine with a 180° crank shaft. Two different firing orders—see diagram below.

Fig. 4. Two-cylinder opposed type engine with 180° crank shaft. Firing impulse every revolution. Mechanically balanced.

Cylinder No.	1	2
1st Revolution	P	C
	E	P
2nd Revolution	S	E
	C	S
—or—		
Cylinder No.	1	2
1st Revolution	P	E
	E	S
2nd Revolution	S	C
	C	P

Cylinder No.	1	2
1st Revolution	P	S
	E	C
2nd Revolution	S	P
	C	E

In the **two-cylinder type of engine** with cylinders opposite and the crank shaft set 180° (Fig. 4), one piston slides inward as the other slides inward, so that one balances the other. This type of engine is called an "opposed" type of engine. Cylinders are set 180° apart, and so also is the crank shaft. When one piston starts down on the power stroke, the other starts down on suction. Therefore, as shown in the diagram under Fig. 4, there would be a firing impulse at each revolution of the crank shaft or every 360°. Thus it is mechanically balanced.

The flywheel of a two-cylinder engine need not be as heavy as that of an engine with one cylinder because it is required to carry the piston through only one dead stroke before another power stroke occurs. On 6, 8, and 12-cylinder engines, the fly wheel is very small in diameter.

The more cylinders an engine has, the more steadily it may run, for the explosions may be arranged to follow one another so closely that there is no moment when one of the pistons is not on the power stroke. This is termed **"lapping"** of power strokes.

Firing Order of a Three-Cylinder Engine

The action of the firing of a three-cylinder engine is as follows: Taking three points of the circle, **A** at the top, **B** and **C** on either side below, the piston of No. 2 cylinder is connected with a crank at **A**, of No. 3 cylinder at **B**, and of No. 1 cylinder at **C**.

The firing order of a three-cylinder engine can be either 1, 2, 3 or 1, 3, 2. In the following explanation the firing order is 1, 2, 3.

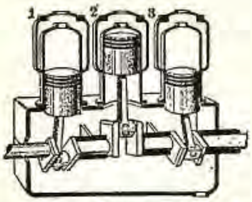


Fig. 5A

Fig. 5. A three-cylinder four stroke cycle engine crank set in three positions of a third of a revolution, or 120° apart.

No. 2 cylinder will be at full compression, **No. 3 cylinder** at two-thirds inlet, and **No. 1 cylinder** one-third, exhaust 240°.

The crank of No. 2 cylinder performs its half-revolution, bringing it to position **A'** (Fig. 5A); while it is doing this, No. 3 piston is completing its inlet stroke and two-thirds of its compression stroke, which brings its crank to position **B'**, leaving only one-third of a stroke to complete compression. When this is done, the crank will be at **A**, when the firing of No. 3 commences.

Meanwhile No. 1 piston is completing its exhaust stroke and has passed through two-thirds of its inlet stroke, so that when No. 3 piston has completed its impulse (180°), No. 1 is still 60° from its top d.c. to which point it must be carried by the momentum of the flywheel. This 60° represents the minus lap or the number of degrees of rotation between impulses when there is no explosion pressure in any of the cylinders.

Each of the three cylinders fires once every 720° (two revolutions), or 240° apart. No. 2 **(A)** fires and moves 240°, which brings No. 3 **(B)** in firing position. No. 1 **(B)** fires and moves 240°, which brings No. 1 **(C)** in firing position. No. 1 **(C)** fires and moves 240°, which again brings No. 3 **(A)** in firing position.

No. 3 **(A)** has now made two revolutions or 720° which completes the four-stroke cycle.

Each piston works 180° during one cycle of 720°. Three pistons will work 540°. 720°—540° = 180° the amount of minus lap for the three cylinders or 60° minus lap for each cylinder. (This varies according to the time the exhaust valve is set to open.)

Firing Order of a Four-Cylinder Engine

Four-cylinder engines are so arranged that there is a power or firing impulse every stroke, or two firing impulses every revolution, one beginning as the previous one ends.

In order to complete the four-cycle evolution of **suction, compression, explosion,** and exhaust for each piston, it is necessary that each piston have four strokes. As 1 and 4 work together and 2 and 3 work together, then during the four strokes (two up and two down), there are two revolutions of the crank shaft which will complete the cycle evolution for each piston, with a firing order of either 1, 2, 4, 3, or 1, 3, 4, 2.

The crankshaft of a four-cylinder four-cycle engine is always set at 180°.

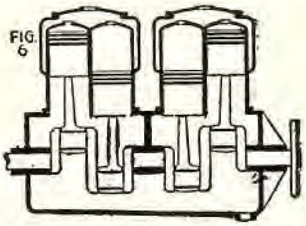


Fig. 6. Four-cylinder engine with crankshaft set at 180°. Power stroke every half revolution, or stroke of piston.

The construction of the crankshaft which is generally used on four-cylinder engines is shown in Fig. 6. This crankshaft would not permit the firing to be 1, 2, 3, 4, because, when No. 2 was ready to go down on the power stroke, No. 3 would have to be coming up on compression, but as No. 3 is always the same position as No. 2, then it could not be coming up, as it would already be up with No. 2. It follows, then, that the firing order must then be as given above: 1, 2, 4, 3, or 1, 3, 4, 2.

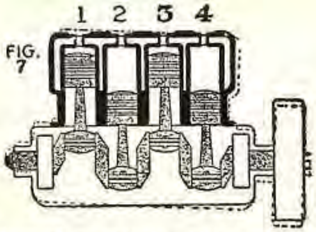


Fig. 7. Type of crankshaft which would permit a four-cylinder engine to fire 1, 2, 3, 4, but which is never used.

A four-cylinder engine which could be made to fire 1, 2, 3, 4, would have a crankshaft made as shown in Fig. 7, but it would vibrate excessively on account of the rocking motion of firing from one end to the other. Therefore the **firing order on all engines is arranged to decrease vibration** as much as possible. The alternate distribution of impulse (firing) tends to steady the engine, as in the sequence 1, 2, 4, 3, or 1, 3, 4, 2.

Cylinders are originally made to fire in proper order by the manufacturer, by setting the cams on the cam shaft and by wiring the distributor to connect with the proper spark plugs. **The order of firing** depends on the ideas of the maker, and may be either, 1, 2, 4, 3, or 1, 3, 4, 2, on a four-cylinder engine.

The eight "V"-type of cylinder engine uses a four-cylinder 180° crankshaft with two connecting rods to one crank pin.

The twin six or twelve "V"-type engine uses a regular six-cylinder crankshaft. This will be treated farther on, together with the firing order.

Relation of One Piston to the Other

On a four-cylinder engine, as already stated, the firing order must be 1, 2, 4, 3, or 1, 3, 4, 2.

The following explanation and charts will make clear just what action is taking place in cylinders when the engine is firing in the order 1, 2, 4, 3, or 1, 3, 4, 2.

If piston No. 1 is going down, say, on power, No. 2 must be coming up on either compression or exhaust. If coming up on compression it would fire next. No. 3 would then be coming up on exhaust and No. 4 going down on suction. In this case, the firing order would be 1, 2, 4, 3. (See chart No. 1, showing firing order 1, 2, 4, 3.)

If No. 1 was going down on power and No. 2 coming up on exhaust, then No. 3 would be coming up on compression and would fire next. In this case, the firing order would be 1, 3, 4, 2. (See chart No. 2, showing firing order 1, 3, 4, 2.)

Remember, the two down strokes are suction and power. The two up strokes are **compression and exhaust.** Each piston must be doing one of the four, during each of the four strokes or two revolutions.

The change of firing is accomplished by the movement of cams on the cam shaft, the cams on cylinders Nos. 2 and 3, being the only two affected. A study of charts No. 1 and No. 2, which represent a four-cylinder engine firing 1, 2, 4, 3, and 1, 3, 4, 2, will give the reader an idea as to what is taking place in each cylinder during the four strokes.

Relation of the Cam Movement to Crank Shaft

As we have seen, the only two firing orders that a four-cylinder engine can have is 1, 2, 4, 3, or 1, 3, 4, 2. To change from one to the other would necessitate chang-

When No. 1 Piston is	No. 2 Piston is	No 4 Piston is	No. 3 Piston is
STARTING DOWN ON FIRING OR POWER STROKE	Just starting up on COMPRESSION	Just starting down on SUCTION	Just starting up on EXHAUST
Just starting up on EXHAUST	TOP ON FIRING STROKE	Just starting up on COMPRESSION	Just starting down on SUCTION
Just starting down on SUCTION	Just starting up on EXHAUST	TOP ON FIRING STROKE	Just starting up on COMPRESSION
Just starting up on COMPRES.	Just starting down on SUCTION	Just starting up on EXHAUST	TOP ON FIRING STROKE

Chart No. 1. Firing order 1, 2, 4, 3.

When No. 1 Piston is	No. 3 Piston is	No. 4 Piston is	No. 2 Piston is
STARTING DOWN ON FIRING OR POWER STROKE	Just starting up on COMPRESSION	Just starting down on SUCTION	Just starting up on EXHAUST
Just starting up on EXHAUST	TOP ON FIRING STROKE	Just starting up on COMPRESSION	Just starting down on SUCTION
Just starting down on SUCTION	Just starting up on EXHAUST	TOP ON FIRING STROKE	Just starting up on COMPRESSION
Just starting up on COMPRES.	Just starting down on SUCTION	Just starting up on EXHAUST	TOP ON FIRING STROKE

Chart No. 2. Firing order 1, 3, 4, 2.

ing the cams operating the valves on cylinders 2 and 3, which of course would necessitate putting in different cam shafts.

Fig. 8 below gives a good illustration of the position of the cams in relation to the two firing orders.

The lower row of cams shows the position of the cams on the cam shaft when the engine is firing 1, 2, 4, 3 and No. 1 piston is ready to start down on the power or firing stroke.

The upper row of cams shows the position of the cams on the cam shaft, when the engine is firing 1, 3, 4, 2 and No. 1 piston is ready to start down on the power or firing stroke.

Every stroke of the piston, or 180° movement, represents a half-revolution of the crank shaft.

Every half-revolution of the crank shaft represents one-quarter revolution, or 90° movement of the cam shaft and of the cams. A careful study of Fig. 8 is recommended.

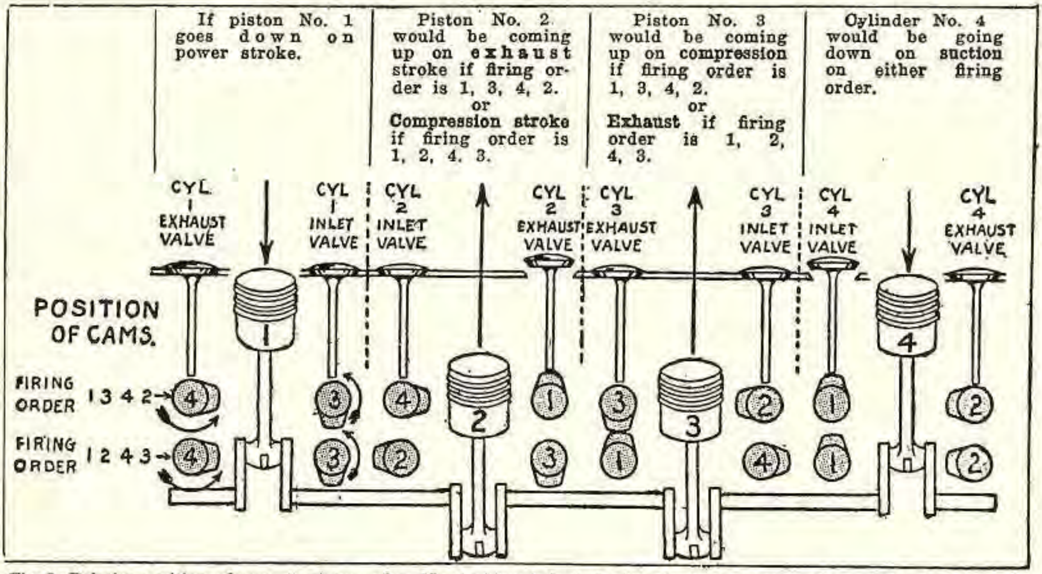


Fig. 8. Relative position of cams to pistons when No. 1 piston is just starting down on power stroke. Approximate position of cams is shown with a firing order 1, 3, 4, 2 (upper row), and 1, 2, 4, 3 (lower row of cams). The figures in the center of the cams correspond with those on the cams in Fig. 10, page 33. At each stroke of the piston, or one half-revolution of the crank shaft, the cams travel 90 degrees or a ¼ revolution.

HOW TO DETERMINE THE FIRING ORDER OF A FOUR-CYLINDER ENGINE

Fig. 9 shows how the cam shaft with its cams is driven by a **silent chain sprocket.** Also note the **mark on the fly wheel** which is in line with the punch mark on the crank case, when pistons 1 and 4 are on upper dead center. Pistons 2 and 3 are on lower dead center. The setting of the valves and of the gears is determined when the pistons are in this position.

the No. 4 exhaust valve tappet in the direction of its rotation), and the inlet will open immediately as the piston starts down.

To determine the firing order: If No. 2 will come up on compression as No. 1 piston goes down, and if the power stroke follows immediately after the compression stroke, then No. 2 will fire next. There-

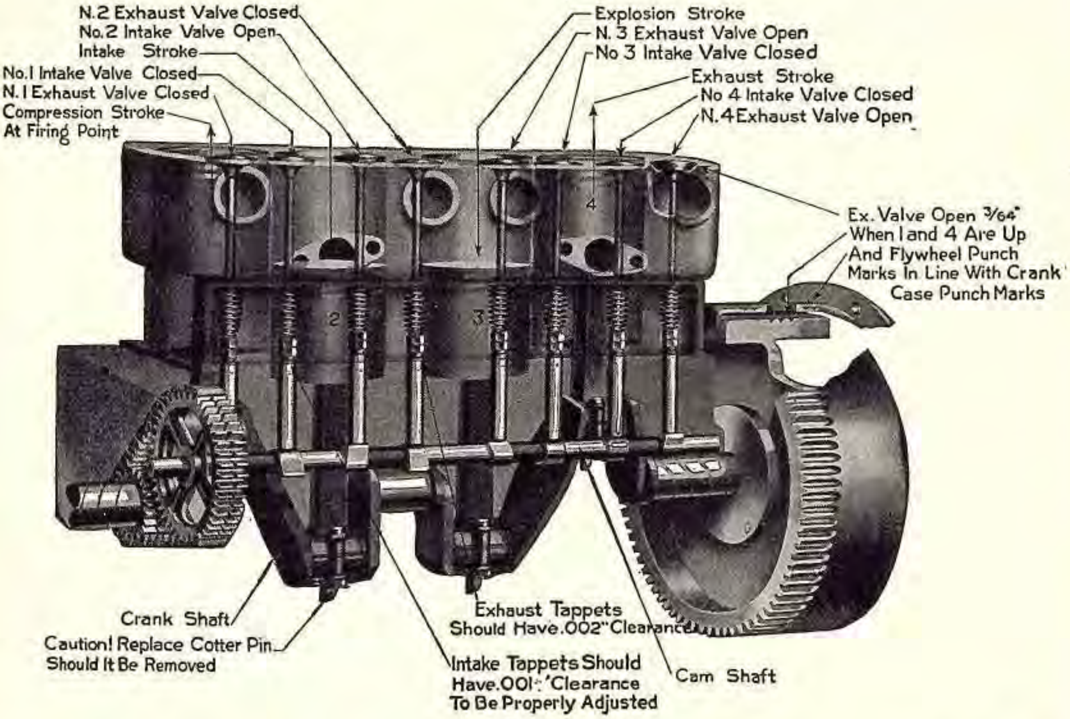


Fig. 9

For example: The exhaust valve on No. 1 cylinder closes at 10° past upper dead center. Therefore, as the piston of No. 1 cylinder is now on top dead center, the fly wheel must be revolved in the direction of rotation, 10° from upper dead center. At this point the exhaust valve of No. 1 cylinder should just close. This is sufficient, as all other valves will be timed to open and close at the correct time, since this is an "L"-head cylinder block with all valves on one side and all cams on one cam shaft. Note that the detachable cylinder head has been removed.

If the exhaust does not close at 10° past dead center, then it is either because the clearance of the exhaust valve tappet is set too close and holds the valve open too long, or the cam-shaft gear is not meshed properly.

The firing order of this engine can be determined by observing the position of the pistons and valves: The exhaust and inlet of No. 1 are closed; the piston of No. 1 cylinder is at the top of compression and will go down on power stroke. The piston of No. 2 cylinder is at the bottom of its intake stroke and will come up on compression; the inlet valve is still open and the exhaust closed. The piston of No. 3 cylinder is at the bottom of its stroke and will come up on the exhaust stroke; the exhaust valve is open and the intake valve is closed. The piston of No. 4 cylinder is at the top of its exhaust stroke and will go down on suction; the exhaust valve will close within a 10° movement of the crank shaft (note the exhaust cam just leaving

fore the firing order must be **1, 2, 4, 3.** The only other firing order it could possibly have would be 1, 3, 4, 2—but this would be impossible because No. 3's exhaust valve is open and it will come up on the exhaust, and after the exhaust comes suction. No. 3 has just fired, therefore No. 1 will fire next.

How to determine quickly the firing order of a four-cylinder engine[1]: When the nose of the first and third cam (inlet or exhaust) are on opposite sides of a shaft, the engine fires 1, 2, 4, 3. When the first and third cams are on the same side of the shaft, the firing order is 1, 3, 4, 2.

Note. The cam shaft is operated by a silent chain and sprocket which turns in the same direction as the crank shaft. The crank shaft turns twice while the cam shaft turns once.

The cams in Fig. 8, page 78, are made to open and close exactly on a full stroke of the piston, or 180° movement of the crank, which is unusual in actual practice.

On the engine in Fig. 9, the cams are set as in actual practice. For instance, the valves open and close as follows: Exhaust closes 10° after top. Inlet opens 6° after top. Exhaust opens 50° before the piston is at bottom dead center. Inlet closes 40° after bottom dead center. The bore of cylinders is 3¾" diameter and the stroke of piston is 4¼".

The make of the engine shown in Fig. 9 is the Golden Belknap and Swartz Co.'s model "E-M 31," four-cylinder side-valve detachable head engine. Horse power is 22½ at 935 feet of piston speed per minute; produces 36.9 h. p. at 2,800 r. p. m. on actual brake test and 31.9 h. p. at 2,000 r. p. m.

[1]This applies to engines where the first valve is an exhaust valve, which is usually the case, as exhaust valves are placed next to the water jacket. On some early models of engines, the first valve was an inlet valve.

INSTRUCTION No. 11

SIX, EIGHT, AND TWELVE-CYLINDER ENGINES: Firing Order; Rotary-Valve and Rotary-Cylinder Engines; Sleeve Valve Engine; Overhead Cam-Shaft Engine

THE SIX-CYLINDER ENGINE

In the six-cylinder engine, **the variance in construction** from the four-cylinder engine is principally in the addition of more cylinders and the shape of the crank shaft.

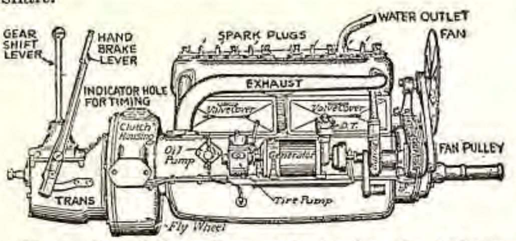


Fig. 1. Six-cylinder unit power plant, valve side. Cylinders of the "L" type. Thus the valves are all on one side.

Fig. 2. Left side or carburetion side. The inlet pipe passes between the cylinders to the valve side.

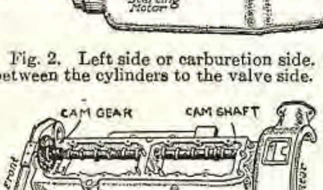


Fig. 3

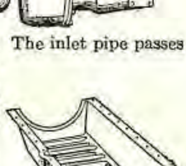


Fig. 4

Fig. 3. Upper part of crank case supporting cam shaft and bearings.

Fig. 4. Lower part of crank case or oil pan.

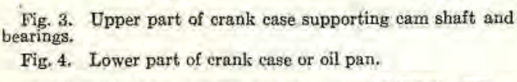


Fig. 5. Six-cylinder cam shaft. All cams on one shaft.

The cylinders may be in "pairs," in "triplets," or "in-block." The six-cylinder engine shown in Figs. 1 to 5 is the **Haynes**, and is a typical example of a "unit power plant." The cylinders are "in-block" with all valves on one side. This is, therefore, an "L"-head type cylinder block. The crank shaft shown in Fig. 8 is a three-bearing crank shaft and the cam shaft (Fig. 5) has three bearings.

The Pierce-Arrow six-cylinder engine (Fig. 97, page 54) is a "T"-head type with cylinders "in-block." The inlet valves are on the right side and the exhaust valves on the left side. There are two exhaust and two inlet valves for each cylinder on the Pierce-Arrow, and this is, therefore, a "dual" valve engine.

The Locomobile six-cylinder engine is also a "T"-head type, but with cylinders in pairs. The inlet valves are on the left side and the exhaust valves on the right side.

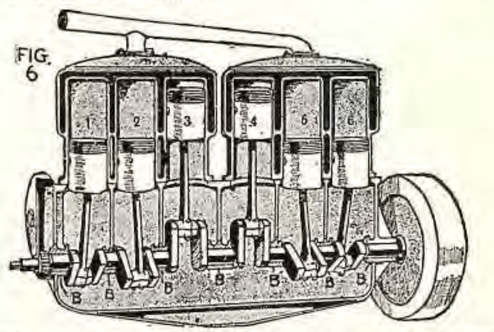
The Haynes, Locomobile, and almost all other six-cylinder engines have but one inlet and one exhaust valve for each cylinder.

Note. The right side of an engine or automobile is the side seen when seated in the car. That is why we designate the cylinders "right" and "left." The reverse is the case, of course, when facing the front of engine.

The six-cylinder engine operates on the four-cycle principle, the same as the four-cylinder; in fact, the general principle is that the crank shaft must turn two revolutions during the cycle or four strokes. The cam shaft turns one revolution.

Each piston completes the four strokes during two revolutions of the crank shaft. The crank shaft is divided into three pairs of "throws." A "throw" on a crank shaft is the part to which the big end of the connecting rod connects and is really the "crank pin." Each pair of these crank shaft "throws" (1 and 6, 3 and 4, and 2 and 5) are placed 120° or one-third the distance of a circle apart.

FIG. 6



There are **two kinds of six-cylinder crank shafts:** left hand and right hand (see Figs. 7 and 8). The cylinders usually fire on a right-hand crank 1, 5, 3, 6, 2, 4, while on a left-hand, the order is usually 1, 4, 2, 6, 3, 5. There are four firing orders which will be explained farther on.

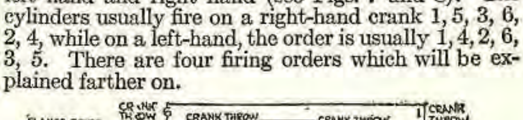


Fig. 7. **A right-hand six-cylinder crank shaft is determined** by noting (from the front end of the shaft) the position of the center throws, 3 and 4 to 1 and 6. If they are to the right of 1 and 6, as shown in Fig. 7, then it would be a right-hand crank (view from front). Being a right-hand crank, therefore, it will fire 1, 5, 3, 6, 2, 4, or 1, 2, 4, 6, 5, 3.

FIG. 8

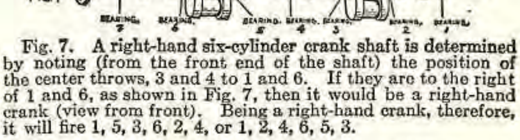


Fig. 8. A left-hand six-cylinder crank shaft. Note that 3 and 4 throws are to the left of 1 and 6, when looking at the crank shaft from the front end. Therefore it would fire 1, 4, 2, 6, 3, 5, or 1, 3, 5, 6, 4, 2.

The number of bearings for the six-cylinder crank shaft may be three, five, or seven. Three or five bearings is the usual number. Fig. 7 shows a seven-bearing six-cylinder crank shaft which is unusual and Fig. 8, a three-bearing crank which is in general use.

Carburetion: A six-cylinder engine usually requires special intake pipes and a double or multiple jet type of carburetor to meet the demand of the multiple of cylinders and the distance which the carburetted gas must travel.

The timing of six-cylinder valves is identical with that of the four. The process is gone through with in just the same manner. It is only necessary to time with the exhaust valve closing on the first cylinder on the "L" type, and with the exhaust valve closing on exhaust side and the inlet opening on inlet side on the "T"-head type.

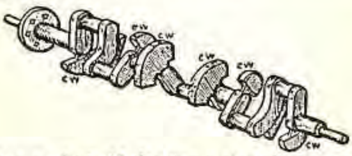


Fig. 8A. One method of balancing a six-cylinder crank shaft.

Counter-balance weights are sometimes applied to a six-cylinder crank shaft to relieve the "whip" or vibration at high speeds. Fig. 8A above shows the counter-balance weights (CW) electrically welded to the crank-shaft arms.

There are six power impulses or explosions during two revolutions of the crank shaft.

Another type of six-cylinder engine is the engine used on the Rumpler, a German make of car. This engine uses three pairs of cylinders placed 60° apart. One pair of cylinders is set vertically over the crank shaft, and there is a pair of cylinders placed at an angle of 60° on each side.

Firing Order of a Six-Cylinder "Right"-Hand Crank

The throws of a six-cylinder crank shaft are divided into three positions, or 120° apart.

1 and 6 are always in line
3 and 4 are always in line
2 and 5 are always in line
They may be placed to the right or the left, as shown in Figs. 9 and 10.

In Fig. 9, the first firing order is 1, 5, 3, 6, 2, 4 (it could also be 1, 2, 4, 6, 5, 3).

Fig. 9, right-hand crank shaft, shows pistons 1 and 6 up. If No. 1 starts down on "firing," No. 5 would be coming up on compression, as it would fire next. No. 3 would be 120° behind No. 5 and would fire next. No. 6 being 120° behind No. 3, it would fire next, then No. 2, then No. 4.

For the second firing order (1, 2, 4, 6, 5, 3) start with No. 1, then 2, 4, 6, 5, and 3 (Fig. 9).

Note. The view is from the front of the engine. Although the pistons are shown out of line, this is necessary in order for the reader to understand the relative positions, one to the other. When in cylinders, they are all in line and the connecting rods are out of line.

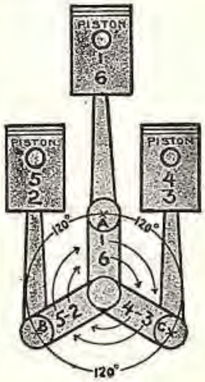


Fig. 9

Fig. 10

Firing Order of a Six-Cylinder "Left"-Hand Crank

In Fig. 10 first firing order is 1, 4, 2, 6, 3, 5 (it could be 1, 3, 5, 6, 4, 2). If No. 1 starts down on firing, No. 4 would fire next, then No. 2, then 6, 3, and 5 in their respective order.

For the second firing order (1, 3, 5, 6, 4, 2), start with No. 1, then No. 3, 5, 6, 4 and 2 (Fig. 10).

Relation of One Piston to the Others for Two Firing Orders of a Six-Cylinder Engine

The chart below shows what action is taking place in the cylinders, when the engine is firing 1, 4, 2, 6, 3, 5 (top row and Fig. 10), and when firing 1, 5, 3, 6, 2, 4 (second row of figures and Fig. 9).

When No. 1 Piston is	No. 4 Piston is	No. 2 Piston is	No. 6 Piston is	No. 3 Piston is	No. 5 Piston is
When No. 1 Piston is	No. 5 Piston is	No. 3 Piston is	No. 6 Piston is	No. 2 Piston is	No. 4 Piston is
TOP ON FIRING	1/3 of a revolution from top of up compression stroke	1/3 of a revolution from top on down intake stroke	Top on Exhaust	1/3 of a revolution from top on up exhaust stroke	1/3 of a revolution from top on down firing stroke
1/3 of a revolution from top on down firing stroke	**TOP ON FIRING**	1/3 of a revolution from top on up compression stroke	1/3 of a revolution from top on down intake stroke	Top on Exhaust	1/3 of a revolution from top on up exhaust
1/3 of a revolution from top on up exhaust stroke	1/3 of a revolution from top on down firing stroke	**TOP FIRING**	1/3 of a revolution from top on up compression stroke	1/3 of a revolution from top on down intake stroke	Top on Exhaust
Top on Exhaust	1/3 of a revolution from top on up exhaust stroke	1/3 of a revolution from top on down firing stroke	**TOP FIRING**	1/3 of a revolution from top on up compression stroke	1/3 of a revolution from top on down intake stroke
1/3 of a revolution from top on down intake stroke	Top on Exhaust	1/3 of a revolution from top on up exhaust stroke	1/3 of a revolution from top on down firing stroke	**TOP FIRING**	1/3 of a revolution from top on up compression stroke
1/3 of a revolution from top on up compression stroke	1/3 of a revolution from top on down intake stroke	Top on Exhaust	1/3 of a revolution from top on up exhaust stroke	1/3 of a revolution from top on down firing stroke	**TOP FIRING**

THE EIGHT-CYLINDER "V"-TYPE ENGINE

The advantage of a multiple-cylinder engine is principally in the flexibility of control, by which is meant quick acceleration or quick pick up of the engine from slow to fast speed, the absence of gear shifting, and a more perfect control. The more cylinders firing or "lapping," the more flexible the control, or in other words, the power impulses are more frequent. In fact, the more cylinders, the more the lapping of one firing impulse with another, or the more cylinders are on power stroke at the same time. Thus we obtain a more even torque, or steady stream of power impulses.

There are two types of eight-cylinder engines: (1) the "straight-eight"; (2) the "V-type eight."

The straight-eight cylinders are vertical and all in a straight line. The Duesenberg and Packard straight-eight engines are examples of this type (see page 45 for crankshaft arrangement). This type of engine will no doubt be used extensively in the future. Heretofore the disadvantage has been in a long crankshaft and extra bearings.

The V-type engine has cylinders arranged in two sets of four opposite to each other, at an angle of 90° on the Cadillac and 60° on the Lincoln and Wills St. Claire.

Crank shaft: Arranged in this way ("V"-type), the eight-cylinder engine is no longer than a four-cylinder one of equal bore. As compared with a six, it has about 30 per cent less length, resulting in a shorter crank case—a weight-reduction factor. In addition, its crank shaft is of the same form as that of a four, the throws being all in one plane; whereas those of a six crank shaft are in three planes, which is a more difficult manufacturing job. Furthermore, the shorter shaft is less given to periodic vibration. The cam shaft is also shorter and less prone to whipping.

Let us next consider the **cylinder and connecting-rod arrangement of the eight "V"-type cylinder engine.** Where the cylinders are "opposite," this means the lower end of the connecting rod is "yoked." The cylinders are in line with the opposite cylinders when looking from the side of the engine.

Where the cylinders are "staggered," this means that the lower ends of the connecting rods are not together but are "side by side" on the same crank-shaft bearing. This necessitates the cylinders on one side being placed a little to the side, or not exactly in line with the opposite cylinder when looking from the side of engine. This arrangement is termed "staggered."

The cam shafts on the eight "V"-engine may be one or two. The majority use one. The Cadillac uses a cam shaft with eight cams operating the sixteen valves, whereas some of the other eight "V"-type engines use one cam shaft with sixteen cams (one for each valve).

Example of an Eight-Cylinder "V"-Type Engine

As an example of an eight-cylinder engine and its construction, the (type 51–55) Cadillac make is shown in the following illustrations.

Although a later model Cadillac is somewhat different in minor construction details, the illustrations of the model given will furnish a good general idea as to how a modern eight-cylinder engine is constructed.

On the later model Cadillac, the engine is of the same bore and stroke as formerly: 3⅛" bore by 5⅛" stroke; piston displacement 314 cubic inches. Cylinder heads are now detachable. It is no longer necessary to remove the radiator to take out the water strainer between the radiator and water pump. Other changes also have been made.

The front end of the Cadillac eight-cylinder engine is shown in Fig. 11. There are two groups of cylinders, each of a block casting of four cylinders, mounted at 90° to each other on an aluminum crank case. The **cylinders** are 3⅛" bore and 5⅛" stroke. **The piston**

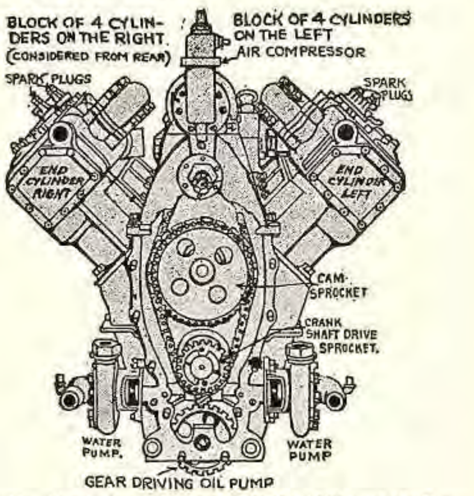


Fig. 11. Front view of an eight-cylinder "V"-type engine.

displacement is 314 cubic inches; the horse-power rating is 31.25. In dynamometer tests the engine shows 70 h. p. at 2400 r. p. m.

The crank shaft is identical in design with that used in a four-cylinder engine, and the cam shaft carries the same number of cams as in a four-cylinder design. This engine weighs approximately 60 pounds less than the former four-cylinder Cadillac engine of equal horse-power. There is but one carburetor used.

Each of the two cylinder castings contains four L-shaped cylinders with detachable heads.

The exhaust valves are of the conventional poppet shape. The inlet valve on the early models (as shown in Fig. 11), was of the "tulip" shape. This is not now used. Over each cylinder is a removable cap which gives access to the water jacket and to the combustion chamber. Between the second and third cylinder in each block the breather pipe is brought up through the cylinder casting (now on the valve cover plates). In rear of the fan is the power tire pump for tire inflation (now bolted to right-hand side of the transmission case).

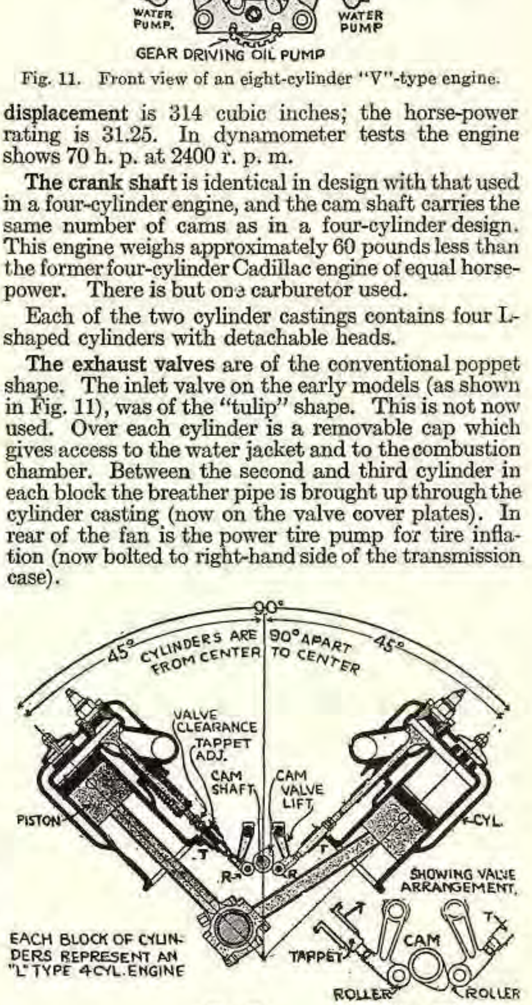


Fig. 12 Fig. 12A

Fig. 12. Valve-operating mechanism of the eight cylinder "V"-type engine (Fig. 11).

A cross-section view of the engine with the cylinder mounted in two groups of four cylinders each at an angle of 45° from vertical center, or 90° from cylinder centers is shown in Fig. 12.

The single cam shaft is located directly above the crank shaft, and the means whereby one cam operates the two intake valves for the opposite cylinders is shown.

The valve operating mechanism is shown in Figs. 12 and 12A. Note how one cam operates two opposite valves. The cam bears against the rollers (R) at the ends of the small arms which are pivoted to the plate above, and which are interposed between the ends of the push rods and the cams, so that the lift will be straight upward instead of having a side thrust.

Adjustment of valve clearance is obtained in the usual way by lengthening the tappet (T). The upper part of the tappet screws into the lower and the two are locked by a nut. The position of the cylinders makes the valves easily accessible.

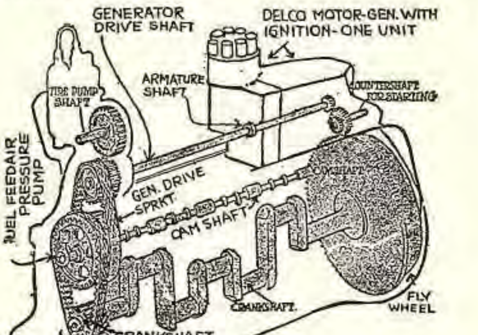


Fig. 13. Note the silent chain of the engine front-end drive from crank shaft to cam shaft and generator shaft. In the later models of the Cadillac the distributor is not mounted on the generator housing, as shown, but is mounted behind the fan housing.

Note the single cam shaft shown in Fig. 13. There are eight cams which operate the sixteen valves (eight inlet and eight exhaust valves). Each cam operates two valves through the rollers shown on opposite sides (Fig. 12A). The shaft is carried on five bearings.

On another make of "V"-type engine, there are two cam shafts. This permits the direct opening of valves without the rocker arms between cams and tappets, and also permits any desired timing.

The front-end drive system is shown in Fig. 13. Note the two silent chains, one driving the cam shaft; the other is driven from the cam shaft which drives the Delco electric system. There are **two water pumps** on the cross-shaft below the crank shaft, and this shaft in turn drives the gear-type oil pump. The tire pump was formerly driven by a spur gear, as shown, but is now driven from the side of the transmission and is driven by a sliding gear.

Crank shaft: A three-bearing crank shaft is used, with the throws at 180°, as in a four-cylinder design.

Connecting rods are "yoked." Two connecting rods attach to each crank pin, this being made possible by having one connecting rod with a split or forked lower end, and the other with a single end to fit between the forks; this is called the "yoked" design.

Note how the two connecting rods are attached to one bearing in Fig. 14. The outer connecting rod fastens to the outer ends of the split bushing with a two-bolt cap for each arm of the yoke. The bushing is fixed to this rod by pins.

The other, or inner connecting rod goes between the two arms of the yoke, as shown by the dotted outline.

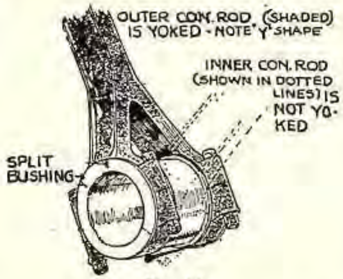


Fig. 14

This inner rod is free to move on the bushing. Therefore, the bearing for the yoke-end rod is the inner surface of the bushing against the shaft, while that of the inner rod is the outer surface of the bushing.

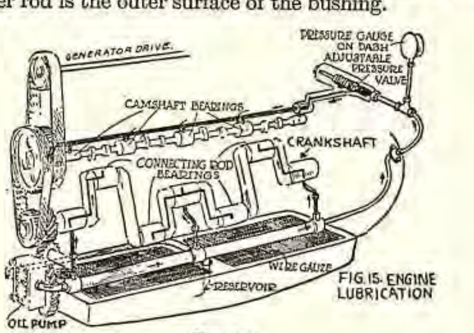


Fig. 15

Lubrication: The oil pump draws the oil up from the reservoir and forces it through the pipe running along the inside of the crank case (Fig. 15). Leads run from this pipe to the crank-shaft main bearing and thence through drilled holes in the shaft and webs to the rod bearings. It also is forced from the reservoir pipe up to the pressure valve, which maintains a uniform pressure above certain speeds, and then overflows from this valve to a pipe extending parallel with and above the cam shaft. Leads from this latter pipe carry the oil by gravity to the cam-shaft bearings and chains. Pistons, cylinders, etc., are lubricated by the overflow thrown from the rods.

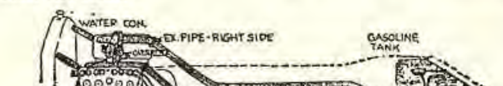


Fig. 16. Diagram showing the general arrangement of the fuel, water, and exhaust systems of the Cadillac chassis. There are two exhausts and two mufflers, one for each set of cylinders; while the gasoline is fed by pressure to the carburetor, which is between the two cylinder blocks. The air-pressure pump for forcing the fuel is at the front of the engine. There are two water pumps and two sets of water connections to the radiator. Carburetion and thermostat cooling are explained in the section on "Carburetion and Cooling."

Firing Order on an Eight-Cylinder "V"-Type Engine

The firing order of an eight-cylinder "V"-type engine is shown in Fig. 17.

On a "V"-type engine (Fig. 17) the right and left block of cylinders is the right and left sides observed when seated in the car. Therefore cylinder 1L would mean No. 1 cylinder of the left block, beginning with the front of the engine; No. 4 cylinder would be the rear cylinder.

The figures 1 to 8 at the side of each block represent the order in which the cylinders fire and do not refer

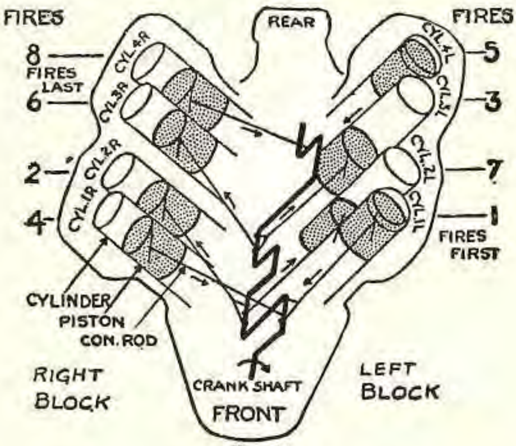


Fig. 17

to cylinder numbers. Therefore note that No. 1L fires first, then 2R, 3L, 1R, 4L, 3R, 2L, 4R.

Relative position of pistons: By observing piston No. 1 (Fig. 17), which is now ready to start down on its power stroke, or just commencing its working stroke, just what is taking place in all other cylinders can be seen by referring to the following:

1L: Just starting down on power stroke.
2R: Going up on compression; it will fire next.
3L: Just starting up on compression; it will fire after No. 2 cylinder 2 R.
1R: Going down on suction.
4L: Just starting down on suction.
3R: Going up on exhaust.
2L: Just starting up on exhaust.
4R: Going down on power.

It will be observed that No. 1 L and 4R will both be on power stroke; No. 2R and 3L on compression; No. 1R and 4L on suction; No. 3R and 2L on exhaust, for a certain period of time, which is termed "lapping" of strokes.

THE TWELVE-CYLINDER "V"-TYPE OR "TWIN SIX" ENGINE

The twelve-cylinder engine is referred to in this instruction as either a "twelve-cylinder" or a "twin six." Manufacturers use both terms. Literally, a twelve-cylinder engine would mean a type of engine having twelve cylinders placed in line on a crank shaft having twelve throws.

The "twin six" or twelve-cylinder "V" engine term, to be exact, consists of two sets of six cylinders placed at an angle of 60° over a regular six-cylinder crank shaft with six "throws" of the crank.

Note. The Liberty engine cylinders are at an angle of 45°.

Therefore, if the reader thoroughly understands the six-cylinder engine, it will not be a difficult matter to understand the twelve-cylinder "V"-type.

Before proceeding with the explanation of the "twin six," refer to the illustrations (Figs. 18, 19, and 20), and note the different angles in which cylinders are placed. Note, too, the evolution of raising the cylinders from 180° to 60°.

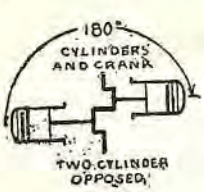


Fig. 18

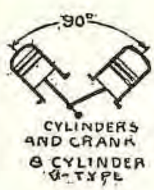


Fig. 19

Fig. 20

Fig. 18 represents the two-cylinder opposed type of engine with cylinders 180° apart. Firing impulse every 360° of crank-shaft movement.

Fig. 19 represents the eight-cylinder engine with cylinders placed 90° apart. Firing impulse every 90° of crank movement.

Fig. 20 represents the twelve-cylinder engine with cylinders placed 60° apart. Firing impulse every 60° of crank movement.

Construction: As previously stated, by placing six more cylinders on a six-cylinder crank case and placing them "V"-type, at an angle of 60°, the same crank shaft and practically the same crank case can be utilized without materially increasing the size or weight of the engine, the addition being merely another set of cylinders and connecting rods.

The "twin six" engine offers more evenly divided impulses than the eight. Two cylinders are working together at all times, and part of the time three are working together.

On the eight-cylinder "V"-type, cylinders are set at an angle of 90°, or one-half the distance of firing of the four cylinders. In other words a four-cylinder fires every 180°, and by setting cylinders at 90° we get an impulse every 90°.

A six-cylinder engine fires every 120°. Therefore on a twelve-cylinder "V"-engine, we would place cylinders at an angle of one-half of 120°, which would be 60° instead of 90°, and thus get a firing impulse at every 60° movement of the crank shaft.

Firing order: The crank shaft of a "twin six" is a regular six-cylinder crank shaft. The crank may be a right-hand crank or a left-hand, as explained. The firing order of a "twin six" would then be the same as a "six," that is, if we consider each block of cylinders on a twin six as a separate six-cylinder engine.

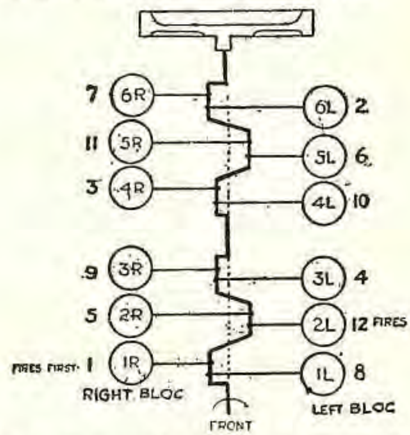


Fig. 21. If we consider each side as a separate six-cylinder engine, the firing order would be 1, 4, 2, 6, 3, 5 on each side. Note the crank shaft; the throws 1 and 6, 2 and 5, 3 and 4 are in line. This would be a left-hand crank shaft.

Taking each side separately as if a separate six-cylinder engine with the firing order 1, 4, 2, 6, 3, 5, note that the right block (Fig. 21), starting from front, would fire, 1R, 4R, 2R, 6R, 3R, 5R. Now start at the rear of the left block, 6L, 3L, 5L, 1L, 4L, 2L. If the cylinders were numbered from the rear, on the left block, as 1L, 2L, 3L, etc., the firing order would be 1L, 4L, 2L, 6L, 3L, 5L, the same as the right block, but from rear to front.

Combining the two six-cylinder engines, the firing order of the "twin-six" engine would be as shown in Fig. 21.

The figures outside of the circles indicate the order in which the cylinders fire on the Packard twin six. 1R fires first, then 6L, then 4R, 3L, 2R, 5L, 6R, 1L, 3R 4L, 5R, 2L.

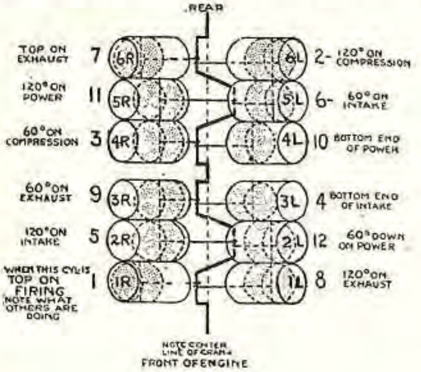


Fig. 22

The relative position of the pistons and what is taking place in each cylinder when cylinder 1R is just starting its power stroke is shown in Fig. 22.

The crank pins are 120° apart, whereas the firing impulses are 60° apart.

The order in which the cylinders fire is designated by the numbers outside of the cylinders, in heavy type.

Note the position of the pistons when No. 1R is just ready to go down on power.

Laps of power strokes: Remembering that the exhaust valves open 46° before bottom dead center, which is the same as saying that they open 134° after top dead center, let us see how the cylinders work together.

In Fig. 23, cylinder 1R has just fired, therefore it is delivering power. Cylinder 6L has completed 120° of its compression stroke. Cylinder 4R has completed only 60° of its compression stroke.

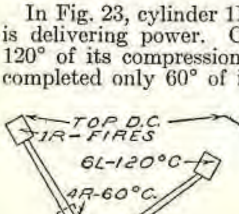


Fig. 23

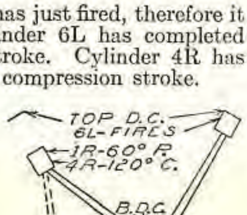


Fig. 24

Let us now examine the engine after the crank shaft has revolved 60° to the position shown in Fig. 24. Cylinder 1R has completed 60° of its power stroke and is still delivering power. Cylinder 6L has fully completed its compression stroke and now fires; thus both cylinders 1R and 6L are delivering power. Cylinder 4R has now completed 120° of its compression stroke.

Let us now examine the engine after the crank shaft has revolved another 60° to the position shown in Fig. 25. Cylinder 1R has completed 120° of its power stroke and is still delivering power. Cylinder 6L has completed 60° of its power stroke and is still delivering power. Cylinder 4R has now completed its compression stroke; it fires and therefore it is also delivering power. Therefore, at this point **all three cylinders are delivering power.**

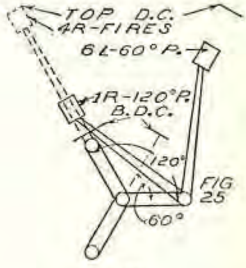


Fig. 25

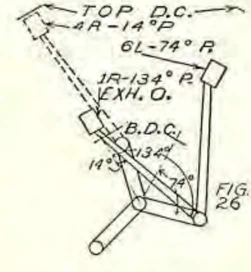


Fig. 26

Let us now examine the engine after the crank shaft has revolved another 14° to the position shown in Fig. 26. Cylinder 1R has now completed 134° of its power stroke and, at this time, the exhaust valve opens so that it has just stopped delivering power. Cylinder 6L has completed 74° of its power stroke and is still delivering power. Cylinder 4R has completed 14° of its power stroke and is still delivering power. Thus we see that during 14° of crank-shaft rotation (the time involved while going from the position shown in Fig. 25 to the position in Fig. 26), we had all three cylinders delivering power, but at the instant shown in Fig. 26, only two cylinders are delivering power.

These two cylinders will carry the load alone until the crank shaft has revolved another 46°, after which, cylinder 3L will start to fire, while cylinders 6L and 4R are still delivering power. Thus it is seen that the revolution of the crank shaft is made up of alternate intervals of 14° during which three cylinders are delivering power, and of intervals of 46° during which two cylinders are delivering power.

The cylinders on the Packard are staggered (see Fig. 21). Note that the left cylinders set ahead of the right. This is in order that the connecting rods may be placed "side by side" on the crank pin instead of being "yoked."

The cam shaft: One cam shaft with a separate cam for each valve is used.

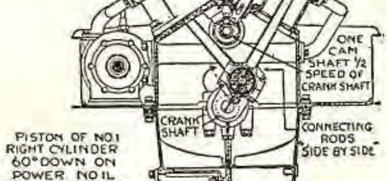


Fig. 27. End sectional view of Packard "twin six" engine. Cylinder 1R is 60° down on power while 6L is on dead center.

Name of Parts

1 Valve-cover stud-nut assembly.
2 Valve—exhaust.
3 Valve-stem guide.
4 Valve spring.
5 Valve-spring collar.
6 Valve-spring collar key.
7 Valve roller-holder screw.
8 Valve roller-holder screw check nut.
9 Valve roller-holder screw plate.
10 Piston pin.
11 Connecting rod.
12 Valve roller-holder guide yoke.
13 Valve roller-holder guide.
14 Valve roller-holder and roller assembly.
15 Crank case upper to lower stud nut.
16 Crank-case overflow valve stud nut.
17 Crank-case overflow valve spring.
18 Crank-shaft oil thrower.
19 Fan driving pulley key.
20 Cam-shaft spiral gear, front.
21 Cam-shaft sprocket.
22 Distributor driving shaft nut.
23 Distributor driving shaft gear.
24 Distributor driving shaft.
25 Cam-shaft driving chain.
26 Cam-shaft driving chain oil tube assembly.
27 Gasoline power-pressure pump eccentric lock.
28 Gasoline power-pressure pump eccentric.
29 Motor-generator sprocket eccentric.
30 Motor-generator sprocket coupling, female.
31 Cam-shaft driving chain oil tube flange nut.
32 Distributor driving shaft bushing, upper.
33 Cylinder water-jacket plate.
34 Cylinder water-jacket plate screw.

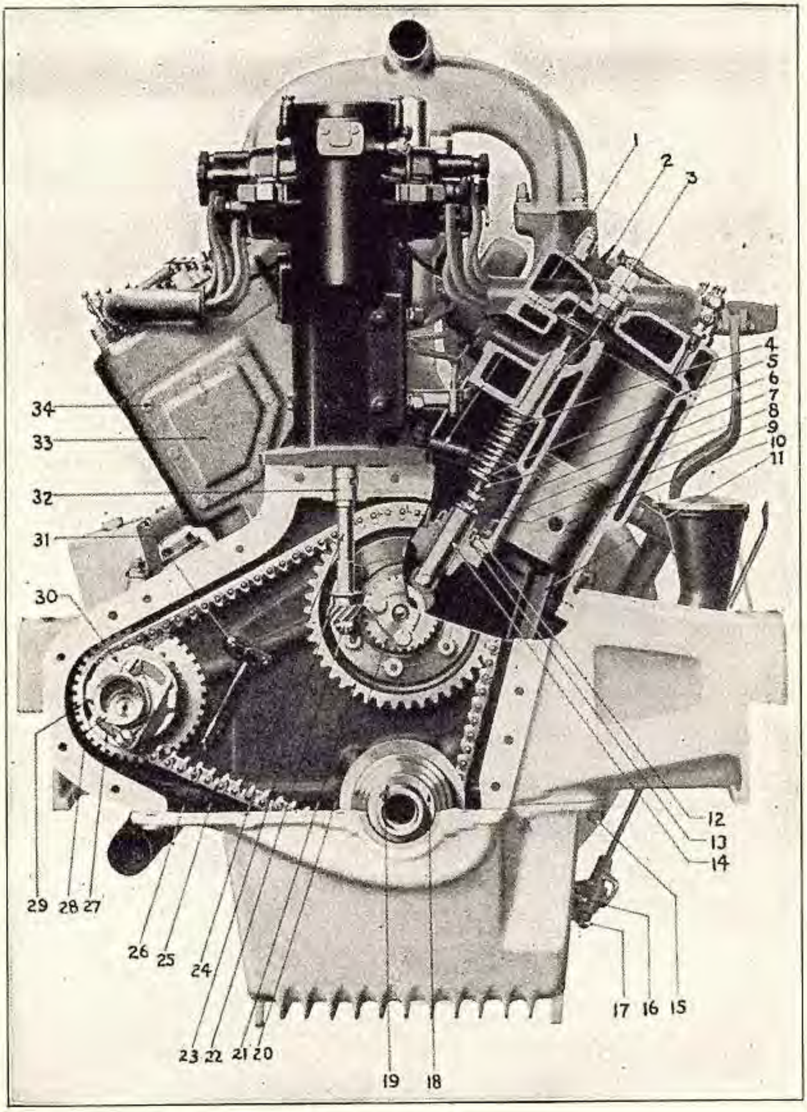


Fig. 28

Fig. 28. Front sectional view of Packard twin-six engine model "3-25" and "3-35." Four-cycle type with two blocks of "L"-head cylinders bolted to the crank case at an inclined angle of 60°. The cylinder bore is 3" and the stroke 5". The left block is set 1¼" ahead of the right block to permit the lower end connecting rod bearings from opposite cylinders being placed side by side on the same crank pin. This arrangement also permits the use of a single cam shaft with a separate cam for each valve operating directly on the valve push-rod roller.

Compression in all cylinders should be equal and up to the standard. Weakness or loss of compression is most probably due to imperfectly seated valves, which may be caused by insufficient clearance between the valve stems and lift rods, carbon deposits on the valve seats, or sticky valve stems and guides. Compression should be tested for uniformity in all cylinders at regular intervals.

To test the compression in a cylinder, remove the spark plug and replace it with a standard compression gauge. Then with the ignition switch off and pet cocks in all cylinders closed, crank the motor, using the electric starter. At cranking speed with the engine cold, the gauge should register 75 pounds plus or minus 3 pounds with the throttle wide open.

A change in the setting of the cam shaft is possible only by removal or disarrangement of the front end chain. Adjustments to the chain do not affect the valve timing.

In resetting the cam shaft, the arrows on both the crankshaft and cam-shaft gears should point directly upward and should be in line with the arrow on the front end cover face of the engine. In this position, the inscription on the fly wheel, "exhaust closes 1 and 6-R," will be on the top dead center line of the engine, which is the center between the two cylinder blocks, and No. 1 right piston will be in the firing position.

The main and connecting rod bearings are of the babbitt-faced bronze type. The bearings are set with a .0015" to .002" clearance and are consequently flooded with a film of oil between the shaft and the bearing surface, making adjustment for wear necessary only at long intervals.

To grind the valves disconnect the carburetor inlet manifold and spark plug connections and remove the cylinder heads.

Valve clearance: Inlet and exhaust valves should have .004" clearance between valve stem and roller-holder set screw when the engine is cold. Be sure that the valve is fully seated when measuring clearance.

The vibration damper on the front end of the crank shaft should be adjusted to slip under a pull of approximately 140 lbs.

COMPARISON OF THE LAPS OF FIRING OR POWER STROKES OF A 4, 6, 8, AND 12-CYLINDER ENGINE

The eight and twelve-cylinder engines are "V"-type. The diagrams shown below as an example are based on the exhaust valve opening 46° before bottom. The point of the exhaust valve opening varies. However, the comparison would be the same.

Four-Cylinder Lap of Power Strokes

On a four-cylinder engine a power impulse occurs every 180°, or half-revolution, or four impulses during two revolutions of the crank shaft. There are four periods of 46° travel, or 184° in all, during the four strokes, in which there is no power impulse.

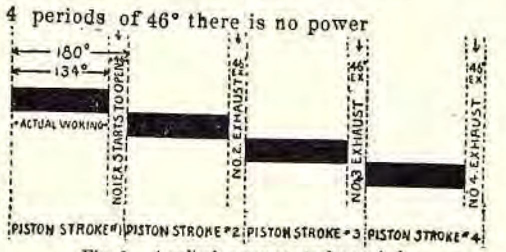


Fig. 1. 4-cylinder power-stroke periods.

Note in Fig. 1 that if piston No. 1 is firing, it does not travel its full stroke with a crank movement of 180° on power, because the exhaust valve starts to open, say 46°, before it reaches the bottom of its stroke, therefore it really travels but 134° on its power stroke. Consequently, before the next piston fires there is a gap of 46°.

Therefore, in a four-cylinder engine there are four periods of 134° when one cylinder is firing or working under a power impulse, and four periods of 46° when no cylinder is firing or working. The fly wheel must then take the pistons over center during the "no" working strokes.

Six-Cylinder Lap of Power Strokes

On the six-cylinder engine there is a power impulse every 120°, or one-third revolution of the crank shaft, or six power impulses during the two revolutions.

Each piston is working on all of its stroke of 180°, except 46°, leaving 134° actually working.

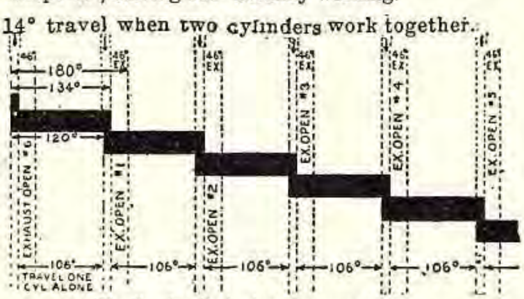


Fig. 2. 6-cylinder lap of power strokes.

The second cylinder to fire starts to work 120° after the first starts to work (Fig. 2), and works 14° before the exhaust opens or the impulse ends on the first cylinder. Consequently there is no idle space between the firing of the cylinders, but quite the reverse, for there is a "lapping" of power strokes.

Thus, there are, during the two revolutions of the crank shaft, six periods of 106° travel when one cylinder is working alone, and six periods of 14° travel when two cylinders are working together.

Therefore, 7/60ths of the time two cylinders are working together and 53/60ths of the time one cylinder is working alone.

The Eight "V"-Cylinder Lap of Power Strokes

The eight-cylinder "V"-type engine with cylinders 90° apart would act very much the same as a four-cylinder engine, if we consider each block separately.

There are eight power impulses or explosions during each cycle of two revolutions of the crank shaft. In other words, the four strokes of two revolutions are just the same as in a four, but there are eight power impulses or explosions during these two revolutions. There is a power impulse every quarter turn (90° movement) of the crank shaft, and thus there is no intermission between them, but rather an "overlapping" so complete that the turning effort is practically constant.

When one cylinder (Fig. 3) is firing, it would travel 134° on the power stroke, at which time the exhaust valve opens (46° before bottom, as an example).

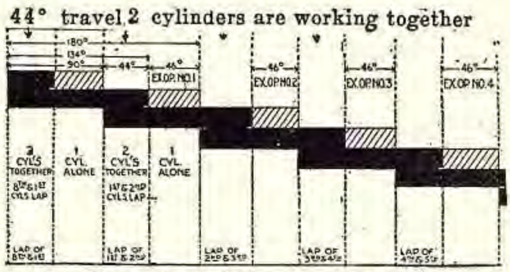


Fig. 3. 8-cylinder lap of power strokes.

The second cylinder starts to fire 90° after the first, and moves for 134° before its exhaust valve starts to open.

Therefore there are, during the four strokes, or two revolutions of the crank shaft, eight periods of 44° travel when two pistons are working together, and eight periods of 46° travel when one piston is working alone. Therefore 22-45ths of the time two cylinders are working together and 23-45ths of the time one cylinder is working alone.

Twelve-Cylinder Lap of Power Strokes

With the twelve-cylinder "V"-type engine with cylinders 60° apart, there are twelve power impulses during two revolutions of the crank shaft. There is a power impulse every 60° movement of the crank shaft.

When one cylinder is firing, it travels the same as those previously described, namely, 134° before the exhaust valve opens; it then continues for 46° more, till it reaches the end of its exhaust stroke.

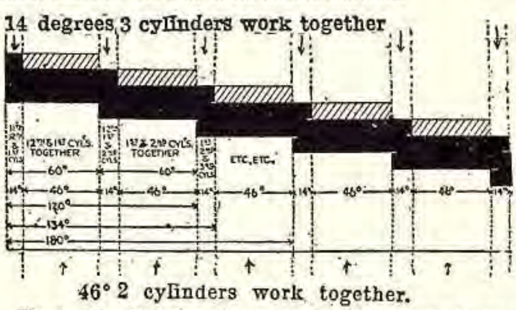


Fig. 4. 12-cylinder lap of power strokes (only part is shown).

When the first cylinder fires (Fig. 4), and the piston has traveled only 60°, the second cylinder fires and joins No. 1; they then work together for a period of another 60°, when the third cylinder fires and joins No. 1 and 2. Now No. 1 has still 14° to travel before its exhaust valve opens; consequentlv the three work together until that occurs.

At the 134° point No. 1 cuts out and Nos. 2 and 3 work together for a period of 46° when No. 4 fires and joins them, and so it continues throughout the cycle. Thus with every 60° movement of the crank shaft there is a period of 14°, during which three cylinders work together; or, in one complete revolution of the crank, or 360° movement, there will be six periods of 14° when three cylinders work together, and six periods of 46° alternating with these, when two cylinders work together. Therefore there are, during two revolutions of the crank shaft, twelve periods of 14° travel when three cylinders are working together and twelve periods of 46° travel when two cylinders are working together.

THE SLEEVE-VALVE ENGINE (STEARNS-KNIGHT AS AN EXAMPLE)

The sleeve-valve engine differs from any other four-cycle engine only in its method of admitting and exhausting the gas.[1]

The sleeve valves: Instead of raising and lowering the poppet valves, to admit and expel the gas, there are two sleeves with ports or slots in them. At certain times, these ports on the same side of the cylinder come in line, as shown in Figs. 1 and 1A and Figs. A to F. These sleeves take the place of valves.

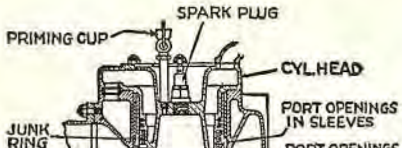


Fig. 1

The openings occur at the proper time, in a similar manner to the opening and closing of any other valves. That is to say, the exhaust opens once during the four strokes and the inlet opens once during the four strokes of the piston. The sleeves of course sliding up and down cause this opening and closing.

The sliding shells or sleeves of each cylinder have a relatively short stroke, about 1 inch, and are driven by two short connecting rods or side-arms working off a lay crank shaft, or eccentric shaft, the cranks having a very small throw.

Eccentric shaft: The sleeves are caused to slide up and down by an eccentric shaft (ES), which takes the place of a cam shaft, and which has eccentrics raising and lowering small connecting rods (OS and IS, Figs. 1 and A to F). This eccentric shaft is driven by a chain from a sprocket on the crank shaft of the engine. It is driven at the same speed as any other cam shaft, i.e., one-half the speed of the engine crank.

The eccentric pin operating the inner sleeve is given a certain lead or advance over that operating the outer sleeve. This lead, together with the rotation of the eccentric shaft at half the crank-shaft speed, produces the valve action illustrated in Figs. A to F, which shows the relative position of the piston, sleeves, and cylinder ports at various points in the rotation of crank shaft.

Valve timing: The timing shown in Figs. A to F is not different from that ordinarily used in poppet-valve engines, but the valve area is greater than that of an ordinary poppet valve. The equivalent of increased valve area is gained also by the directness of the valve opening and the absence of restrictions in gas passages.

Compression or junk ring: The sliding sleeves end right up in the deep cone-shaped combustion head, which is a detachable unit. This head is of a special design, inasmuch as it is provided with a set of piston rings, three narrow and one double, the latter being specially wide and termed the compression or junk ring. These rings prevent any escape of pressure in an upward direction.

Piston rings: The usual set of three rings on the working piston maintain pressure tightness in lower direction.

The main principle of this engine (made under Knight's patent) is the substitution of sliding valves for the usual poppet or tappet valves. The sliding valves consist of two concentric shells of cast iron accurately turned, working in between the driving piston and the cylinder walls. These shells have two series of large area ports or slots cut in the upper ends, which register together at the required instant in the respective strokes of the piston. One pair of slots forms the **inlets** and the other pair the **exhausts.**

Setting ignition: Set cylinder No. 1 piston on top of compression. Retard contact-breaker box on Bosch magneto. Set points on interrupter just breaking. There is a mark on the flywheel which, when lined up with the mark on the cylinder, will show when 1 and 6 or 1 and 4 are up. Firing order on the six is 1, 5, 3, 6, 2, 4 and 1, 3, 4, 2 on the four.

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[1] The sleeve valve engine shown and explained on this page has **double-sleeve valves.** Another sleeve valve engine (not shown) is the **single-sleeve valve** engine, known as the Argyll, or Burt-McCollum engine, the rights of which have been acquired by the Continental Motors Corpn., Detroit, Mich. A single-sleeve valve, cylindrical in form, fits in the cylinder bore between the piston and cylinder wall. This sleeve has a number of specially shaped ports at the top and a single universal driving connection at the bottom. The sleeve is actuated by a cross-shaft consisting of a disk with an eccentric pin on the end engaging in the universal joint at the bottom of the sleeve. There are four ports in the cylinder; two inlet and two exhaust, but there are only three ports in the sleeve. During the inlet stroke the middle port of the sleeve uncovers one of the two inlet ports and on the last stroke of the cycle it uncovers one of the two exhaust ports.

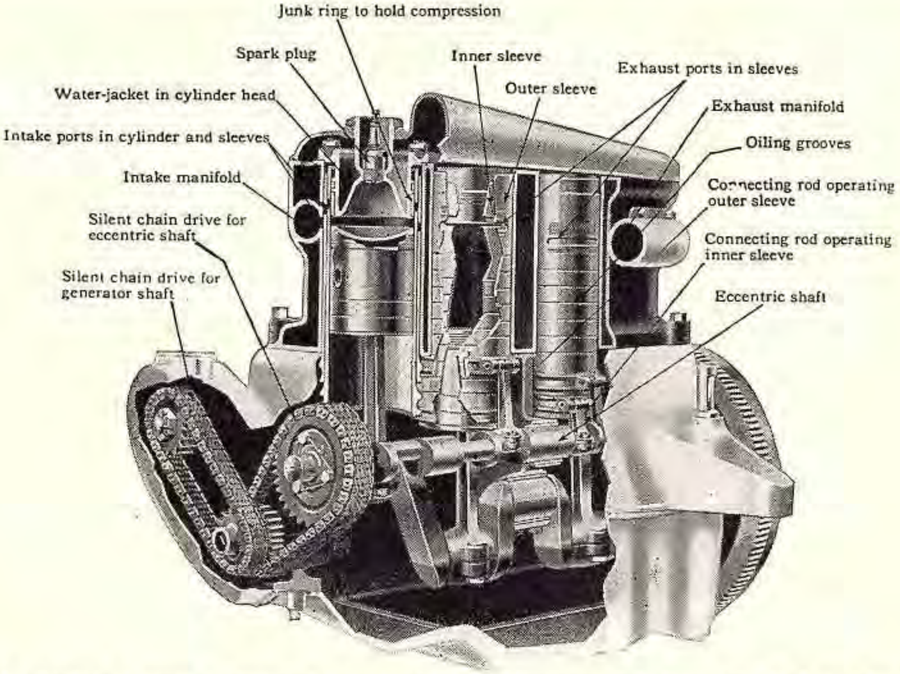


Fig. 1A. Side view showing a partly sectional view and front-end drive system of the Stearns-Knight sleeve-valve engine.

Explanation of Valve Opening and Closing, and Firing Order (Stearns-Knight Six-Cylinder Engine as an Example)

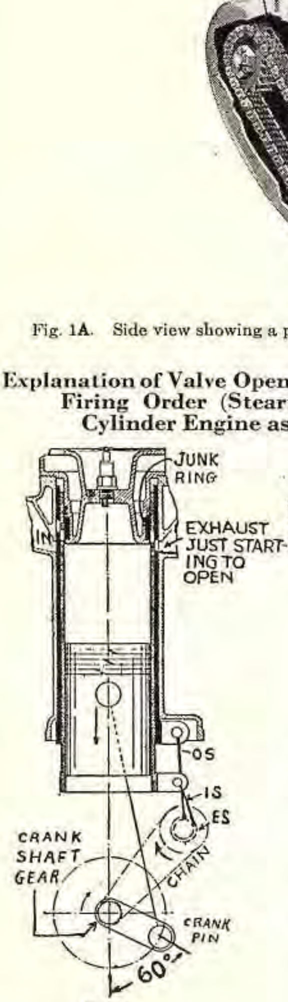


Fig. A

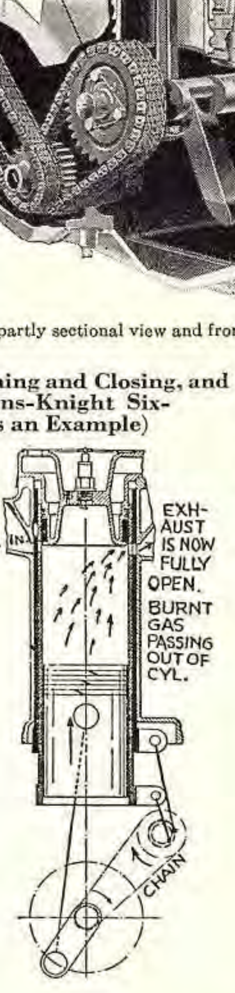


Fig. B

The eccentric shaft sprocket (ES, Fig. A) is twice the size of crank-shaft sprocket. It therefore revolves at one-half the speed of the crank shaft, the same as any cam shaft. **(OS)** means outer sleeve and **(IS)** inner sleeve eccentric rod.

The motion of the eccentric rods (OS) and (IS) is controlled by an eccentric on a shaft driven by sprockets.

Firing order, 1, 5, 3, 6, 2, 4. View is from front of engine.

The "ports" are the openings in the sleeves and cylinders.

In Fig. A, the **exhaust starts to open** at 60° before bottom. Toward the end of the power stroke, as in any four-cycle engine, the exhaust port is uncovered by a downward motion of both sleeves, the inner moving at a higher speed than the outer. Instead of a valve opening, the opening occurs in the sleeve.

In Fig. B, the **exhaust is fully open.** At the starting of the exhaust opening the outer sleeve port is approximately in register with the cylinder exhaust port, the full opening being obtained chiefly through the more rapid motion of the inner sleeve, its port "catching up" with the port in the outer sleeve.

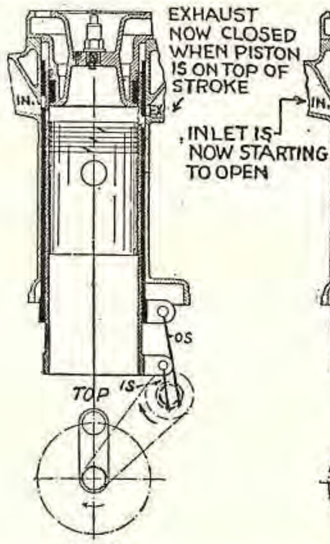


Fig. C

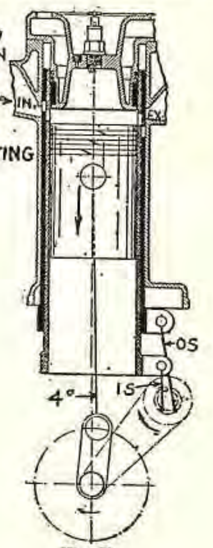


Fig. D

In Fig. C, the **exhaust closes** on top. The inner sleeve first reaches the bottom of its travel (note position of eccentric rod IS), and the outer sleeve, following it, closes the exhaust opening by over-running the cylinder port.

In Fig. D, the **inlet opens** 4° after top. At the closing of the exhaust, the sleeves are moving in opposite directions, the inner one up and the outer one down (see eccentrics **OS** and **IS**). The inlet ports in the sleeve then overlap, the opening being in line with the cylinder wall. The inlet ports in the sleeves are moving in opposite directions.

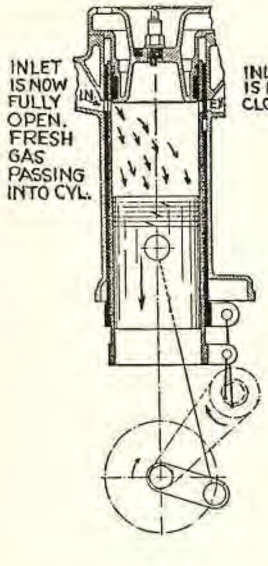


Fig. E

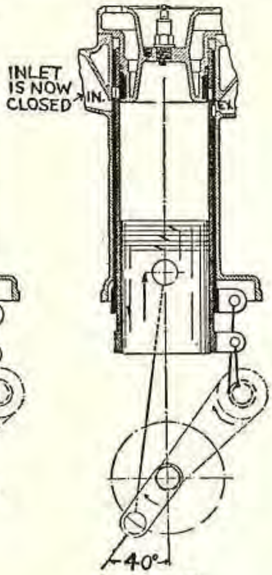


Fig. F

In Fig. E, the **inlet** is **full open.** The continued but slow downward movement of the outer sleeve, together with the increasingly rapid upward motion of the inner, causes the two sleeve ports to coincide with each other.

In Fig. F, the **inlet closes** 40° after bottom center. From the point of full inlet opening, both sleeves travel upward, the inner at a higher rate than the outer. This action is continued until cut-off is secured and the port closed by the lower edge of the inner sleeve port over-running the lower edge of the "junk" ring carried by the head casting of the cylinder.

As the inlet closes, the next stroke up would be the compression stroke, and when on top, the explosion would occur and the piston would go to the position shown in (A).

Valve timing of the Stearns-Knight early model four-cylinder engine is shown in Fig. G. Valve timing of the Stearns-Knight six cylinder (early model): the same except inlet opens 4 degrees instead of 8 degrees, and exhaust closes on top dead center instead of 4 degrees after.

This valve-timing diagram can more clearly be understood after reading under the subject of valve-timing, as on page 69, which gives an explanation of how a flywheel is usually marked. See "note" at bottom of page 63 for meaning of "top dead center," "bottom dead center," etc.

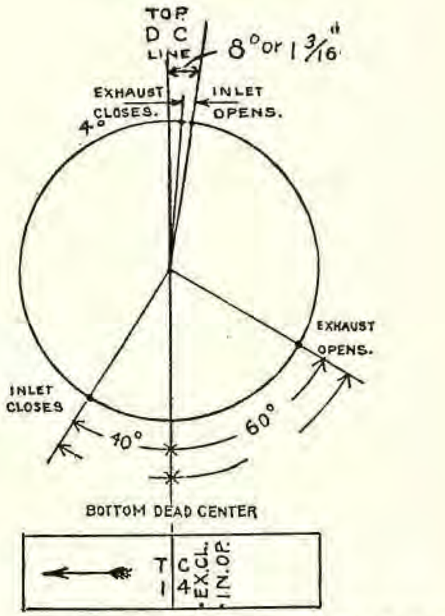
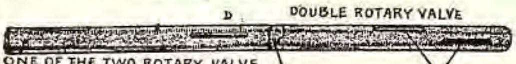


Fig. G. Knight 4-cylinder valve timing. The flywheel below is as if viewed from the rear. The diameter is 17".

THE ROTARY-VALVE ENGINE

This type of engine is the same as any other four-cycle principle of gasoline engine, except instead of the "poppet type" of valves the "rotary type" is used to admit gas to the cylinder and to permit burnt gases to pass out. The Speedwell was one make of car which used the double-rotary valve.



The rotary valve is nothing more than a long cylindrical piece of metal with holes in the shape of slots cut as at (S) and (D) above. Instead of valves popping up and down, this rod is placed alongside of the cylinder and is operated by a chain or gear from the crank shaft. As it turns, the openings in the rods (rotary valve) perform the same function as the poppet valves.

There are two types of rotary-valve engines, the double valve and the single valve.

The double rotary valve can be compared with the poppet-type valve engine using the "T"-head type of cylinder, which has the intake valves on one side and the exhaust on the other. On the double rotary valve we have an "intake rotary valve" on one side and the "exhaust rotary valve" on the other side (Figs. 1, 2, 3, and 4). On a four-cylinder engine, each valve would have four slots.

The single rotary valve can be compared with the poppet-valve type of engine using valves-in-the-head, operated by one overhead cam shaft. Instead of poppet valves and cam shaft, however, there is one long rotary valve, with openings as shown in Figs. 5, 6, 7, and 8. Note the position of these openings during the periods of intake, compression, firing, and exhaust.

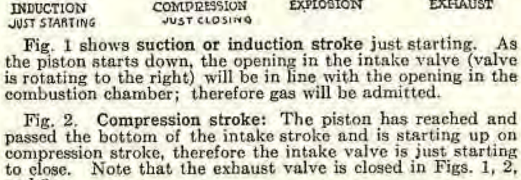


Fig. 1 shows **suction or induction stroke** just starting. As the piston starts down, the opening in the intake valve (valve is rotating to the right) will be in line with the opening in the combustion chamber; therefore gas will be admitted.

Fig. 2. **Compression stroke:** The piston has reached and passed the bottom of the intake stroke and is starting up on compression stroke, therefore the intake valve is just starting to close. Note that the exhaust valve is closed in Figs. 1, 2, and 3.

Fig. 3. **Power or explosion stroke:** Openings in both valves are closed; piston will move down.

Fig. 4. **Exhaust stroke:** The piston is now starting up on exhaust, therefore the opening in the exhaust valve is open to the cylinder, and burned gases will pass out. Intake valve is closed.

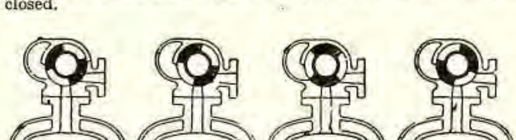


Fig. 5 Fig. 6 Fig. 7 Fig. 8

THE ROTARY-CYLINDER ENGINE

Fig. 9 shows the Gnome aviation seven-cylinder engine which is treated fully in other sections of this book.

In the ordinary motor-car engine the cylinders are bolted to a crank case and the crank shaft is made to turn around by the force of the explosions in the cylinders.

In the rotary-cylinder engine the crank shaft is held stationary and the cylinders are mounted on a cylindrical crank case which can revolve. Connecting rods are fastened to crank-shaft pins (Fig. 10).

The revolving cylinder or "rotary-cylinder" type is a French invention. This style of engine was used extensively during the war in small, high-speed, single-seated machines; another is the La Rhone.

Principle of operation: When an explosion occurs in one of the cylinders the energy can do nothing else but force the piston down. This action turns the rodholder on the crank shaft, which causes the rods, pistons, and hence the cylinder to revolve as a unit. The crank shaft (Fig. 11) remains stationary, and, due to this fact, the pistons will assume different positions in the cylinders owing to the location of the rods on the crank pin. For instance, in the movement of the cylinder **A** from **X** to **Y**, the piston in the cylinder will travel downward, as shown in the illustration, until it reaches bottom of its stroke. This type of engine is not adapted for automobile work.

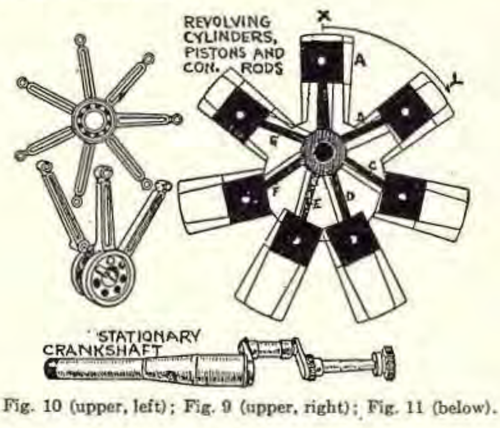
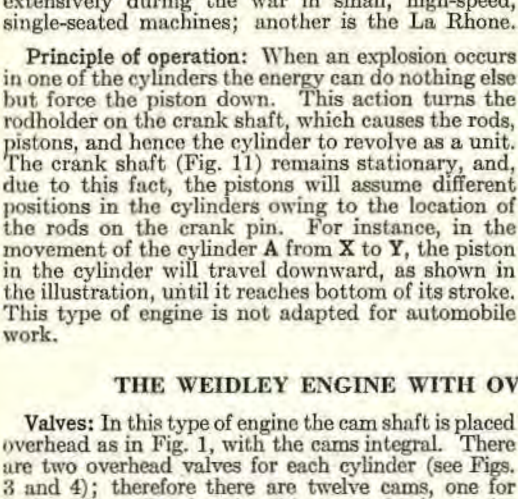


Fig. 10 (upper, left); Fig. 9 (upper, right); Fig. 11 (below).

Fuel system. Gasoline is fed to the crank case through the hollow crank shaft to a spray nozzle in the crank case. The gasoline in the tank is under 5 lbs. pressure per sq. in. by air pump. When the cylinders are within 20° of the end of the inlet half-revolution, a series of small inlet ports around the circumference of the cylinder wall is uncovered by the top edge of the piston whereby the combustion chamber is placed in communication with the crank chamber. The crank chamber is at atmospheric pressure, and the combustion chamber is below atmospheric; the result is, a suction is created which draws gas from the crank chamber to the combustion chamber. The air for mixture is provided by admission through the exhaust valve during the first part of the inlet stroke. Originally an inlet valve was located in the center of the piston head—this is not now used.

THE WEIDLEY ENGINE WITH OVERHEAD CAM SHAFT AND VALVES

Valves: In this type of engine the cam shaft is placed overhead as in Fig. 1, with the cams integral. There are two overhead valves for each cylinder (see Figs. 3 and 4); therefore there are twelve cams, one for each valve. Engine in this example is a six-cylinder.



The cam shaft is operated by a gear (G1) on the crank shaft, which operates a gear (G2, Fig. 2), which is called the lower timing gear; this gear is placed at the lower end of a vertical shaft (VS) with an upper timing gear (G3), which operates the cam-shaft gear (G4). By referring to Fig. 2, it will be seen how the cam (C) operates the tappet arm (F), which in turn opens the valve against the tension of the spring (S). While the construction varies, the principle, it will be noticed, is just the same as in any other engine. The cam shaft turns one revolution to two of the crank shaft.

The cam shaft mounted on the cylinder head has four bearings and these are 1 3/16″ in diameter. The end bearings are 1¼″ by 1¾″ long, and the middle ones, which are on either side of the driving gear, are 1¾″ by 1⅝″ long. A hole ⅜″ in diameter is drilled through the cam shaft for its entire length, and carries oil to the cams and bearings.

The cylinder head is detachable from the cylinder, and the cylinders are all in one block; therefore to grind the valves or to get to the valves, the cover is removed, and then the cylinder head. Fig. 4 shows the cylinder head removed and Fig. 3 shows the cylinder head turned up side down, exposing to view the valves seated in the cylinder-head casting.

To grind valves: First, remove head. If a single valve is to be ground the valve spring may be compressed and the pin holding the spring removed, when the valve can be dropped out and the seat ground, or the cam shaft may be removed, which is easily done. The springs and pins are removed and the cylinder head is turned over on a bench, as in Fig. 3, and the valves are ground as in any other engine. See Index for method of valve grinding.

To set the valves: The inlet opens 10° past top and the flywheel is marked "IO." The exhaust closes at 10° after top. Therefore, set the cam shaft with piston No. 1, 10° past top center; the cam is just leaving the exhaust valve (see **C**, which would be a little farther in the direction of rotation, as it now has the valve open). The gears are then meshed at this point. The timing of both inlet and exhaust is done by one cam shaft, the same as on an "L"-type cylinder.

FRANKLIN AIR-COOLED ENGINE

Engine: Six cylinder, 3¼ x 4 inches. Piston displacement 199 cubic inches. H. P. in accordance with the S. A. E. is 25.3, at maximum 31. About 1,700 r. p. m. is maximum speed. The gear ratio of the car on high gear is 3.9 to 1, the wheel being 32 inches, which means 1,950 revolutions of the engine per mile. Weight of car under 2,300 lbs. Maximum speed of car 50 m. p. h. or over.

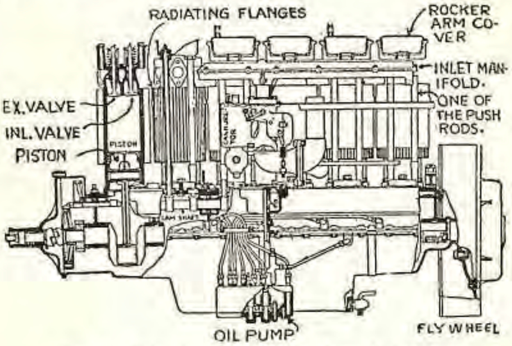


Fig. 5. Side view of Franklin air-cooled engine.

Overhead valve mechanism with one cam shaft on the side is used. Atwater-Kent ignition. Carburetor of Franklin design.

Pistons: As the normal working temperature in the Franklin engine is distinctly high, the makers were not very ready to believe in the aluminum piston, but they have now adopted it as a stock practice and consider that the better mean effective pressure of the new engine is largely due to the improved piston cooling obtained. At first there was a little trouble from wear on the skirt; it was difficult to get a close enough fit to insure absence of slap without abrasion. The trouble was overcome completely by turning a shallow, square groove of screw-thread form from the bottom of the skirt to just beneath the lower ring. This holds oil securely and allows a smaller clearance than is possible with a plain piston. Piston clearance is .005". Three piston rings 3/16" wide with .015 to .020" clearance between ends are fitted to each piston.

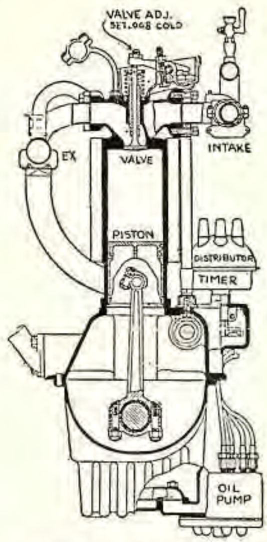


Fig. 6. End sectional view of Franklin engine.

There is an interesting **lubrication system** employed, individual oil supply being sent to every point. The oil pump, which is a conventional gear pattern, is mounted on a large plate, and the delivery from the pump is distributed to a number of oil leads by means of passages in the plate. Actually the plate is die-cast aluminum with distributing grooves, and these grooves are made into closed passages by putting a piece of thin sheet copper over the face. This gives direct-pressure feed to all bearings on the crank shaft and to various other points.

Valve Clearance

Valve clearance is .010" when cold and adjustment is made between the end of the rocker arm and the adjusting screw. See Index for "Franklin cooling system and wiring diagram."

INSTRUCTION No. 12

Continental Model "7R" Red Seal Engine

Model "7R" is a popular six-cylinder engine as used on several makes of passenger automobiles.

Specifications: Cylinder, 3¼" bore, 4½" stroke; displacement, 224.00 cu. in.; horsepower, S. A. E. rating 25.35; B. H. P., 1,000 r.p.m., 26; 2,600 r.p.m., 55; weight 575 lbs.; cooling, centrifugal pump; lubrication "force-feed" with drilled crank shaft and gear-type oil pump; carburetor, vertical outlet type, 1¼"; provisions for standard makes of starter, generator and ignition systems; clutch, multiple disk or 10" plate; construction, unit power plant; suspension, three point.

Valve Timing

Valve timing, 7R: Inlet opens 12° after top; **closes** 20° after bottom; **exhaust opens** 40° before bottom; **closes** 8° after top.

The timing marks on the flywheel can be seen through the inspection hole in the housing, directly over the flywheel. A steel pointer is used to line up the flywheel marks when checking the valve timing.

Valve timing, "7W" (an older model engine): **Intake opens** on upper dead center and **closes** 33° past lower dead center. **Exhaust opens** 67° before lower dead center and **closes** on upper dead center. This setting gives an inlet period of 213° and an exhaust period of 247°.

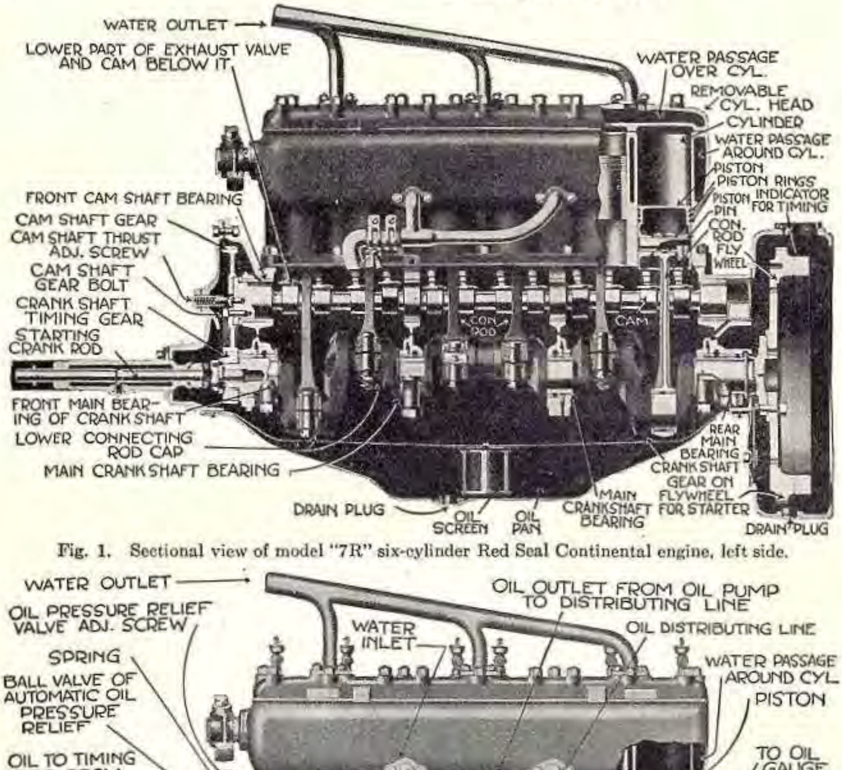


Fig. 1. Sectional view of model "7R" six-cylinder Red Seal Continental engine, left side.

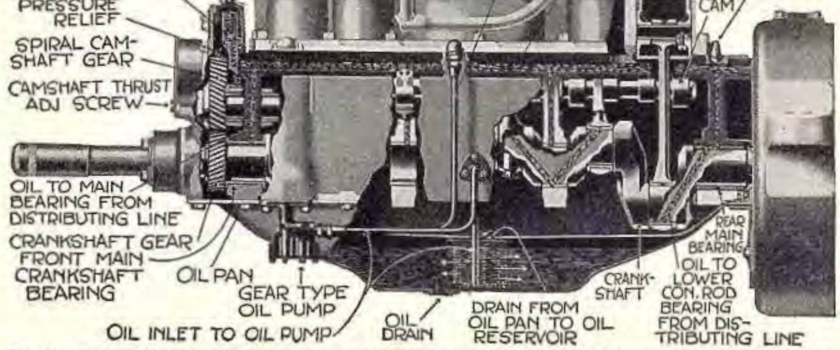


Fig. 2. Lubrication sectional view of model "7R" six-cylinder Red Seal Continental engine, left side.

See the instruction on "Commercial Cars" for valve timing of the Continental "L4" engine.

See Index "Questions and answers on Continental engines."

Lubrication of Continental "Model 7R" Red Seal Engine

Gear type of oil pump attached as a separate unit outside of the engine, near the front end of the crank case. Driven by spiral gears. Maintains a pressure of 5 to 30 lbs., depending upon car speed, temperature of oil, and general operating conditions.

Oil pressure is adjusted in the same manner as explained of the Continental "L4" engine in the Commercial car instructions, except that the amount of pressure should range from 10 to 15 lbs. at a car speed of 15 m.p.h. Oil is forced from the pump to the main oil line and distributed through ducts to the four main bearings. The crank shaft is drilled to conduct oil to the six connecting-rod lower end bearings. Through a secondary line connecting with the main reservoir, oil is fed to the timing gears and to the pressure-adjusting valve in the gear case. An oil spray lubricates the piston-pin bearings, cylinder walls, and four cam-shaft bearings, as well as the valve-spring chamber, valve stems, valve-spring bearings, and push-rod bearings.

Details of the Continental Model "N" Red Seal Engine

Model "N" engine is an engine with four cylinders, 3¾" bore, 5" stroke. It is designed for trucks ranging from ¾ to 1½ ton carrying capacity. When fitted with a governor, the recommended governing speed is 1,300 r.p.m. Pistons and connecting rods can be removed from below. At 1,000 r.p.m., 23 h.p., at 2,000 r.p.m., 34 h.p., weight 410 lbs., with flywheel. Carburetor 1¼". Cooling: thermo-syphon. Three or four-point suspension.

Lubrication would be termed force-feed and splash system. The forced-feed system supplies oil to the crank-shaft main bearings and the timing gears. The splash system serves to lubricate the interior of the engine, such as the pistons, cam shaft, push rods, and connecting-rod bearings. The oil pump is a horizontal plunger-type pump operated by an eccentric from the cam shaft. The oil pressure is automatically controlled.

To grind the valves, see Index under "Valve grinding."

To take up connecting-rod bearings, remove the lower half of the crank case. Shims are used and it is very necessary to remove one or two—being careful to remove equal number on each side and not to have a bearing too tight.

If the bearings are too far gone to take up by removing shims, it is then necessary to fit new bushings (see repair subject).

The pistons and connecting rods can be taken out past the crank shaft.

Renewing piston rings is accomplished by lapping new rings to the cylinder (see Index under "Fitting piston rings").

Valve Timing

Valve timing of the model "N" engine is as follows: **Inlet opens** 17° 53′ past upper dead center and **closes** 29° 25′ past lower dead center. **Exhaust opens** 42° 36′ before lower dead center and **closes** 8° 20′ past upper dead center.

This gives an intake period of 191° 32′ and an exhaust period of 230° 56′.

Remarks

The words "Red Seal," as used with these engines, represents the highest grade of motors manufactured by the Continental Motors Corpn., Detroit, Mich. Many passenger and truck model engines are manufactured. The model "7R" is a popular passenger car engine, and model "L4" (see Commercial Car Instruction) and model "N," below, are popular truck engine models.

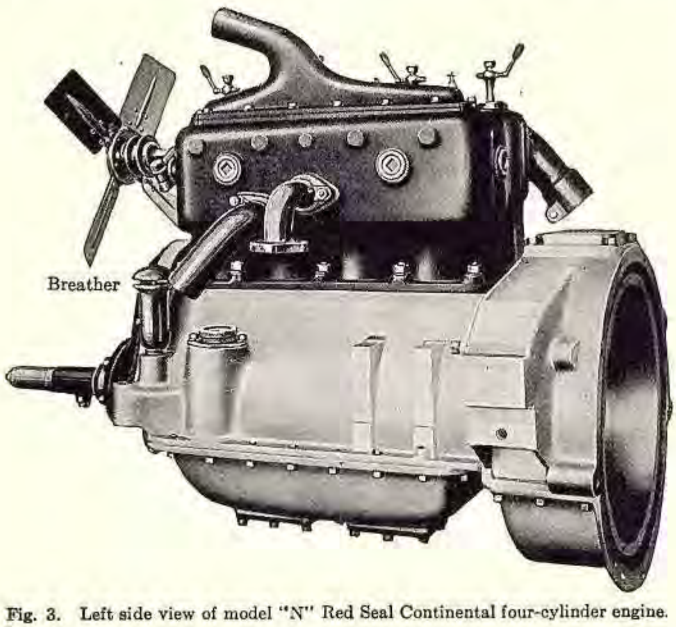


Fig. 3. Left side view of model "N" Red Seal Continental four-cylinder engine.

INSTRUCTION No. 13

CARBURETION: Early Carburetion Principle; Parts; Carburetor Principles; Gasoline; Priming Methods; Heating Methods; Vaporizing Gasoline; Size of Carburetor to Use; Gasoline Troubles; Gasoline Tank and Gauge; Fuel-Feed Methods; Vacuum Gasoline Feed System

EARLY CARBURETION PRINCIPLE

Meaning of carburetion: The mixing together of gasoline vapor and air is called **"carburetion,"** and the device that keeps the two in proportion is called a **"carburetor."**

To get energy out of the gasoline it is necessary for it to be **converted into a vapor** and then mixed with a volume of air before it can be exploded in the cylinder.

There are two ways of producing this vapor, one being to expose a considerable surface of this liquid to the air, which is also caused to bubble through it and thus become impregnated with the gasoline vapor. This was the original method, and was called the **"surface type"** of carburetion.

The second method is to **"spray"** the liquid gasoline through a fine spray nozzle or jet into the mixing or vaporizing tube, into which air can be drawn to intermingle with the vapor.

The device in which this operation is performed is termed a **"carburetor,"** and the operation itself is known as **"carburetion,"** from the fact that the gasoline largely consists of carbon. The mixture might also be termed **"carbureted air."**

Amount of gasoline and air: It has been found that the best explosive mixture, with the gasoline commonly used, is a proportion of 14 parts air to 1 part gasoline (this when maximum power is desired) and ranging to 17 to 1 (the latter for maximum economy), proportioned by weight of air and gasoline.

That is, 14 to 1, or rich mixture, is best for quick acceleration or 15 to 1 or leaner mixture best for pulling with wide-open throttle, and 17 to 1, or still leaner mixture, for high-speed work (figures only approximate).

Pure gasoline vapor will not burn; it must be mixed with air before it can be used in an engine. To burn with the greatest rapidity and heat, the air must be in correct proportion to the vapor. The exact amount of air to be mixed with a certain amount of vapor depends on the quality of the gasoline, and other conditions. The carburetor, by which the proportions of the mixture are maintained, is so made that a current of air passes through it when the piston makes a suction stroke.

In general gasoline is approximately 85 per cent carbon and 15 per cent hydrogen.

Approximately 15 pounds of air per pound of gasoline would be considered a **chemically correct mixture.** This figure changes somewhat with the source and grade of gasoline.

A **perfect, or correct mixture,** as mentioned in the previous paragraph, is one which contains just sufficient oxygen (which is in the air) to burn completely all the hydrogen and carbon present in the fuel.*

"Mixing Valve"—an Early Form of Carburetor

In the early days the method of mixing the gasoline and air in proper proportions was by means of a "mixing valve" (Fig. 1). It could also be termed a carburetor but without the float cut-off mechanism. The air was drawn in at "air intake," through valve (3), being opened automatically by suction of the piston, forming a vacuum in the crank case when going up (on a "two-cycle" engine), or when the inlet valve was open and the piston traveling down on suction stroke on a "four-cycle" engine. If, therefore, the gasoline needle valve was open, gasoline would also be drawn in, mixed with the air, and pass into the cylinder in a partially vaporized condition.

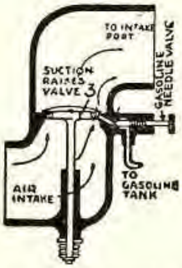


Fig. 1. Early form of a carburetor; a mixing valve.

The mixing valve, also called a "generator valve," is still used to a small extent on two-port two-cycle engines. It takes the place of a check valve, as the valve (3) serves the same purpose.

Note the absence of any float arrangement. The gasoline is fed bv gravity, and when the engine stops the gasoline needle valve must be cut off, otherwise the gasoline will drip.

Constant-Level Type of Carburetor

Fig. 2 explains the purpose, location, and parts of a simplified carburetor.

The gasoline tank is above the level of the carburetor; therefore the gasoline is fed to the carburetor float chamber by gravity.

The air goes through a passage, in which is a small pipe called a "spray nozzle," that sprays the gasoline so that it comes in contact with the air (see Fig. 2). The gasoline, being volatile, is taken up by the air, and the mixture goes to the cylinder.

The amount of air that may flow through the carburetor, and the quantity of gasoline that may flow out of the small pipe, are adjustable, so that for a certain amount of gasoline the proper proportion of air may be admitted.

When the mixture is not correct, that is, when there is too much or too little air for the gasoline flowing out of the small pipe, the running of the engine is affected, and it will not deliver its full power.

When there is too much air for the gasoline, the mixture is said to be "too poor" or "lean"; when there is too little air, the mixture is said to be "too rich."

The carburetor is connected to the inlet pipe, and no air or gas can enter the cylinder through the inlet valve without first passing through the carburetor.

The air drawn through the carburetor on the suction stroke enters it through the "air intake" and passes around the spray nozzle, drawing gasoline with it; the level of the gasoline in the float chamber then drops, and the float drops also and permits more gasoline to enter the float chamber.

* Forming carbon dioxide. **Carbon monoxide** (a poisonous gas) results from insufficient air (oxygen) to completely burn the carbon.

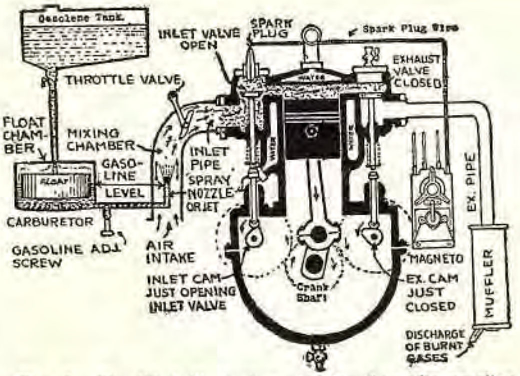


Fig. 2. Simplified illustration showing how the gasoline flows from the gasoline tank to the carburetor; how it is mixed with air and then drawn into the cylinder when the inlet valve is open.

It is in the "mixing tube," or "mixing chamber," as it is sometimes called, that the air is brought into contact with the gasoline. The "spray nozzle" projects into the mixing tube, so that it is in the center of the current of air.

How the gasoline is drawn into cylinder with the air: When the air is not passing through the mixing tube, the liquid gasoline stands just below the open end of the spray nozzle, but as soon as the current of air passes through, it sucks the gasoline out. The current of air sucks up gasoline, very much as would a child trying to draw the last few drops of soda through a straw, drawing in really more air than soda.

The piston of the engine, on its suction stroke, produces the suction effect similar to a squirt-gun drawing in water. (See "suction, vacuum," pages 1078, 1079.)

The inlet valve must be open to permit the gas to be drawn into the cylinder—which is the case if the piston is on the suction or intake stroke, but in no other stroke.

The **adjusting screw** or **"gasoline needle valve"** regulates the amount of gasoline to be admitted into the mixing tube through the spray nozzle or jet. The regulation of this needle valve is very important, and after once being properly adjusted, a very slight turn one way or the other will affect the running of the engine.

The throttle valve, usually placed in the mixing tube, above the spray nozzle, governs the amount of gas which enters the cylinder on the suction stroke.

The throttle-valve lever on the carburetor connects with the throttle lever on the steering wheel. Moving the throttle lever on the steering wheel, in a certain direction opens the throttle valve on the carburetor, which increases the speed of the engine.

The more gas admitted by the throttle lever through the throttle valve, the more gas will enter the cylinder; hence more power or greater force on the power stroke results, thereby giving more speed to the piston of the engine.

Moving the lever in the opposite direction closes the throttle valve on the carburetor, reducing the amount of gas which enters the cylinder, thereby reducing the speed of the engine.

The throttle valve is never entirely closed, but is set by means of a **throttle-arm stop-screw,** called **idling adj. screw** (see Fig. 46, page 138 and (X) (Y) (Fig. 1, page 124) showing location on a carburetor, and page 125 for explanation of adjustment). A **clearance** of about .005" is allowed, so that the engine will **idle** and not stop entirely when throttle lever on steering wheel or accelerator is closed. **To stop engine,** the ignition switch is opened.

The float in the carburetor is provided merely to prevent the gasoline overflowing and running out of the spray nozzle, when the engine is not running. The float is adjusted so that the level of the gasoline will not quite reach the top of the spray nozzle or jet. Thus, as the float automatically governs the level of the gasoline in the float chamber and automatically cuts off the supply from the gasoline tank when the engine stops, it is termed a "constant-level type" of carburetor.

The floats are usually made of cork or hollow metal balls, which float in the gasoline inside of the mixing chamber. A needle point arrangement is connected with the float, which cuts off the gasoline flow when the engine stops.

The reason why engines must first be cranked, when starting a gasoline engine, is due to the fact that a charge of gas must be drawn into the cylinder and then compressed. Compressed gas is ignited by the electric spark; this produces the power stroke, and the power from this combustion of compressed gas, together with the momentum of the fly wheel, will keep the engine in motion until the next power stroke. The cycle operation of suction, compression, power, and exhaust is repeated over and over again.

Early Constant-Level Type of Carburetor

Maybach conceived the idea of using a float to maintain a constant level of gasoline just below the spray-nozzle head, with a **main air inlet** below the nozzle, as shown in Fig. 3.

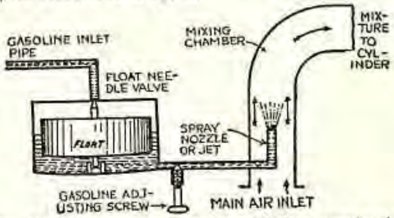


Fig. 3. Early type of carburetor with float mechanism A "main air inlet" is provided.

The gasoline is drawn from the spray nozzle by a vacuum or suction effect produced by the piston. It is thus drawn through the mixing chamber and through the open inlet valve into the cylinder. At the same time, air is drawn into the mixing chamber at the main air inlet, but inasmuch as the greatest power of an engine is obtained by having a mixture of exact proportions of air and gasoline, it is clear that if the speed of the engine is increased, more gasoline would be drawn into the cylinder without sufficient air supply to mix with it. Thus too rich a mixture would be the result. If the air opening were enlarged to give a greater supply of air at high speeds, the result would be too great an air supply at low speeds, or too lean a mixture. This type of carburetor was evidently designed for a constant steady-speed engine.

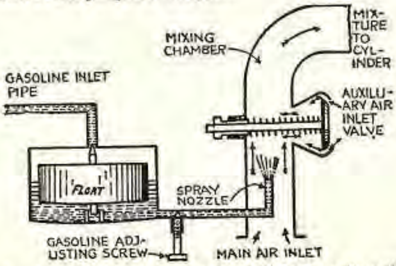


Fig. 4. In addition to a "main air inlet" an "auxiliary air inlet" is provided here.

An auxiliary air inlet was added to this type of carburetor by Krebs. Note that in addition to the main air inlet below the nozzle, an automatic auxiliary air valve was placed above the nozzle (Fig. 4).

At low speeds, the main air inlet was sufficient, but at high speeds, the suction effect being greater, the spring caused the auxiliary air valve to open, thus permitting more air to be drawn into the mixing chamber, and resulting in a better proportion of air and gasoline than the carburetor shown in Fig. 3. The greater the speed of the engine, the greater the suction effect, and consequently the greater the opening of the auxiliary air valve. At slow speeds, the air valve would remain closed and was thus automatic in action.

Another feature of the auxiliary air valve, is to break the gasoline up into as many fine particles as possible, so that the air will more readily mix with the gasoline and form a vapor. There are different methods of doing this which will be shown farther on.

Adjustable auxiliary air valve: The difficulty arising from the fact that the coil spring which held the auxiliary air valve closed at low speeds and was intended to open as the speed of the engine increased did not always function, because temperature changes would affect its sensitiveness and because the variations in the volatility of gasoline varied when cold and when warm, was overcome in a way by changing the adjustment of the tension on the auxiliary air-valve spring which was provided as shown in Fig. 5.

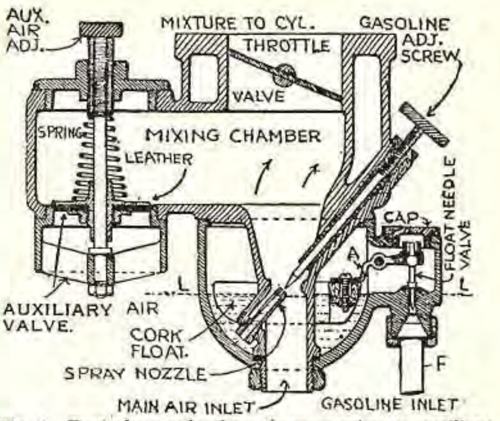


Fig. 5. Typical example of a carburetor using an auxiliary air valve.

The reader should closely observe the difference between the **main air inlet** and the **auxiliary air valve.** All carburetors have main air inlets, where air is drawn into the carburetor below the spray nozzle, thus mixing with the gasoline. This opening can be at the bottom or the side of the carburetor.

When an auxiliary air valve is used, it is usually placed so that air is drawn above the spray nozzle and thus combines with the mixture of gasoline and air. Many carburetors do not have auxiliary air valves.

PARTS OF A CARBURETOR

Before proceeding farther with the principle of different types of carburetors we will take up the subject of parts of a carburetor.

The concentric-float type of carburetor is the term applied to a carburetor where the float surrounds the mixing chamber and spray nozzle, as in Fig. 5. This makes a compact carburetor and maintains a constant gasoline level in the spray nozzle regardless of the angle at which the engine may be. On almost all concentric-type carburetors the float is made of cork.

The side-float type of carburetor is the term applied to a carburetor where the float and float chamber are placed to the side of the mixing chamber, as in Fig. 4.

Floats

Floats are usually made of light brass or copper in various hollow forms; the joints, if any, being carefully soldered or brazed, so that gasoline cannot enter the float itself. Floats are also made of cork, well shellacked, so that they will not absorb gasoline and lose their buoyancy. (See Fig. 5.)

The sole **duty of the float** is to maintain a predetermined or constant level of the gasoline in the carburetor. This level is generally a small fraction of an inch below the jet or nozzle opening.

The float chamber is that part in which the float operates; it is sometimes placed around the spray nozzle and sometimes to the side, as previously explained.

The float level: In different makes of carburetors, the level of the gasoline in the float chamber, and the gasoline in the spray nozzle, varies from about one-sixteenth to one-eighth of an inch below the top of the spray nozzle.

As gasoline flows from the main supply tank through the gasoline pipe or line into the float chamber of the carburetor, the float rises and the needle valve shuts off the further entrance of the fluid into the carburetor.

When the engine is running and using gasoline, the float in the carburetor is continually falling and rising slightly, always maintaining the approximate gasoline level in the float chamber.

There are many types of floats and float mechanisms, as will be seen in the illustrations of various carburetors in this instruction. By referring to Figs. 6, 7, and 8, the reader will observe several floats (T) and float needle-valve (V) arrangements.

Gasoline leaking into the float would increase its weight, thereby changing the proper gasoline level in the spray nozzle and causing the carburetor to flood and would thus give too rich a mixture.

Float Needle Valve

Float needle valve: The part V (Figs. 6, 7, and 8) explains how the float causes the float needle valve (V) to close the opening at the gasoline supply pipe (F) when the gasoline has reached the proper level in the float chamber, and how it causes the needle valve (V) to open the outlet at the end of the pipe (F) when the gasoline level is reduced. (C) is the opening leading to the spray nozzle.

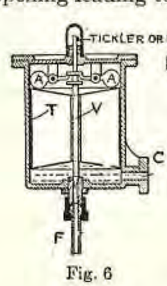


Fig. 6

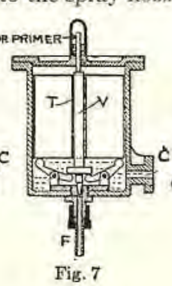


Fig. 7

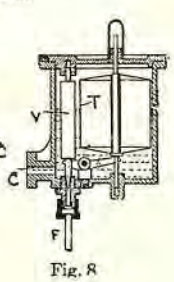


Fig. 8

Note that in Fig. 5 the float needle valve is to one side of the float. A glance will show how the float needle valve would be caused to open when the float drops below its level (L) and how it would cause the float needle valve to close when at the proper level. **Adjustment of the height of the float** can be made by slightly bending the arm (A) (Fig. 5).

A method of priming, or to supply an increased flow of gasoline at the spray nozzle when starting a cold engine, is sometimes found by what is termed "tickling" the carburetor, by raising the needle-valve rod through the float, as in Fig. 6, which projects above the carburetor and usually has a cap screwed over it to keep out dirt.

Another method is to close the main air inlet (Fig. 5), which is termed "choking" or "strangling" the carburetor, while the engine is being cranked. The fact that the air is shut off causes an increase of gasoline to be drawn in for the initial charge.

Dripping of gasoline from the bottom of a carburetor is usually due to grit or dirt getting under the float needle valve. Thus, when engine stops, instead of the needle valve seating properly and cutting off the gasoline supply from the supply pipe (F), it overflows at the spray nozzle and drips out of the main air inlet.

Remedy: By working the float needle valve up and down in its seat, which can be done by means of the rod above the carburetor float chamber (Fig. 6), or by unscrewing the cap (Fig. 5), the grit will very likely be removed. If this does not remedy the dripping, then the float should be readjusted, or possibly a new float needle valve is required.

Gasoline Needle Valve

The gasoline needle valve controls the flow of the gasoline to the spray nozzle, and the correct adjustment of it is necessary for the operation of the carburetor. It is also called the "gasoline adjusting screw" (see Fig. 5). Don't confuse this needle valve with the "float needle valve."

The regulation of this gasoline needle valve is very important and likewise very sensitive. After the carburetor is once adjusted by regulating the auxiliary air valve and the opening of this gasoline needle adjustment valve, the slightest turn one way or the other of this valve will make a difference in the running of the engine.

Types of gasoline needle valves are as follows:

1. Hand operated, as in Fig. 5.
2. Mechanically operated, by movement of a throttle through a cam arrangement by hand (treated farther on).
3. Automatically mechanically operated, by action of the auxiliary air valve, called a "metering pin" (explained farther on).

A main air inlet is on all carburetors, and, quite often, an auxiliary air valve also.

Auxiliary Air Valve

Auxiliary air inlet valve: The greatest difference in the air type of carburetor is in the construction, position, and action of the auxiliary air inlet, discussed farther on.

The auxiliary air valve is controlled automatically by the vacuum created by the engine piston, which draws air through the auxiliary air intake against a spring tension; for instance, see the auxiliary air intake in the carburetor shown in Fig. 5, page 97, the opening being controlled by the tension of a spring.

The air-valve spring: The weaker the spring the less vacuum it will take to draw the valve open, and it may be adjusted by means of a threaded sleeve (as in Fig. 5 and in various other ways).

The stronger the spring, the less air, hence a "richer" mixture. The weaker the spring, the more air, and hence a "leaner" mixture.

Another method for automatically opening and closing the auxiliary air intake is shown in Fig. 9. Note the action of the ball (L). Instead of a valve and a spring, balls are utilized instead. This carburetor is the **Kingston** air-valve type, with an auxiliary air inlet. Instead of using a spring to control the amount of air drawn into and through the auxiliary air valve, balls are used.

The **gasoline needle** valve is adjusted by hand. The float is concentric. Note the Venturi mixing tube. Another air-valve type of carburetor, with an auxiliary air valve controlled by one large ball placed in the main air inlet pipe of the carburetor is shown farther on.

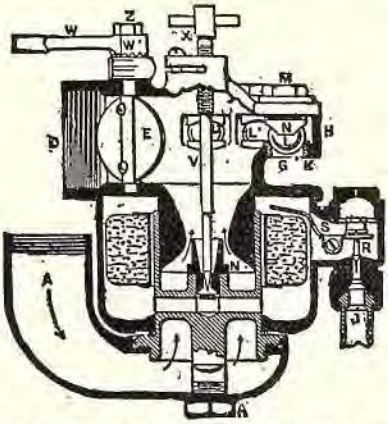


Fig. 9. Kingston air-valve type of carburetor. Note the balls in the auxiliary air valve which control the quantity of air entering the auxiliary air valve. Parts: A, main air inlet; D, outlet of mixture to engine; E, butterfly throttle valve; G, auxiliary air inlet; L, balls which rise as the suction increases or as the speed of the engine increases, thus admitting more air; V, gasoline needle valve; X, hand adjustment of needle valve; W, butterfly throttle lever connects with steering-wheel throttle lever; N, Venturi mixing tube.

The float is a cork float and concentric to the mixing chamber. S is an arm connected with the float needle valve, R. As the float rises, the arm forces the needle (R) to seat.

Explanation of the Venturi Action

If two buckets are placed side by side, both filled with water, with a one-inch opening cut in the bottom of each, one with a plain opening (A), as in Fig. 10, and the other with a "Venturi" opening (B), as in Fig. 11, the same volume of water would flow out of the Venturi one-inch opening in Fig. 11 more quickly than through the plain one-inch opening in Fig. 10.

Fig. 10

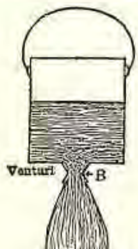


Fig. 11

Note the shape of the Venturi opening (B), in Fig. 11, then note a similar shaped tube in the mixing chamber in Fig. 9, where the arrow-points lead from (N).

The Venturi tube around the spray nozzle in the mixing chamber, is used in almost all makes of carburetors. The principle and purpose of the Venturi tube around the spray nozzle is to obtain a greater volume of air through a predetermined sized opening in quicker time. Another purpose of the Venturi tube is that the lowest pressure of the inrushing air will be at a point where it will cause the greatest suction in the spray nozzle.

Spray Nozzles or Jets

Spray nozzle: The fuel is discharged into the mixing chamber through the spray nozzle (also called **"jet tube"**). As its name implies, it is intended to deliver the liquid in the form of a fine spray, which is: (1) vaporized more or less; (2) mixed with the entering air, and (3) carried by the suction into the engine cylinder. The simplest form of spray nozzle is one having a single opening, as shown in Fig. 5 (page 97).

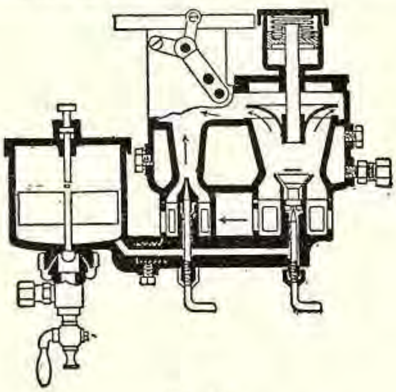


Fig. 12

Some carburetors have two spray nozzles or jet tubes, as shown in Fig. 12. Another type has what is called a "multiple jet" spray nozzle.

When a carburetor has more than one jet, it is particularly adapted to a multiple of cylinders of large size, and especially to six-cylinder engines.

The mixing chamber consists of an enclosure or passageway containing the nozzle. The gasoline and air are mixed within this tube in proper proportions and then drawn through the throttle into the engine.

Throttle Valves

There are three types of throttle valves: the butterfly, the rotary and the sliding.

butterfly throttle valve **rotary throttle valve**

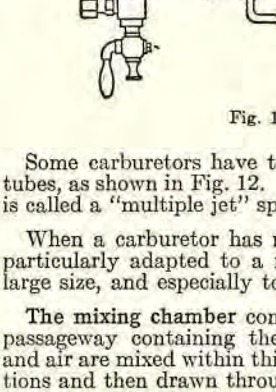


Fig. 13

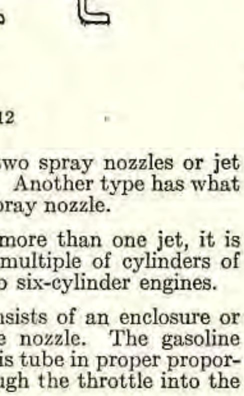


Fig. 14

Fig. 13. The throttle is placed in the mixture outlet, and the form that is shown is called a "butterfly valve." It is a disk of metal turning on pivots, so that it acts like the damper of a stove pipe. When wide open, the butterfly valve is edgeways to the flow of the mixture, but even in this position it presents resistance to the flow, which is something that should be avoided.

Fig. 14. The rotary type of valve. The passage of gas from jet to intake manifold through passage (P) is controlled by a rotary cylinder (R). It is now shown full open, but by moving throttle lever (L), it can be closed or partially opened as desired.

The butterfly throttle valve is the type of throttle used on almost all makes of carburetors. This type of throttle is shown in Figs. 13 and 9. The mechanism and method for controlling the throttle is shown in Fig. 11, page 33 and in Fig. 16, this page.

The "rotary" or "barrel" throttle valve (Fig.14), presents no resistance whatever.

The sliding throttle valve is another type which presents no resistance to the flow of gas. This type is now practically obsolete, although it was formerly used quite extensively when governors were used.

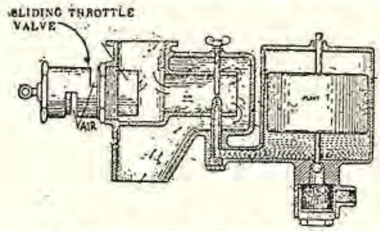


Fig. 15. The sliding throttle valve consists of a cylinder-type of throttle, but instead of being rotated, it is moved in or out of its passage, which controls the amount of gas passing to the intake manifold. As it is moved out, additional air is admitted through port holes. This type was the type formerly used with a governor.

Engine Speed; How Controlled

The method for controlling the speed of an automobile engine is by opening and closing the throttle valve on the carburetor by the hand throttle lever or foot accelerator.

A rod leading from the throttle lever on the throttle valve connects with a hand lever on the steering wheel. The driver then has the speed of the engine under his control at all times.

When running on a level and if more speed is desired, the throttle is opened by the throttle lever until the required speed is obtained. By closing the throttle, the speed is decreased.

Idling

The throttle valve is never entirely closed: the lock screw (also termed "idling adjusting screw," "throttle-arm stop-screw"; see also page 96) prevents the throttle from closing entirely. Therefore the engine will run slow, or "idle," as it is called, when the throttle valve lever on the steering wheel is closed and the car standing. To stop the engine entirely, throw off the ignition switch. **To adjust carburetor for idling of engine,** see an example on page 125.

The Accelerator

This is the usual means for controlling the speed of the engine.

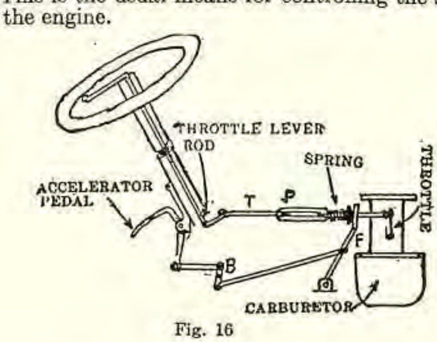


Fig. 16

The accelerator consists of a foot pedal which opens and closes the carburetor throttle valve independently of the hand-throttle lever. By referring to the illustration (Fig. 16), it will be noted that the accelerator will operate the throttle of the carburetor without moving the hand-throttle lever, by an arrangement as shown. When the foot-accelerator pedal is depressed, the rod (**F**) moves against a shoulder which is fastened to the throttle shaft. The end of the shaft (**T**) works free in a turnbuckle (**P**). Thus the throttle can be opened without disturbing the hand lever, or the hand lever can be operated without moving the foot pedal. The accelerator is used more than the hand-throttle lever. Its purpose is the same as the hand-throttle lever on the steering wheel: to open and close the throttle valve.

1—Steering wheel
2—Spark advance lever
3—Hand throttle lever
4—Air adjusting collar
7—Accelerator pedal
8—Outer casing
9—Steering shaft
10—Quadrant bracket tube
11—Throttle tube
12—Spark advance tube
13—Steering column bracket
14—Adjusting ring for roller bearings
15—Lock ring for No. 14.
16—Steering worm
17—Worm wheel
18—Spark advance mechanism
19—Hand throttle mechanism
20—Steering worm housing
21—Carburetor air adjusting rod
22—Grease plug worm gear housing
23—Inlet pipe to cylinders

Fig. 17 illustrates the relation of the accelerator connections to the spark lever and its controls on the steering device. The Locomobile is shown as an example.

When pressed downward for increase, or released for decrease of speed, its action is instantaneous. When the accelerator is released, the engine immediately resumes the speed determined by the positions of the hand lever on the steering wheel. Although either the hand-throttle lever or the accelerator may be used to control the speed of the car, the use of the hand lever is advised for beginners. After confidence in driving has been gained, the more delicate action of the accelerator will be preferred.

The word "accelerate" means "to hasten." The term, therefore, is applicable here because it is quicker to operate throttling.

The Governor

There are no pleasure cars using the governor. Nearly all truck, tractor, marine and stationary engines use governors. See Index under "Governors." One governor, which is a "throttling" type, is the centrifugal ball type illustrated in Fig. 18**A**, the principle of which, is, no doubt, familiar to all. The "sliding" throttle in the carburetor is actuated by the movement of the sleeve controlled by the balls (**B**). The balls fly out as the speed increases, causing the throttle to close. Another principle is that of the "hit and miss type."

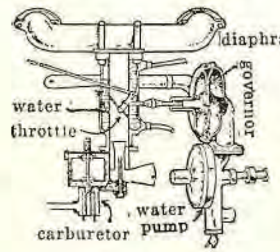


Fig. 18

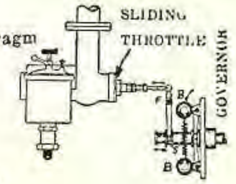


Fig. 18A

The governor formerly used on the **Packard** was termed a "hydraulic" governor of the diaphragm type, located directly above the water pump. It was operated by the pressure of the water in the water circulation system and consisted of a circular chamber divided by a flexible diaphragm of leather and rubber. On one side of the diaphragm was a water space through which the water of the circulating system passed. On the other side was an air space and a plunger head against which the diaphragm pressed. The plunger was directly connected with the throttle valve (Fig. 18).

CARBURETOR PRINCIPLES

Although tremendous advancement has been made in recent years in construction and performance of the gasoline engine and carburetor, the original *basic principles of operation* remain unchanged.

The carburetor still depends upon suction of the piston during its descent on the inlet stroke to draw from a jet (spray nozzle) or jets, variable or otherwise, the necessary gasoline to mix with the air.

This jet can be of a fixed size or it can be variable in size. This spray of gasoline is affected by the temperature, valve timing, exhaust, inlet, and combustion chamber design.

Carburetors for the purpose of brief summarization can be divided into five classes or types:[1]

(1) **Air-valve type.** In this the fuel issues through a fixed orifice and the additional air required when the throttle is opened is admitted through an auxiliary air valve.

(2) **Compensating-jet type.** In this an auxiliary fuel jet comes into action as the throttle is opened.

(3) **Metering-pin type.** In this the size of the gasoline orifice (jet) is increased automatically to increase the flow of fuel as the throttle is opened.

(4) **Expanding type.** In this there are a number of fixed orifices which come into action one after the other as the throttle is opened.

(5) **The "plain tube" or "pitot" principle.**[2] A modern principle now adopted extensively. The metering pins, dash pots, and auxiliary air valves are dispensed with. It derives its name, "plain tube," from the fact that both the air passage and the gasoline jet are of fixed size for all engine speeds. The action is to supply an increased supply of gasoline or rich mixture for acceleration and then to thin down to an economic mixture for normal engine speed.

Carburetor Principle

The principle of the constant-level type of carburetor is previously shown in Fig. 3, page 96. In this early type it is only possible to adjust

[1] **Although some of these principles are not now in general use,** the reader should carefully study them all in order to more clearly understand later models, such as, for example, on Inserts Nos. 6 and 7. [2] See page 102 for explanation of the function of a pitot tube.

the amount of gasoline flowing to the spray nozzle. It is therefore only suitable for engines which run at a steady, constant speed, as previously explained.

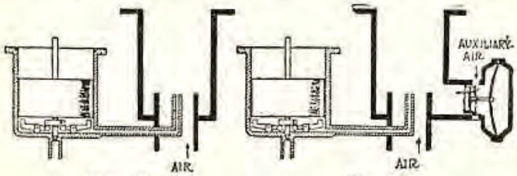


Fig. 19 Fig. 20

The engine of an automobile, however, does not run at a steady speed; sometimes it is running fast and sometimes slow.

The speed of the air current passing through the carburetor depends on the speed of the engine; when the engine is running fast the speed of the air current through the carburetor is much greater than when the engine is running slow.

The greater the speed of the air current, the more gasoline it will suck out of the spray nozzle, and the adjustment of the gasoline flow that will give a correct mixture at a low speed will give a rich mixture when the air current moves at a higher speed. For this reason the air supply must also be varied in order to give a more combustible mixture.

Auxiliary Air Valve

To vary the air supply, different methods are used, but the one used most is the auxiliary air valve, and this is where the "air-valve type" carburetor derives its name (see Fig. 20).

The auxiliary air valve was designed for engines which run at changing speeds, so that an extra supply of air is admitted when the air current flows so fast that it would result in too rich a mixture.

The disadvantage of this type is that owing to the relieving action of the spring valve, it does not increase the proportion in proper ratio, and is hardly suitable for the present-day high-speed flexible engine.

There are several different models now manufactured, based on the principle of the auxiliary air valve only. In these, the problem is worked out in different ways; one manufacturer uses a "spring-controlled valve"; another hopes to get better results by regulating the movement of the valve by "two springs," instead of one; still another maker adds an "air dashpot" with the hope of getting finer regulation and a better functioning of the auxiliary air valve; another uses a "dashpot filled with gasoline"; and there are others who use metal "balls" to serve as the auxiliary valve, while others use what are known as "weighted air valves," in which the suction lifts balls, thus admitting the air which sweeps over the spray nozzle. While they all differ in the details of working out the design, all are, nevertheless, based on the basic principle of the auxiliary air valve as originally worked out, and shown in Fig. 4, and in Fig. 20 above. For simplicity in nomenclature we shall refer to this type as the auxiliary air valve type.

Relation of Acceleration to Gasoline Consumption

The rapid advance of high-speed and multiple-cylinder engines demands "quicker acceleration," meaning quicker "get away" or "pick up" of the engine.

Flexibility of control means practically the same thing, i.e., the capabilities of the engine to "pick up" from low to high speed and vice-versa. Rapid "acceleration" and "flexibility," both call for a sudden greater amount or percentage of gasoline to air. Quick acceleration therefore demands a surplus of gasoline for but a brief period, after which the normal supply will care for the engine. It may be but a matter of a few seconds, yet it is of importance that this additional supply be ready and in available form for that brief period.

To meet the sudden demand for gasoline, the added nozzle, or **multiple jet** has been introduced by some makers, so that when the suddenly opened throttle brings the auxiliary air valve into use, the valve in turn brings more gasoline into the mixture by opening the gasoline needle valve wider. This is termed the **"metering pin"** method. One maker does this by a "dashpot" on the auxiliary valve stem, the dash pot performing a regular pump stroke and forcing gasoline into the mixing chamber by way of a separate nozzle as the auxiliary air valve opens. Once open, the pumping action ceases, but the nozzle remains open for a more even demand for more fuel.

Proportion of air and gas: All of these methods of providing "acceleration" are based on the accepted belief that in carburetion, different mixtures of air and gasoline vapor are needed for different engine requirements. The days are past when the uniform-mixture argument dominated, the argument that the ideal carburetor was one that would give, say, a mixture of fifteen proportions of air to one of gasoline vapor for all speeds, "acceleration," "hard pulling" with open throttle, and high-speed work with open throttle, etc., etc. **The new rule** is that the amount of gasoline fed into the air volume must be changed according to demands. Thus a twelve-to-one or "rich" mixture might be best for quick acceleration; a fifteen-to-one or "leaner" mixture may be best for pulling with the throttle wide open; and a seventeen-to-one, or still "leaner" mixture may be desirable for particularly high-speed work. Therefore a "varying mixture" must be supplied.

The Compensating-Jet Principle

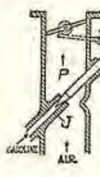
The compensating jet type of carburetor is where an **auxiliary fuel jet** comes into action, as the throttle is opened. Types of carburetors coming under this heading would be the Zenith; the Stromberg model "H" and the Marvel (see Index).

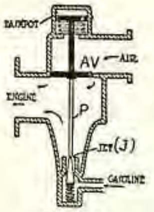
The Metering-Pin Principle

In the metering-pin type the size of the gasoline orifice, or jet, is increased automatically to increase the flow of fuel as the throttle is opened. In other words, as the throttle is opened, the metering pin (P, Figs. 21, 22, 23), which is similar to a gasoline needle valve, is moved so as to permit more gasoline to flow throught the spray nozzle or jet (J). Thus, instead of the gasoline needle valve (metering pin), being adjusted by hand, it is automatically adjusted by the speed of the engine, thereby permitting more or less gasoline to flow as the speed increases or decreases. This principle is called the "metering pin" principle, also the "pneumatic" principle, when operation is by air control.

Various methods are employed to operate this needle valve or metering pin as follows:

On the Schebler model "L" (Fig. 21), the metering pin (P) is connected with the carburetor **throttle lever** in such a manner that the metering pin (gaso-





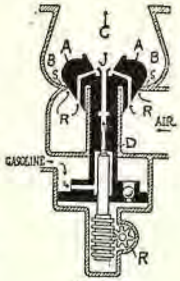


Fig. 21 Fig. 22 Fig. 23

Fig. 21. Schebler model "L." Metering pin controlled mechanically.

Fig. 22. Schebler model "T." Metering pin controlled by auxiliary air valve.

Fig. 23. Stewart model metering pin controlled by air suction.

line needle valve) is raised as the throttle is opened. See Index under "Schebler carburetors."

On the Schebler model "T" (Fig. 22), the metering pin (P) is connected to and controlled by the **auxiliary air valve.** As the throttle is opened, the speed of the engine increases, the suction becomes greater, and the air valve (AV) is sucked downwards, causing the metering pin (P) to give a greater opening at jet (J), thus admitting more gasoline.

On the Stewart carburetor (Fig. 23), the metering pin (D) is controlled by **air suction.** As the throttle is opened the suction becoming greater, the metering valve (A) (part in black) rises enlarging the opening at the metering pin (D) and drawing more gasoline through jet (J). At the same time more air is drawn around the valve seat (B). A ratchet (R) is connected with a control on the dash for the purpose of enlarging the opening at the metering pin, so as to obtain a rich mixture when starting.

Example of a Carburetor with Both a Metering Pin and Dash Pot

The Rayfield uses a "metering pin," which is lifted as the throttle opens in the main jet (N) (Fig. 24), through a link arrangement, which establishes a right for it to be classified as a metering pin type. But it goes farther. It incorporates an auxiliary nozzle (AN) which also has a metering pin that is depressed when the auxiliary air valve opens. Thus, by having two distinct nozzles it establishes its right also to be classified as an expanding type of instrument.

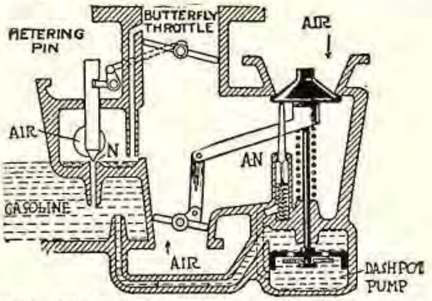


Fig. 24. The Rayfield carburetor principle with "metering pin" connected with the throttle and "dash pot," with auxiliary air intake.

But the Rayfield goes still farther, in that it combines a **pumping action** on the gasoline in the auxiliary nozzle (AN) whereby a very rich mixture is furnished for acceleration whenever the air valve is suddenly opened. This is accomplished by the piston on the lower end of the air-valve stem working in a "dashpot" filled with gasoline. Gasoline enters the dashpot above the piston and is admitted to the space below the piston by the disk valve in the piston. When the air valve suddenly opens, forcing the piston downward, this disk valve is automatically closed, forcing or pumping the gasoline upward through the dotted fuel passage into the nozzle (AN), where it is sprayed into the inrushing air. Only when the valve opens is this pumping function occurring; at other times the gasoline issues through this auxiliary nozzle according to the suction of the engine. Thus the **Rayfield is a compound** of two metering pins in conjunction with the pumping function for acceleration.

Expanding Principle

In the expanding principle, there are a number of fixed orifices which come into action, one after the other, as the throttle is opened. Types of this class of carburetors are shown in Fig. 25 and in the description of the "Master" carburetor (see Index).

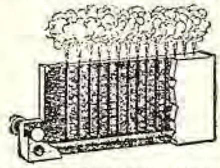


Fig. 25. The multiple jets of the Master carburetor.

The Pitot or Plain-Tube Principle

The "Pitot" or "plain tube" type of carburetor differs from other principles. It is the principle now being used to a considerable extent, and derives its action as well as its name from a Pitot tube.

A Pitot tube is a very old instrument for measuring velocities of flowing streams of water, invented by Henri Pitot in 1730.[1] It consisted of a vertical glass tube with a right-angled bend as shown at (E).

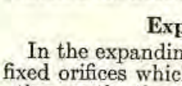


Fig. 26. The impact of the flowing water against open end (F) of tube (E) causes a column to rise above the surface of the stream as at (A), and by this small difference in height, the velocity of the stream can be calculated.

Function of the "pitot" or "plain tube"[2] as applied to a carburetor. If this tube was *reversed*, so that the submerged end (F) faced *downstream* instead of upstream, a *suction* instead of a pressure would exist at end (A), because the water flowing away from (F) would create a partial vacuum in the tube, thus reducing the pressure in tube. Atmospheric pressure would then force air into the tube at (A). If end (A) was connected to a liquid under atmospheric pressure, the liquid would then be forced through the tube. The faster the flow of water (or any other liquid or gas, such as *air*, in which the end [F] is submerged), the greater the suction at (A).

An illustration which will serve as an example to show how the pitot tube functions, is Fig. 17A, page 130.[3] The opening (G) of the jet (Fig. 17A) represents the submerged end of the pitot tube facing *downstream* in a current of *air* into which it is submerged. The other end of the tube, opening into the gasoline float chamber, will correspond to end (A) (Fig. 26). Since the direction of the flow of air is away from the submerged end of the tube, the pressure at end (G, (Fig. 17A) of tube is reduced, consequently the atmospheric pressure on the gasoline in the carburetor float chamber will force the gasoline through the jet (G). Faster the flow of air, greater the suction, consequently greater the flow of gasoline into mixing chamber of the carburetor to be mixed with air and drawn into the engine.

[1] The pitot tube is also used for measuring pressure in moving streams of gas or liquids. It is also used for measuring fire streams, chimney drafts, etc.

[2] See page 100, also Index, for explanation of "plain tube."

[3] Although this is an up-draft type of carburetor the same principle applies to the later down-draft type.

GASOLINE: PRIMING METHODS; HEATING METHODS; VAPORIZING GASOLINE

Before taking up the subject of various constructions and adjustments of carburetors, we shall first deal with the subject of gasoline, vaporizing gasoline, and fuel-feed methods.

Gasoline

The usual fuel for automobile engines is gasoline. Gasoline is distilled from mineral oil (petroleum).

When petroleum is heated, it gives off gases, just as water, when heated, gives off steam. When these gases are cooled, they become liquids, and are called gasoline, kerosene, benzine, naptha, etc.

The chief difference between them is their **"volatility."** When a liquid turns to vapor, or gas, it is said to be "volatile." Gasoline should be very volatile to insure prompt starting, and power.

Temperature makes a great difference in the volatility of liquids; for instance, thick, heavy oil is not volatile at the ordinary temperature of the atmosphere, but is volatile when heated.

Gasoline is very volatile at the ordinary temperature of the atmosphere. It is so volatile that it must be kept in air-tight tanks, for it would entirely evaporate if left exposed to the air. Gasoline vaporizes easily, and as the vapor is heavier than air, it sinks to the ground.

Gasoline and fire: Because of this volatility, gasoline must be handled with care to prevent fires and explosions. It should never be handled near an open flame.

In case of fire, do not try to put it out with water, for the burning gasoline will float and spread the fire. Always keep a pail or two of sand handy, and smother the flames with it. Damp sand, flour, or a wet blanket will smother the fire. In case of fire, the first thing to do, if it is possible, is to turn off the supply cock from the tank to the carburetor, and then push the car away from the blazing gasoline on the ground. Do not let a pool of gasoline drip from the carburetor when priming it, as a chance short circuit may give a spark that will set it on fire. Note: Carbon tetrachloride is superior to sand, etc. Gasoline fire extinguishers can be had of supply houses.

A low grade of gasoline will produce poor results in any carburetor. Difficulty in starting is the main disadvantage in its use, as it is not as volatile as a high-gravity gasoline.

Inferior, or too much gasoline is generally indicated by a **black smoky exhaust** and a disagreeable odor. When a low-gravity gasoline is used some effective method for vaporizing it must be employed.

A test by hand: To ascertain how near kerosene you are getting, pour a little gasoline in the hand. When it evaporates slowly and leaves a greasy deposit, it is of a very low grade. When it evaporates rapidly and leaves the hand dry and clean, it is of a higher grade. This furnishes a fairly reliable test.

Testing gasoline with a hydrometer was the method used a few years ago. It is used as follows: Fill the glass tube with gasoline, and insert the hydrometer, which will float. The gravity of the gasoline is determined by the depth the hydrometer sinks in it. A scale is graduated on the upper portion of the hydrometer and the level of gasoline indicates the specific gravity. The scale usually runs from 60 to 80. Gasoline under 60 test ought not be used. It averages about 64 to 68, and the better grade is 72.

Gravity is no longer an accurate test of the merits of the fluid, the only really accurate test being from a maximum and minimum boiling-point. It is, of course, not practical for the average owner to make such tests, and the best rule is to purchase from a reliable distributor, who handles gasoline manufactured by responsible distillers.

Most of the gasoline today sold for motor-car use differs from that of several years ago in that it is not all of one grade, but is a compound or blend of the different petroleum elements; some of it being very light and volatile, while about one-fourth of it may have a boiling point higher than that of water, and is correspondingly difficult to convert into a vapor. Gasoline of 56° to 64° Baume paraffine base is used almost universally in the United States east of the Rocky Mountains. Fuels of lighter gravity are also produced from asphalt base petroleum. In certain sections of the country gasolines of very low grade have recently been introduced, one-half being actual kerosene. With this fuel and the ordinary intake manifold it is almost impossible to make an engine operate properly either at closed or open throttle, unless radiator is covered up and cooling water is brought to a temperature of 160° to 180° F.

To use this fuel it is necessary that the whole carburetor and intake manifold system be thoroughly heated. Without this heat the carburetor setting will have to be changed and made richer than necessary, while the extra heavy part of the fuel, not vaporized, will burn slowly in the cylinder, forming carbon, and sooting up spark plugs, etc.

There is, of course, a period of time when starting the engine cold, when the rich mixture will be necessary (and can be furnished by the dash control), but the control should be released as soon as the engine becomes warm.

It is also advisable, while the engine is cold, to avoid opening the throttle full, as the fuel vaporizes much more readily in the suction or partial vacuum which exists in the manifold while the throttle is partly or completely closed.

In very cold weather it is advisable, instead of readjusting the carburetor or using the dash control continuously, to cover part of the radiator surface, so that normal temperature is maintained under hood.

In some parts of the country there is so great a range in the constituents of the gasoline sold that the lighter or more volatile fractions may, in warm weather, **boil in the carburetor,** under normal operation of the car. In this case, the hot-air supply to the carburetor may be disconnected, while care should be taken that the gasoline supply line from the tank to carburetor does not approach exhaust pipe, cylinder walls, or other heating influences.

Low and High-Gravity Gasoline

The proper gravity of gasoline to use is governed by conditions. In the summer a low gravity vaporizes much more easily than in the winter; therefore the engine starts easier.

A great many claim that the low gravity gives results as good as or better than high-gravity. Probably it does, as there are more heat units per gallon, but as a matter of easy starting and absence from carbon deposit, the high gravity is preferable, unless the carburetor has been properly adjusted, and priming and heating methods are provided.

With the high gravity we have a high "flame" rate (mixture burns rapidly), whereas, with the low gravity, we get a higher combustion heat, but slower "flame" rate. With a high flame rate the mixture burns rapidly—pressure rises quickly and imparts a powerful push at the commencement of the stroke, but falls away equally quickly as the stroke progresses.

With low-gravity gasoline, the reverse occurs. The explosion generates slowly and does not impart a violent shock, but with a retarded flame rate, and the pressure predominates through a much greater proportion of the stroke. The results are obvious. With high speed, as in racing, the high gravity is best. For medium speeds, where steam-engine-like power is required, combined with fuel economy, low gravity is best—providing the carburetor has been readjusted for the low-gravity fuel and proper heating arrangements are provided.

Owing to the great amount of **carbon in low-gravity gasoline** it is very necessary that the carburetor be properly adjusted.

The starting will be more difficult with low gravity, but with the use of a primer and a hot-air arrangement, this trouble can be overcome.

It is a well-known fact that **an engine,** especially an old one with loose bearings and slack pistons, **will run much more quietly on low-gravity gasoline.** This is due to the slow flame rate; the pressure is gradual on the piston head and presses rather than slams.

How Unvaporized Gasoline Thins or Dilutes the Lubricating Oil

Gasoline vapor that is not completely consumed in the engine does one of three things: it either passes out into the exhaust in an unburned state and is wasted, is deposited in the form of carbon within the cylinder, or condenses and runs down past the pistons into the crank case.

The first of these is the most direct loss, but the other two are equally important in the long run. A carbonized engine is of itself inefficient. Carbon makes the engine miss, makes it overheat and preignite. All of these things are sure to shorten the life of the engine.

When the unburned fuel runs down past the piston, it destroys the seal between piston rings and cylinder, removes the oil film which is to protect the surface of the cylinder, piston, cam, and crank shaft bearings from friction and wear, and, lastly, dilutes the lubricating oil in the crank case to such an extent that in time it becomes worthless.

Manufacturers are advising now that the crank case be drained even more frequently than ever before for this very reason. As cold weather approaches, the necessity for frequently refilling completely with new oil will become more imperative. Either the motorist is forced to drain out his oil and refill with fresh at an increased outlay, or he must suffer the consequences of an engine damaged by insufficient lubrication. See also page 167.

Dilution test: See page 1075, also page 166.

Starting Engine

Remember, when you start an engine by closing the air intake and thus choking off the air, that pure raw gasoline is being drawn into the cylinder. For this reason, a **heating method** of some sort should be attached to every carburetor, so that the gasoline will become heated and vaporized as quickly as possible, thus avoiding the use of the choker for any length of time.

Priming Methods

On a cold morning, **after the engine and all parts have become chilled,** we find that the ordinary grade of gasoline now in use does not vaporize readily until it is heated. Considerable cranking of the engine is sometimes necessary in order to ignite the cold, damp, unvaporized gasoline.

There are several methods of overcoming this; one being to use a higher grade of gasoline. But even with the higher grade, which is difficult to obtain, on a really cold day the starting will be somewhat difficult with some makes of carburetors. For these reasons, **priming,** by injecting raw gasoline into the cylinder, is necessary.

Examples of various priming methods are explained in Figs. 1–6:

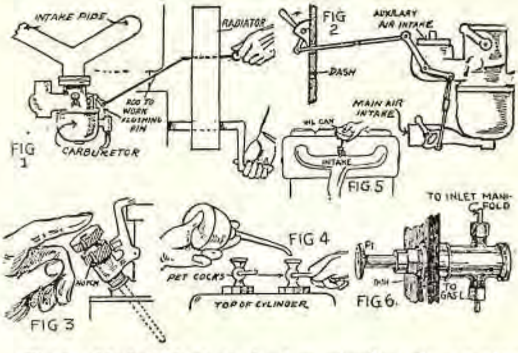


Fig. 1. Method of priming by depressing float, thus opening the float needle valve, and providing an excess of gasoline to be drawn into cylinder.

Fig. 2. A damper is provided in the main air-intake pipe. When closed, the suction provides more gasoline than air. Sometimes the tension of the spring on the auxiliary air valve is regulated from the dash or steering post.

Fig. 3. Priming the carburetor by opening the gasoline needle valve. This method is not advisable, however, because the adjustment valve is a very sensitively adjusted part of the carburetor, and will upset the proper working of the carburetor after the engine is heated up. If this method is employed, be sure to mark a notch on the head of the valve, so that it can be turned back to its original adjusted position.

Fig. 4. Priming with gasoline through priming cups.

Fig. 5. The oil-can primer, where gasoline is injected into the intake manifold. Simple and effective when other methods fail.

Fig. 6. The spray primer; a small injector pump. The suction part of the pump is connected to the gasoline supply pipe between the tank and carburetor. The other part connects to the intake manifold; one stroke of the plunger sprays a charge into the manifold. The Imperial Brass Co., of Chicago, manufactures a pump primer of this type.

When an engine fails to start during cold weather and you are positive there is a good hot spark, an effective method is to pour boiling water over the carburetor and inlet pipe. A resort to the "choker" or "damper" principle, however, usually results in starting the engine.

The "damper" or "choke" method is shown in Fig. 7. Instead of lowering the float, the air intake is closed. This causes an increased suction of gasoline and is called "choking" the air supply.

Too much priming, however, will fill the float chamber so full, that gasoline will run out of the spray nozzle, giving a rich mixture, on which the engine will not start; it will then be necessary to open the switch and close the throttle, and to crank the engine a few times to draw in more air. Then close the switch and crank again, when the engine ought to start if there is a good spark.

In either method explained, remember that **a good hot spark must be provided** in order to ignite this raw gasoline, because it is harder to ignite when cold than after it is warmed up.

After the engine is started, some means should be employed for heating the gasoline so it will vaporize quickly and thus prevent raw gasoline being drawn into the cylinder.

Vaporizing Gasoline

Gasoline gives off more vapor at about 170° Fahr. It is the vapor mixed with air which is most desired. With the proper mixture there is more uniform power and flexibility.

Carbureting means breaking up the gasoline into infinitesimally small particles, mechanically, without heating, which is called "spraying." This is the best method, but is very difficult to accomplish, owing to the different amounts of gasoline passing from the spray nozzle, and on account of the variation of the throttle, or of the speed.

If a low gravity of gasoline is used, it is necessary to heat and vaporize the mixture, because it is practically impossible to break it up; but if it is a high-gravity gasoline, it generates into gas or vapor more quickly. In other words, it is the vapor that we must obtain, which is possible with high-gravity gasoline. In using high-gravity gasoline, however, it must be remembered that it will not stand as much heating as low-gravity gasoline, for if too much heat is used, it makes the mixture so rare that the actual amount of gasoline that goes into the cylinder is so small and at such a low flash point, that it ignites quicker, and will burn and expand more like powder. It will do its work and cool before the piston gets well under way. Furthermore the pressure on the piston does not last as long.

Owing to the low-gravity gasoline now being used, the mixture is not a true vapor. Instead of forming a gaseous mixture, it condenses inside of combustion chamber and manifold. Therefore a plentiful supply of heat is required.

As previously stated, the use of **low-gravity gasoline** requires more heating or vaporizing than a high grade. It might be compared with the firing of a furnace with soft coal. If soft coal is properly fired and is properly mixed with air, it will produce the most heat without producing very much smoke. Just so with a low grade of gasoline. If properly vaporized, it will work fairly well, otherwise carbon deposit and smoke will be the result.

High-gravity gasoline may be compared with hard coal. It is very easy to get the proper mixture of air with the high-gravity gasoline, because it is so very "volatile"—meaning that there is more vapor, and less vaporizing is necessary, and that it will "carburet" more readily. Therefore it will work satisfactorily in most any carburetor construction. Just so with hard coal. It will burn with less smoke and produce an equal amount of heat even though you burn it in an open shovel, and makes very much less carbon.

On stationary and high-duty marine engines a low gravity fuel is used, as kerosene and oil, but before it can be used it must be "vaporized."

An engine with a correctly heated mixture runs on less gasoline. Therefore a closer adjustment of the gasoline needle valve or a smaller jet in carburetor is usually necessary.

An engine requires **more gasoline in winter than in summer,** as the gasoline does not vaporize and readily mix with the air until warm. See also page 462B.

Heating Methods

What we desire to heat is the gasoline, so that it will **vaporize** and enter the cylinder in the form of gas or **vapor** instead of raw gasoline, and thus readily mix with the air.

We might classify heating methods under six classifications as follows:

1. **Heating the air** which is drawn into the main air intake of the carburetor, and which mixes with the gasoline vapor as it is drawn into the cylinder.
2. **Heating the mixture** when drawn into cylinder.
3. **Heating the air and the mixture.**
4. **Heating the carburetor.**
5. **Restricting the water flow** by a water thermostat (see page 149).
6. **Covering the radiator front and hood louvers** (pages 149, 150, 650).

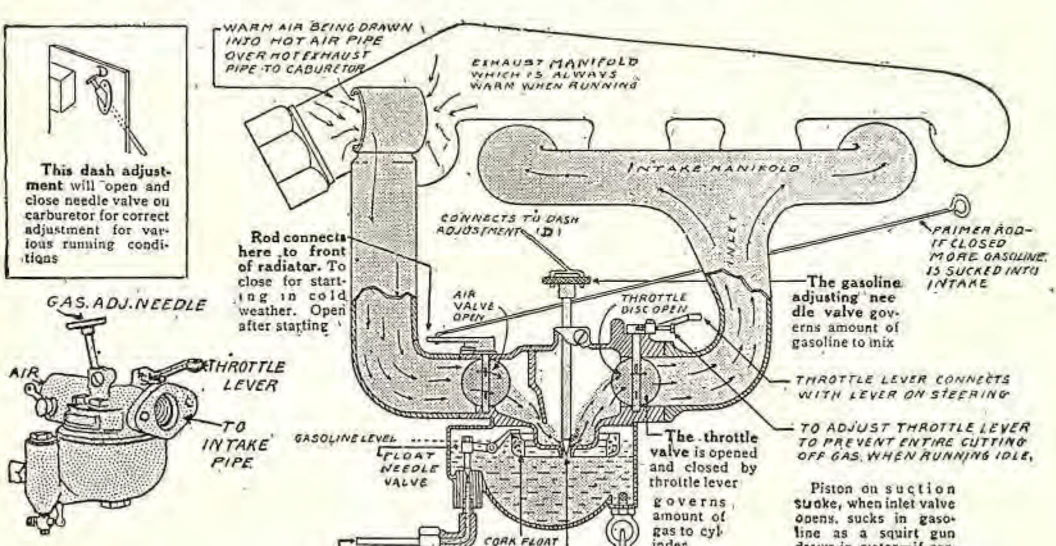


Fig. 7. **Float principle:** When gasoline and air are drawn into the cylinders by suction of the piston, the float automatically lowers, thereby opening the float needle valve and permitting more gasoline to enter the float chamber. When the engine is not running the float chamber fills up, causing the float to rise, thereby closing the float needle valve. This prevents more gasoline entering, which would cause overflowing and dripping. If the float happens to become loose or lowered more than intended, it would not cause the needle to cut off the gasoline supply—hence dripping would result. (Note the dotted lines indicate the gasoline level.)

Heating the Air*

The illustration (Fig. 7) is that of the early model "Y" Kingston carburetor, used on the Ford.

The air is taken in at the "air-valve" opening. A hot-air pipe is shown connected, which admits warm air to be drawn in from around the exhaust pipe. This is a good example of **how the air is heated** before being drawn into cylinders. It will be noted that there is no auxiliary air valve on this carburetor.

Priming method: The damper or "choker" or "primer" method (Fig. 7), for priming or feeding the engine more gasoline for starting is operated by closing the damper or "air valve." This is used principally during cold weather.

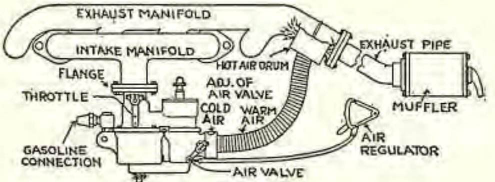


Fig. 8

Another example of **heating the air** drawn into the carburetor and also a method of admitting cool air is shown in Fig. 8. This is practically the same principle as in Fig. 7. Hot air is drawn into the main air-supply opening of the carburetor. A **hot air drum,** also called a "stove," is fitted around the exhaust pipe, not close, but placed so that air ca be drawn in where the arrows indicate. A flexible tube then permits the air to flow to the air opening of the carburetor.

A valve is provided, called the **"air valve,"** also called a "damper" or "choker," which can be opened or closed by the "air regulator" lever, usually placed on the steering column or dash. This lever operates a butterfly type of valve in the air opening of the carburetor.

Choking air supply to start engine: When starting the engine, this air valve is closed, cutting off the air supply to the carburetor and causing an increased suction of gasoline to enter the cylinder (or an extremely rich mixture). This gives the initial priming for starting. Immediately the engine is started, the air valve is slightly opened to admit air. As the engine becomes warmed up, the air valve is opened more and more until fully open, or, in other words, to where the engine runs without missing or jerking which is common during cold weather. It is well known that engines will miss when first starting, due to the gasoline particles being unevaporated, which, in turn, is due to lack of heat. But after the engine is warm, the gasoline becomes vaporized and the engine runs without missing. The idea is to run on as much air as possible at all times. Therefore open the air valve to the point where missing will not occur.

By this method, warm air will be drawn into the carburetor whenever the air valve is open. But after the engine is thoroughly warm, and especially in summer, the air valve is opened more fully, thus permitting more air to be drawn in and mixed with cool air taken in at the "cold air" opening.

Temperature regulator: After the engine is well warmed up, it ought to have more air, and the more air used, the less gasoline required.

If warm air is drawn into the carburetor after the **engine is very hot,** then the mixture would be made too rare or lean.

We also know that gas expands in direct proportion to the degree to which it is heated. Therefore, when **heated too much,** the gas is unduly or prematurely expanded to such an extent that it **loses** a certain percentage of **its energy.** Furthermore, the piston will draw in a smaller amount of gas during each stroke.

The best degree for general running appears to be somewhat below the boiling point of water, i.e., between 170° and 200° Fahr.

Therefore some means of **admitting cool air** must be employed which will mix with the warm air. This would be termed a "temperature regulator."

Adjustable temperature regulator: It will be observed, in Fig. 8, that the cold-air opening is a fixed opening and the amount of cold air drawn through the air valve is not adjustable. The amount of warm air drawn in, however, is governed by the air regulator. The arrangement shown in Fig. 9 is slightly different. The cold-air opening is adjustable.

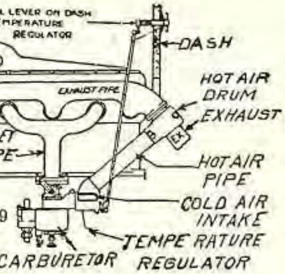


FIG. 9

The temperature of the warm air entering the carburetor can be regulated by opening the cold-air intake, thus permitting cool air to be drawn in. The use of this opening is governed more or less by the temperature. In summer, the opening is usually wide open, but closed more or less during cold weather.

Heating the Carburetor Mixture

There are various methods employed for heating the mixture, as it enters the cylinder, as follows:

1. **The hot-spot method** or heating the inlet manifold by placing it adjoining the exhaust manifold, as in Figs. 10 and 11.
2. **Passing hot exhaust gases** through a jacket surrounding the inlet manifold (Fig. 12).
3. **By circulating hot water** through a jacket around the inlet manifold (Figs. 13 and 14).
4. **By circulating hot water** through a jacket around the carburetor (Fig. 15).
5. **By passing exhaust gases** through a jacket around the carburetor (Fig. 16).
6. **By heating the mixture** with an electric resistance (Fig. 17).
7. **By a method termed a "fuelizer,"** as used on the Packard (Fig. 18).

The various methods mentioned above will now be illustrated and described. The reader should observe, however, that these examples refer to "heating the mixture" after the air has been taken into the carburetor through the main air inlet and mixed with the gasoline.

* This method now seldom used. More modern methods are heating the mixture or heating the unvaporized gasoline (explained further on) to avoid the disadvantages of overheating the air as explained on this page. (Fig. 7 applies to early model "T" Ford.)

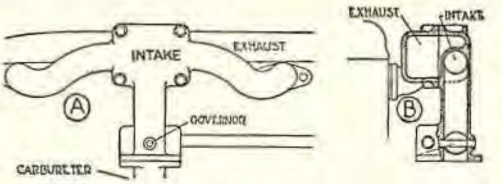


Fig. 10. "Hot-spot" heating of mixture by placing the exhaust manifold adjoining the inlet manifold. Only a part of the inlet manifold is heated: the upper part. The idea here is to prevent condensation of fuel. The liquid particles, when they reach the top of the vertical passage, do not swing to the left or right with the gas, but go straight, since they are heavier, until they strike the hot spot.

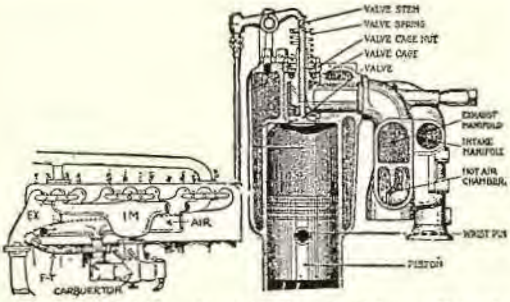


Fig. 11. Buick's exhaust heating of mixture. Note the exhaust manifold which adjoins the inlet manifold (IM). The lower part of the exhaust manifold (hot-air chamber) is divided from the exhaust (above). Air passes through the lower chamber which is heated. Hot air is also drawn into jacket around the upper part of the carburetor by a flexible tube connection (FT).

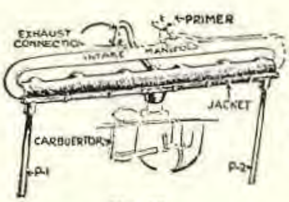


Fig. 12

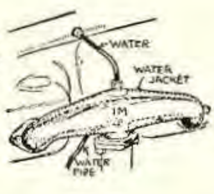


Fig. 13

Fig. 12. Franklin exhaust method of heating the mixture. Note the jacket which encloses the intake manifold through which exhaust gas passes. A cut-off is provided when the engine becomes very warm. **P1** and **P2** pipes are left open. See also page 142.

Fig. 13. Stutz hot-water-heated intake manifold.

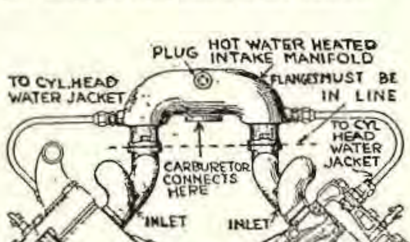


Fig. 14

Fig. 14: Hot-water heating of mixture as employed on the Oldsmobile eight-cylinder "V"-type engine. Note the hot water circulates through a jacket around the inlet manifold. This principle is more effective than heat around the carburetor. Exhaust gases can be passed through this jacket instead of hot water, which will heat the mixture quicker, and is more generally used.

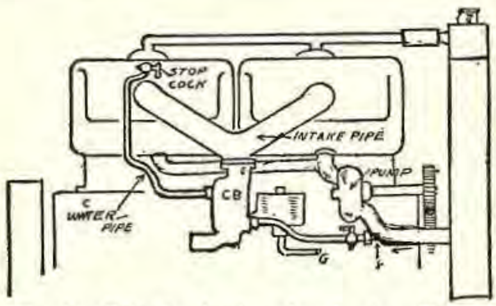


Fig. 15. Hot-water heating of carburetor. The usual method of connecting the hot water to the carburetor water jacket is to connect the upper water connection to the cylinder water jacket or pipe, and the lower one to the suction end of the pump (between radiator and pump). See that the connections are made in such a way that water will drain out of the carburetor jacket when the system is drained. Place a shut-off cock in the line for use in extremely hot weather.

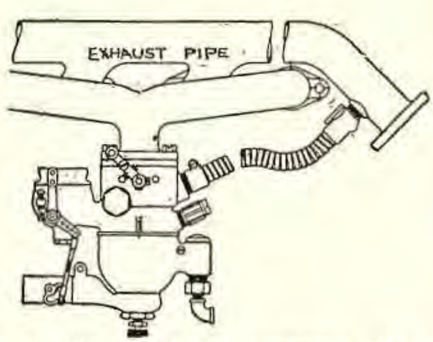


Fig. 16. Exhaust-gas heating of carburetor. The exhaust gases from the exhaust pipe can be carried to the carburetor water jacket, by tapping the exhaust pipe and connecting a flexible or copper tube to the water jacket. It is advisable to use as large a pipe as possible—say ½", as it has a tendency to clog up. The other opening of the water jacket is left open by a ⅜" or ½" copper-pipe connection extending to the lower part of the engine for emission of gases.

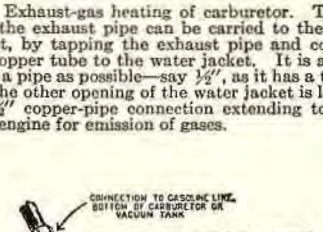


Fig. 17. Heating the priming mixture electrically. A pipe connects with gasoline supply. The primer is screwed into the inlet manifold. Suction of the piston draws in raw gasoline. An electric heating coil connected with the battery heats the gasoline used for priming as it passes into the manifold. There are various electrical methods for heating.

See also page 142 for **Franklin electric vaporizer.**

Packard "Fuelizer" for Heating Mixture

The pipe marked "By-Pass" (Fig. 18) carries a minute quantity of gas direct from the carburetor to the fuelizer, a small combustion chamber surrounding the intake manifold.

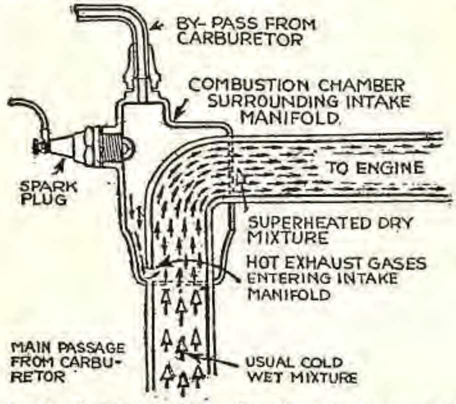


Fig. 18. Packard fuelizer. See also Fig. 51, page 140.

The gas is ignited by means of an independent spark plug in this chamber, as shown, and circulates at a very high temperature through the fuelizer chamber which surrounds the intake manifold. At the bottom of the fuelizer chamber are two small holes through which the superheated exhaust of the fuelizer enters directly into the main inlet manifold.

Thus the main inlet manifold temperature is raised by direct mixing with the fuelizer exhaust as well as from the heat developed in the fuelizer chamber.

The result is that all gas passing through the main manifold is thoroughly dried, sufficiently heated, and broken up into a completely combustible fuel. Any grade of commercial gasoline, after receiving this treatment, explodes without a trace of carbon and without depositing lower grade fuels.

The circulation of gas through the fuelizer pipe and chamber is maintained by the same cylinder suction which draws gas through the main manifold. However, the circulation of gas through the fuelizer starts below the butterfly valve of the carburetor and exhausts into the main inlet manifold.

When the butterfly valve is closed, engine suction is very heavy upon the fuelizer; it receives a maximum supply of gas and gives off a maximum heat.

On the other hand, the farther the butterfly valve is opened, the less becomes the suction of the engine by the way of the fuelizer, because it is easier for the engine to suck the gas by way of the main manifold. This automatically decreases the heat given off by the fuelizer directly in proportion to the decreasing need of the engine for heat.

When the engine is being started, or idling, the fuelizer is going at maximum. But when the engine reaches an ideal combustion heat, because of high-speed traveling, or heavy low-gear work, the fuelizer automatically shuts off until it is again needed.

The Lexi-Gasifier

The following illustration and explanation is taken from the instruction book of the Lexington series "S" model. The air is not heated, but is drawn in cold.

Incorporated in the Moore multiple exhaust system manifold is a device that converts all the heavy portions of the fuel not vaporized by the carburetor into gas, which is taken up by the air stream and carried into the engine cylinders to do useful work instead of going down the cylinder walls, destroying lubrication. All of the highly volatile portion of the fuel, in passing through the carburetor, is vaporized and is carried by the air stream into the engine cylinders. The heavy portion, or "high-end point," after passing the throttle valve, is deflected into the hot grid back of the manifold, by the bend in the pipe immediately above the carburetor.

The system is so designed that all six of the exhausts play on the back of the grid, keeping it quite hot. All heavy particles of fuel falling into this grid are instantly converted into gas, which rises and is carried by the air stream directly into the engine cylinders. Its action is similar to pouring gasoline on a hot stove.

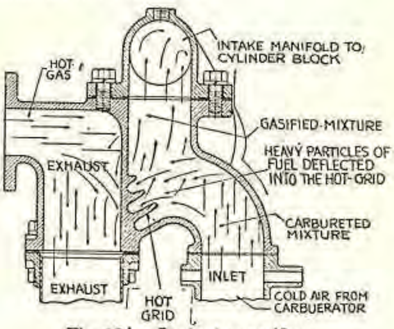


Fig. 18A. Lexington gasifier.

This device is not to be classed with the hot-spot manifolds, which heat the carburetor mixture (both air and fuel). Heating the air expands it, and prevents the cylinders from taking in the maximum amount of oxygen units to mix with the fuel, thereby weakening the explosions.

In the Lexi-Gasifier the air passes in almost cold, taking with it the gasified fuel, providing the maximum oxygen units in a given space for this fuel. This excess of oxygen and gasified fuel produces a greater pressure in the cylinders, hence more power.

After all, the power obtained from the internal combustion engine is the difference in temperature of the incoming mixture and the temperature to which we can raise this after burning.

Cadillac "61" Carburetor Thermostatically Controlled

The carburetor on the type "61" Cadillac is provided with thermostatic control for the tension on the auxiliary air-valve spring and also for regulating the effectiveness of the accelerating pump.

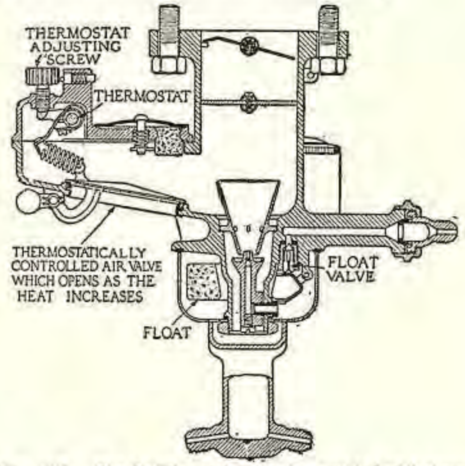


Fig. 18B. The Cadillac carburetor is provided with thermostatic control on the auxiliary air-valve spring and also for regulating the effectiveness of the accelerating pump.

Referring to Fig. 18B showing a sectional view of the carburetor, it will be noted that the manual setting for the air valve is employed as usual, but superimposed on this manual setting is a thermostat which alters the tension of the air-valve spring in accordance with temperature requirements.

On a cold engine the spring tension is increased, thereby causing increased resistance to the opening of the auxiliary air valve.

In warmer weather the effect is the reverse, thus tending to make the mixture leaner.

The thermostat on the accelerator pump (not shown in the illustration), which is located in the fuel chamber, operates a shutter which covers and uncovers a vent, thus increasing the effectiveness of the pump when the engine is cold, and decreasing it when the engine is warm. In other words, when the vent is open the accelerator pump has little or no effect, but when it is closed the accelerator pump or throttle pump will force gasoline through the spray nozzle, when the throttle is opened quickly for acceleration. When the throttle is opened slowly the pump has practically no effect on the gasoline. The throttle pump is interconnected with the throttle, and its function is to force compressed air into the float bowl. When the thermostat comes into effect and opens the vent, the air, of course, cannot be compressed, and consequently the pump operation is materially reduced.

It is claimed that the introduction of these two thermostats materially reduces the warming-up period of the engine. (*Motor Age.*)

Heating the Air and the Mixture

A combination of heating the mixture and heating the air is shown in Fig. 19. The exhaust manifold adjoins the inlet manifold which heats the mixture as it enters the cylinders. Warm air is drawn around the upper part of the carburetor, admission of which is controlled by a throttle which keeps the upper part of the carburetor warm. Warm air is drawn in the main air supply which heats the air. **A temperature regulator,** controlled from the dash, admits cool air into the main air supply when the engine is thoroughly warmed up.

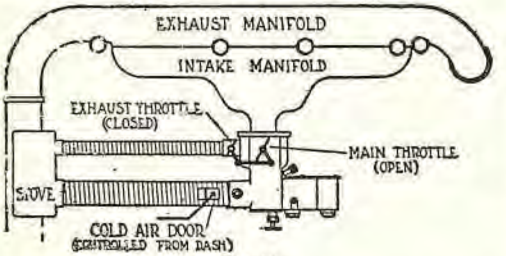


Fig. 19

For starting, the lower air opening of the carburetor can be closed entirely, which "chokes" the air and causes gasoline to be drawn into the cylinder until the engine starts. This system is used on the Nash trucks and is an ideal system.

Fig. 20. Wilmo exhaust-heated intake manifold, designed for Fords and other cars. An example of method for heating the mixture just before it passes into the cylinders. The carburetor connects with the lower, or inlet part of the manifold; the exhaust is the upper part, with a plate between. By completely vaporizing the gasoline, no residue is left to seep into the crank case to thin the lubricating oil.

Remarks on Water and Exhaust Heating

If the intake manifold is heated with water, the temperature is not so liable to cause overheating, as the temperature seldom goes above 170° to 200°, especially if a thermostatic principle is used.

When the engine is cold, after standing all night, the water does not heat as quickly as if exhaust-gas heated, but when the engine is run and warmed up and left standing, the water will remain warm for some time and will quickly heat again. The water is quite often circulated around the carburetor and inlet manifold and in connection with a temperature regulator and heated air intake. A water heating system can be used only with engines using a force or pump water-circulating system.

When the intake manifold is heated by the exhaust, the temperature is liable to increase to a high degree, if the engine is run continuously for a long period. The latter system, however, will heat the mixture more quickly than the water system, when the engine is cold. Therefore means for admitting cool air and some means for cutting off the exhaust gases from the manifold jacket ought to be provided, especially in case of the long-continued running of the engine.

HOW TO DETERMINE THE SIZE OF CARBURETOR TO USE

The size of the carburetor should be determined by the area of the valve opening on the engine, and not by the cylinder displacement, as the former is a true measure of the engine capacity. A carburetor cannot deliver more charge to a cylinder than the area of the valve opening will allow to pass.

A large carburetor with too much passage area cannot cause an engine to deliver more power than it would with one having a passage equal in area to that of the valve opening. Too large a carburetor would not only waste fuel, but would reduce the power of the engine by furnishing a weak mixture.

If the carburetor is too small the engine will not develop its rated power, as it could not deliver a full charge at high speed.

When a carburetor is small for the engine, it **becomes very cold** while in operation, as the amount of heat necessary to effect the vaporization of the gasoline is more than is available from the entering air or than could be secured through the metal carburetor by conduction. The temperature of the metal part of the carburetor becomes so low that water condenses on it, and, in some cases, is in the form of frost. These results are produced by the use of a carburetor too small for the engine. To meet these conditions, some makers provide means for heating the air supply, as previously shown.

It follows that the carburetor of proper size should have its passage area equal to the valve opening of the engine. In multiple-cylinder engines this area is equal to the valve opening multiplied by the number of suction strokes which take place simultaneously, determined from the sequence of cranks.

It will spell failure to fit a carburetor with a large jet and opening to an engine in which the exhaust closes very early, because the surplus gas cannot be expelled as completely as with an engine having a very late-closing exhaust valve.

Carburetor sizes are determined by the opening leading to the manifold. These openings are slightly larger than the indicated size of the carburetor.

For example: The opening on three different makes of carburetors varies as follows: **1-inch:** Schebler, 1 3/16″; Rayfield, 1¼″; Stromberg, 1 3/16″; **1¼ inch:** Schebler, 1⅜″; Rayfield, 1½″; Stromberg, 1 7/16″; **1½ inch:** Schebler, 1⅝″; Rayfield, 1¾″; Stromberg, 1 11/16″.

In fitting a carburetor to the manifold, the carburetor opening should be slightly smaller and never larger than the opening in the intake manifold.

S.A.E. flange openings are as follows: **1-inch carburetor** has 2⅜″ between bolt-hole centers; **1¼ inch carburetor** has 2 11/16″ between bolt-hole centers; **1½″ carburetor** has 2 15/16″ between bolt-hole centers.

GASOLINE OR FUEL FEED TROUBLES[1]

The tank of a fuel system is always provided with a small hole, usually drilled through the filling cap, as at (V), Fig. 1, by which air may enter to replace the gasoline as it is drawn off. If this hole becomes clogged with dirt, the gasoline in flowing out will tend to create a vacuum, and the flow will stop.

The outlet pipe should project slightly above the bottom of the tank, so that water and dirt may settle, and not be carried to the carburetor. A filter screen should also be provided.

A temporary repair for a slight leak in a gasoline tank can be made by applying ordinary soap. Such a repair may last till the defective part can be soldered. Leaks at gasoline taps can generally be cured by screwing up the nut securing the tap plug, or by grinding in the tap with crocus and oil.

If gasoline drips from the feed line, examine connections (A) and if it **drips from the carburetor** it is probably due to the float needle valve failing to seat properly. Gasoline leaks are sometimes difficult to locate.

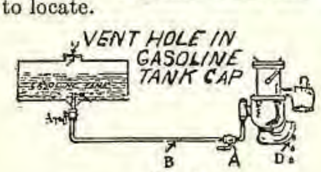


Fig. 1

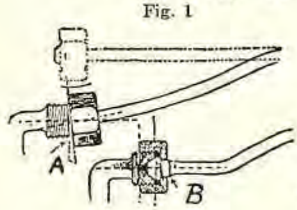


Fig. 1A

Fig. 2

If gasoline fails to flow to the carburetor, see that (V), Fig. 1, is open. If this is open, then examine the filter screen at the bottom of the tank. If this is open, then remove pipe (B) and blow it out. If this is open, then take the carburetor apart and see if it is clogged up with waste or sediment.

Gasoline feed-pipe connections should have special unions. See Index under "Pipe connections." The threads are very fine and can easily be crossed. Therefore use every precaution not to "cross-thread" when joining a gasoline pipe coupling as at (A) (Fig. 1A). In (B) the threading is straight and correct.

Gasoline rots rubber rapidly and should not be conveyed through a rubber hose, nor should joints be packed with rubber. Shellac or soap may be used when screwing joints together, as it helps to make them tight.

Draining: The lowest point of the gasoline line on a vacuum-feed system is the bottom of the gasoline tank. On a gravity feed system it is at the carburetor. A strainer made of brass wire mesh is usually at the lowest point, and should occasionally be removed and cleaned.

Water in gasoline is indicated generally when the engine runs irregularly and finally stops. This will often prevent starting of the engine. Water is frequently present in gasoline, and, particularly when the tank is low, is liable to get into the pipes and carburetor. The drain cock at the bottom should be opened occasionally to let off the water and sediment.

In cold weather, this water is liable to freeze, preventing the action of the carburetor parts. Ice in the carburetor can be melted only by the application of hot water (or some other non-flaming heat) to the outside of the float chamber.

To prevent water getting into the gasoline and freezing during cold weather, thereby clogging the flow, strain through a chamois.

Gasoline ought to be strained. Many carburetor troubles would be avoided if more care were taken to free gasoline of all dirt before its entrance into the tank, and, later, into the carburetor (Fig. 2).

It is said that **static electricity will be generated** when straining through a funnel and chamois, and a spark is liable to ignite the gasoline. If the funnel is grounded to the tank this cannot occur.

Old gasoline left in the carburetor for some time, when the car is not in use, will lose its strength. If the engine should not start easily, then drain the float chamber.

Stale gasoline: After standing for some time, gasoline will become dead and slow to ignite. This is partly due to evaporation, and partly to chemical changes that take place.

A strainer should be on all gasoline tanks or lines, as water and sediments being heavier, always settle at the bottom.

Addresses of carburetor manufacturers, classified under the type of carburetor they manufacture, are given elsewhere; see Index under "Address of carburetor manufacturers." For detailed information catalogs are of value.

Broken gasoline pipe can be temporarily repaired by wrapping with tape. Be sure the **gasoline pipe is not bent at too sharp an angle.**

Another method of repairing a broken gasoline pipe is to scrape the tube near the break and to wind about 1" of clean copper wire on each side and over the break, and then to solder carefully.

Air leaks cause missing. If the engine persists in missing and this is not due to faulty ignition, then look for air leaks in the inlet manifold. Examine gaskets and see if a crack is in the intake casting—providing the trouble is not in the ignition.

Leaks in the intake pipe gasket are a very common cause for missing at low speeds. This is best detected by letting the engine 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.

Fig. 3

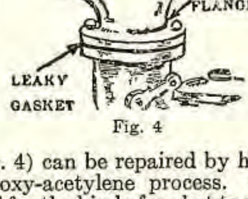


Fig. 4

Cracked flanges (Fig. 4) can be repaired by having them welded by oxy-acetylene process. See Index under "Gaskets," for the kind of gasket to use.

[1] See also pages 462A, 462H-462M.

MAIN GASOLINE TANK, GAUGE, AND SHUT-OFF VALVE

Main Gasoline Tank

The main gasoline tank contains the greater amount of gasoline, and is usually suspended at the rear of the car. The **auxiliary tank** is placed under the hood (see page 112).

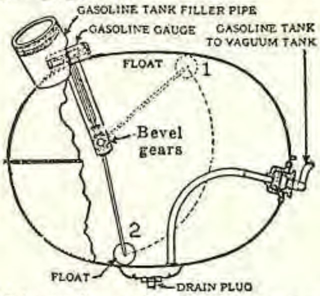


Fig. 5. Main gasoline tank, showing operation of gasoline gauge float. See Index, "Gasoline tank capacities."

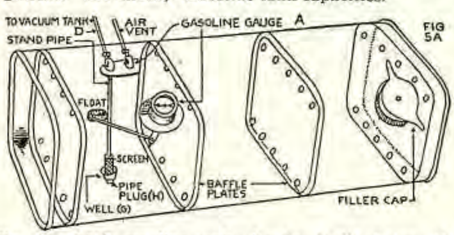


Fig. 5A. Main gasoline tank, showing baffle plates. (G) is a well below the screen which may be opened for cleaning by removing plug (H).

The gasoline feed pipe is the pipe leading from the main gasoline tank to the vacuum tank, and is usually of copper or brass pipe 5/16″ outside and 7/32″ inside diameter.

Baffle plates are provided in the gasoline tank to keep the gasoline from surging from one side of the tank to the other (Fig. 5A).

The gasoline tank gauge most used is the float type. As the tank is filled the float rises until the tank is filled (position 1, Fig. 5); position when empty is as at (2). See also page 649.

Note. Sometimes the bevel gears stick. If so, remove the entire gauge with the float by unscrewing at top. Be careful to replace the cork gaskets.

Gasoline Tank Shut-off Valve

On many cars there is a **reserve of gasoline provided.**

An example is the shut-off valve used on the King (Figs. 5B and 5C). The capacity of the tank is 18 gallons.

The normal supply position of the shut-off valve lever is shown **down** (1) in Fig. **5B.** When in this position, gasoline must feed through pipe **(A)**; consequently the gasoline level must be above pipe **(A)**. When the gasoline level is below pipe **(A)**, with the lever in position (1), the gasoline feed stops, although there is still a two-gallon **reserve** supply left in the tank.

The reserve supply position of the shut-off valve lever is shown in a horizontal position (2) in Fig. **5B.** All gasoline in the tank will now flow out of the tank through (B) (Fig. 5C).

To shut off the supply, place the lever in position (3) (Fig. 5B). **To drain,** remove the drain plug.

There are other similar methods employed on different cars; for example, see page 112 under heading, "A three-way valve located on the top of the gasoline tank," as used on the Packard twin-six car.

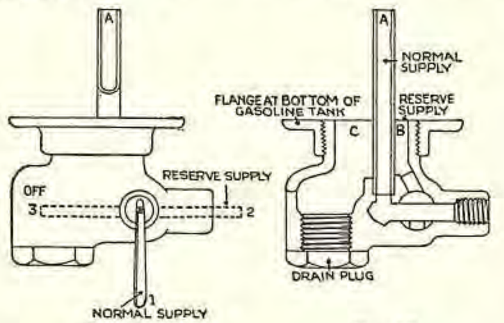


Fig. 5B Fig. 5C

Figs. 5B, 5C. Gasoline tank shut-off valve as used on the King car, as an example.

FUEL FEED METHODS

There are **six methods for feeding gasoline,** some of which are not in general use. They are as follows:

1. By **gravity.**
2. By **exhaust pressure.**
3. By **combined gravity and exhaust pressure.**
4. By **forced air pressure.**
5. By **vacuum and gravity.**
6. By **fuel pump** (there are three types; see page 116A).

The fuel pump, vacuum, and gravity method is used most.

Gravity Feed

A tank is placed above the level of the carburetor so that the gasoline flows from tank to carburetor by gravity (Fig. 6). The tank can be placed at any point on the car, providing it is above the level of the carburetor.

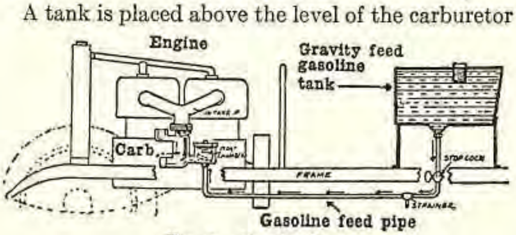


Fig. 6. Gravity feed.

The disadvantage of this where the tank is not close to the carburetor lies in the fact that when ascending hills, or on the side of an incline, the gasoline may fail to flow through the pipe.

Exhaust-Pressure Feed

With this system (Fig. 7, page 112), the tank is placed in the rear. A hand air pump is connected to obtain the initial pressure in the tank. After the engine is started the exhaust gases pass through a check valve to the tank, creating a pressure, which forces the gasoline to the carburetor.

A small pipe is used for the exhaust passage. The pipe being exposed to the air, the gases are cooled and prevent a flame. A check valve prevents the gas passing back, as it can pass in but one direction.

Disadvantage: The pressure is liable to interfere with the proper operation of the float. This system is practically obsolete.

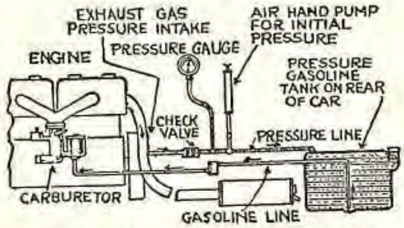


Fig. 7. Exhaust-pressure feed (obsolete).

Gravity and Exhaust-Pressure Feed

Gasoline is forced by exhaust pressure from the main tank to a smaller, auxiliary tank, placed above the level of, and close to the carburetor. The gasoline then flows to the carburetor by gravity (Fig. 8). This system was used in the early days of motoring, but not to any great extent.

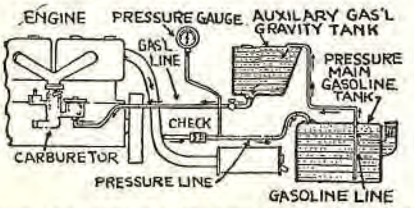


Fig. 8. Gravity and exhaust-pressure feed (obsolete).

Air-Pressure Feed

A gasoline air-pressure feed is shown in Fig. 9, which represents the Packard twin-six system.

General principle: The supply of gasoline is carried in the tank at the rear of the frame. The gasoline is supplied from the tank to the carburetor by **air pressure** (at 1½ to 2½ lbs.) provided by an air pump attached to the engine front-end cover and driven by forward extension of generator shaft.

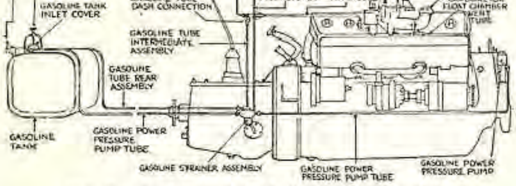


Fig. 9. Air-pressure feed (Packard Twin-six).

The carburetor is mounted above and between the cylinder blocks, and receives heat generated by engine, which assists in vaporizing gasoline.

The gasoline tank is located on the rear of the frame. The capacity of the tank on all models is twenty gallons, including a three-gallon reserve.

A three-way valve located on the top of the gasoline tank connects with outlet pipes leading to each side of the tank. Turning the valve handle to the right permits the gasoline to be completely drained from the right side of the tank and vice versa. When gasoline has ceased to flow, turn the valve handle to its opposite extreme regardless of the previous running position, in order to obtain the reserve supply. Turning handle up shuts off the gasoline.

Caution: If the gasoline tank has been completely drained and is replenished with less than a five-gallon supply, turn the valve handle to the left, which is the side of the tank which receives the first three to five gallons, otherwise, gasoline will not flow.

Air pressure for supplying gasoline to the carburetor is furnished by an air pump attached to the crank-case front-end cover, and driven by an eccentric mounted on the generator shaft.

The air is drawn from outside the crank case and forced under pressure to the gasoline tank. To **increase** the pressure, remove the plug at the top of the pump cylinder and unscrew the smaller plug at its base. To **decrease** the pressure, the small plug should be screwed down.

The hand or auxiliary pump on the instrument board provides a means of obtaining initial air pressure before the engine is started, providing the gauge on the dash shows that there is no air pressure in the gasoline tank.

To obtain pressure by hand, unscrew the handle to the left. When the plunger is free, operate the pump until pressure shows on the gauge. Do not pump higher than 2½ lbs. pressure.

When air pressure is used, if the carburetor has a small float, the pressure should not be over 2½ or 3 lbs. With a larger float, the greater area will withstand more variation in pressure.

If the gasoline gauge does not respond to the hand-pressure pump, it is probably caused by the tank outlet valve being shut off.

Caution: Having finished operating the pump, push the plunger in, and be sure to lock it in place by screwing the plunger handle to the right. **The plunger leather of the pump should be oiled occasionally** with neat's foot-oil. Mineral oils improve the operation of the pump only temporarily, and tend to dry up the leather.

A gasoline pressure gauge on the instrument board is connected directly with the supply line at the gasoline strainer housing. The gauge indicator should show from 1½ to 2½ lbs. pressure when the engine is running.

If the pressure gauge indicates that the pump is not maintaining the proper pressure in the tank, proceed as follows:

Inspect the gasoline-tank filler cap, seat, and gasket to make sure that they are in good, clean condition and free from nicks.

Be sure that the **filler cap is tightly seated.** If the trouble is not found by this method, **examine all connections on the air pressure and gasoline supply lines** to make sure that there are no leaks. **A good method of locating leaks in the air line** is to put pressure in the tank and go over the line carefully with soap suds. If it is determined that all pipes and connections are absolutely air-tight, raise the air pressure by adjusting the pump as described above.

STEWART VACUUM GASOLINE FUEL-FEED SYSTEM

Gasoline is fed to the carburetor through a $\frac{5}{16}''$ copper pipe **by gravity** from the lower chamber of the vacuum tank. **The vacuum tank** is usually placed on the inside of the dash and should be 3″ or more above and near the carburetor, so that the gasoline will feed to the carburetor at all times, regardless of the angle or position of the car.

The **main gasoline tank** is placed at the rear of the car below the level of the **auxiliary, or vacuum tank,** and **gasoline is drawn from the main gasoline tank to upper chamber of vacuum tank by a vacuum process.**

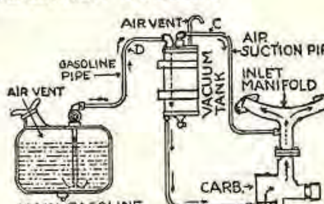


Fig. 1. Connections of Stewart vacuum gasoline fuel-feed system. (See also page 462H.)

Principle of Operation

First, read pages 1078 and 1079 for the definition of "vacuum" and "suction," and page 1074 for "atmospheric pressure."

For example (see Fig. 2B), **suppose the gasoline had just been discharged from the upper chamber to the lower chamber** (which it is doing in Fig. 2C). **The float would have gone down to its lowest position** (Fig. 2B), and in doing so, would have caused the float mechanism (**E** and **F**) to **open** the suction valve (**A**) and **close** the air valve (**B**).

A suction or vacuum action then takes place in the upper chamber, as a result of the valve (A) opening being connected by (C) with the inlet manifold, and the air is thus drawn out of the upper chamber. The vacuum or suction action produced in the inlet manifold is the result of the inlet valve of the engine being open and piston going down on suction stroke.

The flapper valve (**H**) closed because pressure inside of the lower chamber was greater than in the upper chamber.

There is now but one other opening, and that is through the strainer (**V**) and pipe (**D**) leading to the main gasoline tank. There is no valve here. It is always open.

There is an air opening at the vent hole in the filler cap in the main gasoline tank, but the gasoline is between this air opening and the vacuum tank. What is the result?

Gasoline is forced from the bottom of the main gasoline tank through the standpipe, to the upper vacuum chamber, because the atmospheric pressure entering the vent hole in the filler cap of the main gasoline tank exerts a pressure of approximately 14.7 lbs. per square inch on the gasoline, whereas there is practically no air, or a considerably reduced pressure in the upper vacuum chamber. Thus the gasoline flows from a **lower level of a higher pressure** (main gasoline tank), **to the higher level of a lower pressure** (upper vacuum chamber).

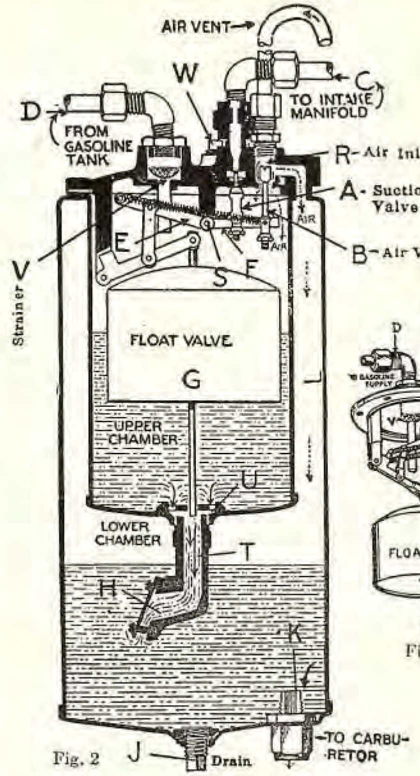


Fig. 2

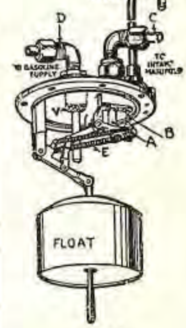
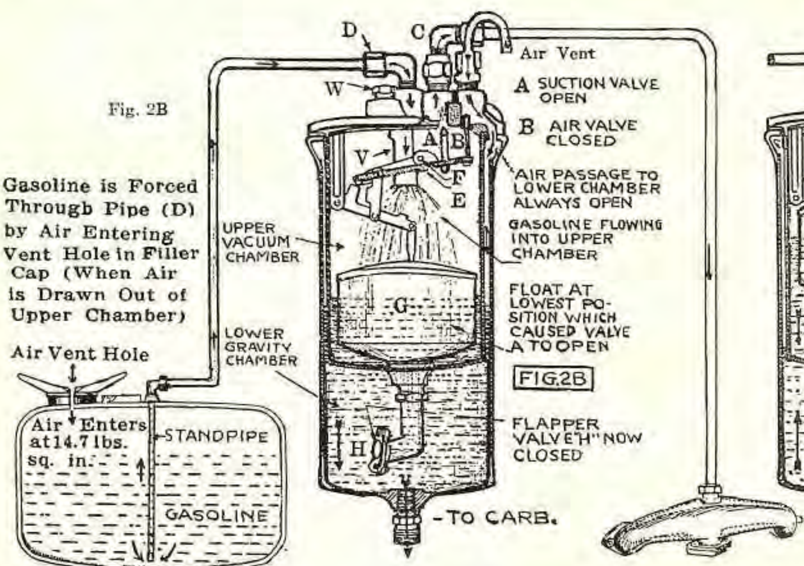


Fig. 2A

Fig. 2. Sectional view of Stewart vacuum tank.

Fig. 2A. View of top of Stewart vacuum tank removed, showing how valves A and B are opened and closed by action of float rising or lowering.

Fig. 2B



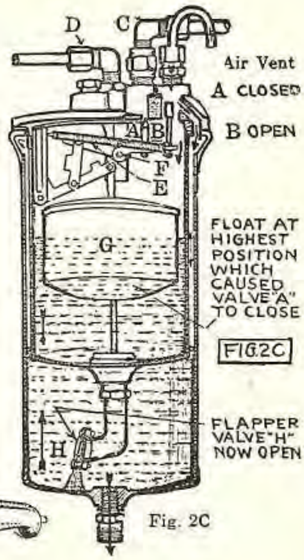


Fig. 2C

Fig. 2B. Gasoline is flowing into the empty upper vacuum chamber from the main gasoline tank. Note that float (G) is at a low level, which caused (A) to open and (B) and (H) to close.

Fig. 2C. The upper vacuum chamber is now full. Float (G) is at high position, which caused (A) to close and (B) and (H) to open. Gasoline from the main tank has ceased flowing. The upper vacuum chamber is feeding gasoline to the lower chamber. During both actions the gasoline still feeds to the carburetor from the lower gravity chamber.

As the gasoline flows into the upper vacuum chamber, the float gradually rises until the upper chamber is full (Fig. 2C), at which time the float mechanism causes the suction valve (A) to close and the air valve (B) to **open.** What is the result?

With air valve (B) open, air enters into upper chamber at atmospheric pressure (from the air vent at top of vacuum tank) and creates air pressure on the gasoline equal to the air pressure above the gasoline in the main gasoline tank. Thus the flow through (D) and (V) stops. At the same time the air pressure on the gasoline in the upper chamber (also because the level of gasoline is higher in the upper chamber) causes flapper valve (H) to open, and to discharge into the lower chamber at which time the float gradually lowers until it assumes the lowest position again (Fig. 2B), and the operation is again repeated, thus constantly supplying gasoline to the lower chamber.

During both operations, as shown in Figs. 2B and 2C, the gasoline still feeds to the carburetor from the lower gravity chamber.

If both upper and lower chambers are empty, the same principle would apply as in Fig. 2B. The flapper value (H) would close because the air pressure inside the lower chamber was greater than in the upper chamber.

It will be noted that the lower chamber is always open to atmospheric pressure (14.7 lbs.) through the "air-vent tube," between the inner and outer tank shell, otherwise the gasoline would not flow by gravity to the carburetor.

Installation

The top of the vacuum tank must be above the level of the gasoline in the main gasoline tank when full, even when the car is going down a steep grade.

Never tap through a water jacket, if the intake manifold is provided with one. Always tap the intake manifold at a point as close to the intake of one of the cylinders as possible.

Vent-Tube Overflow

The air vent allows an atmospheric condition to be maintained in the lower chamber, and also serves to prevent an overflow of gasoline in descending steep grades. If once in a long while a small amount of gasoline escapes no harm will be done, and no adjustment is needed. However, if the vent tube regularly overflows, one of the following conditions may be the cause:

(a) The air hole in the main gasoline tank-filler cap may be too small or may be stopped up. If the hole is too small or if there is no hole at all, the system will not work. Enlarge the hole to ⅛" diameter, or clean it out.

(b) The vacuum tank may not be installed quite high enough above the carburetor. If the bottom of the tank is not 3 inches above carburetor, raise it.

Gasoline Leakage

If gasoline leaks from system, except from vent tube, it can do so only from one of following causes:

(a) A leak in the outer wall of the tank may exist. If so, soldering up the hole will eliminate trouble.

(b) The carburetor connection in the bottom of the tank may be loose. If so, tighten.

(c) There may be a leak in the tubing leading from (D) (Fig. 2).

Failure to Feed Gasoline to Carburetor

This condition may be due to causes other than the vacuum system. To test: after flooding the carburetor, or "tickling the carburetor," as it is commonly called, if gasoline runs out of the carburetor float chamber, you may be sure that the vacuum feed is performing its work of feeding the gasoline to the carburetor.

Another test is to take out the inner vacuum tank, leaving only the outer shell. If you fill this shell with gasoline and the engine still refuses to run properly, then the fault clearly lies elsewhere and not with the vacuum system.

If the failure to feed is in the vacuum tank, one of the following may be the cause:

(a) The float (G), which should be air-tight, may have developed a leak, thus filling up the float with gasoline and making it too heavy to rise sufficiently to close the vacuum valve. **This allows gasoline to be drawn into the manifold, which in turn will choke down the engine.** See page 1041 for testing.

(b) The flapper valve may be out of commission.

(c) Manifold connections may be loose, allowing air to be drawn into the manifold.

(d) The gasoline strainer (V, Fig. 2), or tubing may be clogged up. Look to this first. Pipes can be cleaned by disconnecting and blowing out with air pump.

(e) Suction valve (A), or air valve (B) may not seat properly. See also pages 1041 and 122.

Remedies

(a) **To repair float:** remove top of tank (to which float is attached). Dip the float into a pan of hot water, in order to find out definitely where the leak is. Bubbles will be seen at the point where the leak occurs. Mark this spot (hot water expands the air inside of the float, causing it to show the slightest leak).

Next, punch two small holes, one in the top and the other in the bottom of the float, **to permit discharge of the gasoline.** Then solder up these holes and the leak. Test float by dipping in hot water. If no bubbles are seen, float is air-tight.

In soldering the float, be careful not to use more solder than required. Any unnecessary amount of solder will make the float too heavy.

A temporary repair for a leaky or logged float is to remove head; take out float and punch a small hole at top and bottom; this will permit it to float when replaced; or after punching the holes and gasoline is drained, the holes can be temporarily sealed with chewing gum or tape. **Another plan** is to cut bottom of float off entirely and replace it. A new float should be installed.

To overcome the condition of a leaky float temporarily until you can reach a garage, remove plug (W) at the top. In some cases the suction of the engine is sufficient to draw gasoline into the tank, even with this plug open, but not enough to cause it to continue to be drawn into the manifold. If, however, you are not able to do this, close up plug (W) with the engine running. This will fill the tank. After running the engine until the tank is full, remove plug (W) until gasoline gives out. Continue repeating these operations until a repair station or garage is reached, when the leaky float can be remedied.

(b) **A small particle of dirt getting under the flapper valve (H) might prevent it from seating air-tight,** and thereby render the tank inoperative.

In order to determine whether or not the flapper valve is out of commission, first plug up the air vent; then detach the tubing to the carburetor from the bottom of the tank. Start the engine and apply a finger to this opening. If suction is felt continuously, then it is evident that there is a leak in the connection between the tank and the main gasoline supply, or else the flapper valve is being held off its seat and is letting air into the tank, instead of drawing gasoline.

In many cases this troublesome condition of the flapper valve can be remedied by merely tapping the side of the tank, thus shaking loose the particle of dirt or lint which has clogged the valve. If this does not prove effective, remove the tank cover, as described below. Then lift out the inner tank.

To fill the tank, should it ever become entirely empty: With the engine throttle closed and the spark off, turn the engine over a few revolutions. This takes less than ten seconds, and will create sufficient vacuum in the tank to fill it.

If the tank has been allowed to stand empty for a considerable time and it does not easily fill when the engine is turned over, this may be caused by dirt or sediment being under the flapper valve (H). Or, perhaps, **the valves are dry.** Removing the plug (W) in the top and squirting a little gasoline into the tank will wash the dirt from this valve, and also wet the valves, and cause the tank to work immediately, if due to this cause. **Another method** is to remove filler plug (W) and fill the tank with gasoline drawn from the main gasoline tank, by means of an oil gun or from drain.

Auxiliary vacuum pump: On some cars a small hand vacuum pump is provided on the dash. If the vacuum tank should become empty, it would not be necessary to turn the engine over, but merely to operate a pump connected by a check valve to pipe (C), which will create sufficient vacuum to draw gasoline from the main tank. **A primer for starting the engine during cold weather** (on some cars) consists of a hand pump on the dash, connected with (J, Fig. 2, page 113) by means of a tee and pipe to the pump, thence to inlet manifold through a check valve.

To clean tank: Remove top of tank and take out inner shell, or vacuum chamber. This will give access to lower chamber from which dust or dirt may be removed. Clean every few months; also clean strainer (V).

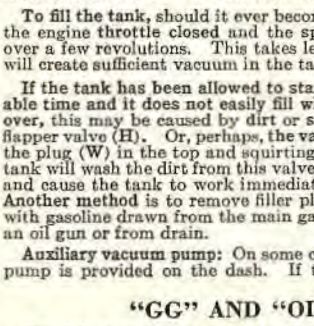
To remove top: After taking out screws, run the blade of a knife carefully around the top, between the cover and the body of the tank, so as to separate the gasket without damaging it. The gasket is not shellacked (see Fig. 2A, page 113).

When removing head (top), first scratch a mark on the side of head and tank, so it will be replaced exactly as taken off otherwise the air-vent hole may not come in line.

Testing vacuum fuel-feed system: see pages 1041, 122, and 462H.

"GG" AND "OIL-VAC" VACUUM GASOLINE FUEL-FEED SYSTEMS

The GG is another vacuum fuel-feed system which utilizes the suction produced through the inlet manifold.



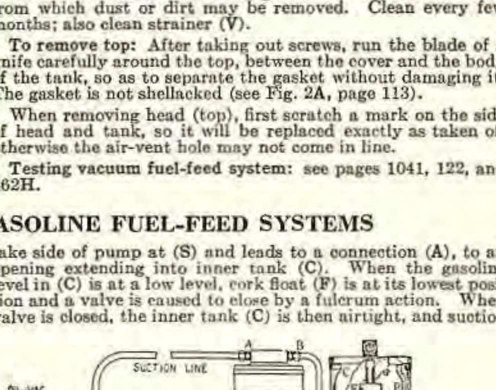
Operation: Inlet manifold connects with (25). If float (16) is at low position, ball valve (8) is thus opened by float arm. A partial vacuum is created in vacuum tank (17) and gasoline is drawn from main gasoline tank through a pipe connected with (23).

When float rises to high position, ball valve (8) is automatically closed by bent arm on float. This shuts off the suction. Atmospheric pressure is then established within inner chamber (17) by air entering at the permanent vent hole (1). The weight of the gasoline opens lower valve (19) and flows into outer chamber (21). Pipe (20) is a breather for (21). Gasoline then passes through opening (24) to carburetor. A back-fire disk is provided inside of (25).

Oil-Vac System

The "Oil-Vac" vacuum fuel-feed system utilizes the suction (vacuum) produced by an oil pump. With this system the vacuum increases as the speed increases. If the oil supply gets so low that the oil is not being drawn into oil pump, no vacuum is produced and tank ceases operation, causing engine to stop for lack of fuel.

Operation: An oil pump of the vane or rotary type is operated from engine to circulate oil for general engine lubrication. Oil is drawn into this pump from the oil pan by vacuum produced in the pump at its intake. A suction pipe connects at the intake side of pump at (S) and leads to a connection (A), to an opening extending into inner tank (C). When the gasoline level in (C) is at a low level, cork float (F) is at its lowest position and a valve is caused to close by a fulcrum action. When valve is closed, the inner tank (C) is then airtight, and suction



(vacuum) at pump reduces the air pressure sufficiently in (C) for the gasoline in the main gasoline tank (T) to flow to (C) through connection (B). *The reason why gasoline will flow from this level to a higher level is explained on page 113.*

As the level of gasoline gradually rises to a predetermined height in inner chamber (C), float (F) rises and opens valve. This permits fuel to flow from slip tank (C) to outer tank (D), which is connected with the carburetor at (U). This operation is repeated, and thereafter the level is maintained at this height during the operation of engine.

If the gasoline fails to feed from lower tank (which can be determined by opening drain plug V), it may be due to the following causes: No gasoline in main tank (T); loose connections at (B) or (A), or at pump; insufficient oil supply in engine oil pan; oil too heavy; spring between the revolving rotors weak (remedy by removing rotor and dressing sides down slightly and stretching spring); valve dirty (remedy by removing slip tank and cleaning). Mfg'd. by Kingston Products Corp., Kokomo, Ind.

RELATION OF THE INLET MANIFOLD TO CARBURETION

An inlet manifold for a six- or eight-cylinder gasoline engine which would deliver an equal mixture to each cylinder was a problem with manufacturers in the early days. If the distance was too great, the charge of gas would tend to condense.

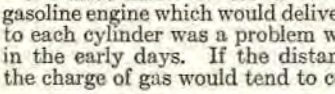


Fig. 3. Early types of inlet manifolds.

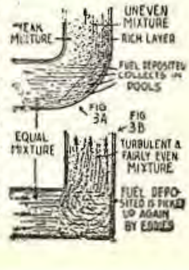
The inlet manifold in use today is smaller in diameter than formerly. Some gasoline, especially of low gravity, is difficult to "break up" and vaporize readily. It condenses and clings to the inner walls of the manifold. By having a smaller inlet manifold, the mixture is drawn through at a greater speed, which in a way prevents condensation.

With too large an inlet, using low-gravity fuel, after a hard pull with an open throttle, the engine tends to "choke" and "lope" when the throttle is first closed again, until after run a short distance.

Exhaust heated inlet manifolds thermostatically controlled are now the approved method. See Insert No. 7 for an example of this type. See Addenda page 60 and Insert No. 6 for an example of a dual inlet manifold for a V-type engine.

Turbulence, an Aid to Fuel Distribution

While an easy bend of the inlet manifold (Fig. 3A) undoubtedly offers less resistance to motion than an abrupt bend, it is claimed by some engineers that **only the lighter particles of fuel are kept in suspension in the center of the air stream and the heavier particles of fuel will be deposited along the sides of the manifold.** This condition would result in some cylinders receiving a lean mixture, while others received an over-rich mixture, thus causing a variation of power and the inability of an engine to idle at low speed.



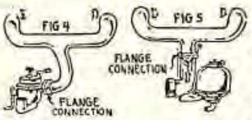
It is now claimed that turbulence (violent mixing) will overcome this to a great extent. A sharp or right-angle bend (Fig. 3B) would cause a very sudden change in the direction of motion of the mixture, thereby forming eddies or whirlpools. Even though the heavier particles of the fuel might be deposited, the whirlpool would pick them up again and mix them, so that the heavy and light portions of the fuel are kept in suspension in the air stream. Thus the ratio of air and fuel should be kept constant over the entire length of the manifold, and this being the case, a thoroughly mixed charge is distributed, rather than a dry vapor.

Some engineers are of the opinion that a **square section inlet manifold** is better than a round section.

Heating of the inlet manifold to promote vaporization of fuel so that it will more readily be broken into smaller units and mix with the air is also very important, but overheating should be avoided. See footnote page 39, Addenda. See also page 806, relative to the method of creating a turbulence effect in the cylinder.

Fitting Carburetor to Inlet Manifold

Carburetors are attached to the inlet manifolds,



either with a horizontal connection (Fig. 4) or a vertical connection (Fig. 5).

When fitting a carburetor, a gasket must be placed between the carburetor flange and the flange on the intake pipe. Be sure there are no air leaks where the carburetor joins the intake pipe, and where the intake pipe connects to engine, otherwise the mixture would be changed.

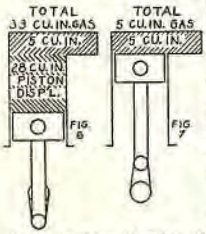
Carburetor gaskets are made of soft fiber material, asbestos, copper interlined with asbestos, or multibestos; or a similar packing could be used, and in an emergency, leather could be used. If material is used which has a rough edge, it is important to watch that none of it gets into the carburetor pipe.

Where inlet manifold covers the inlet ports (D), a copper gasket is generally used and must be drawn tight to prevent air leakage.

If there is excessive vibration of carburetor, place a small iron hanger from a nut on engine to carburetor, to steady it and prevent joints from working loose (see also page 1050).

COMPRESSION RATIO

Compression volume is the volume (number of cubic inches of space) in the combustion space when the piston is at **top dead center.** In Fig. 7, the compression volume is 5 cubic inches.



Total volume is the volume in the combustion space and cylinder when the piston is at **bottom dead center.** In Fig. 6, the total volume is 33 cu. in. Note that the total volume is equal to the compression volume plus the piston displacement (see Index for meaning of piston displacement).

Compression ratio is defined as the total volume divided by the compression volume. For the engine shown in Figs. 6 and 7, the compression ratio is 33 cu. in. ÷ 5 cu. in. = 6.6 compression ratio.

The final compression pressure (at about top dead center) depends mostly on two things: (1) **the compression ratio** and (2) **the pressure of the gas in the cylinder when piston is at bottom dead center** as shown in Fig. 6. It is obvious that the greater the pressure in Fig. 6, the greater will be the pressure in Fig. 7. The pressure in Fig. 6 (the piston has just reached bottom dead center of the intake stroke) is dependent upon the atmospheric pressure which forces the gas into the cylinder; therefore, the lower the atmospheric pressure, the lower will be the pressure in Fig. 6, and therefore the lower will be the compression pressure in Fig. 7 (with piston at top of compression stroke).

The combustion pressure (sometimes incorrectly called explosion pressure) which occurs shortly after ignition, and which gives the engine its power, depends on the **compression pressure.**

Conclusion: A low atmospheric pressure will cause a low compression pressure, which in turn will cause a low combustion pressure, and therefore the power of the engine will be reduced.

EFFECT OF ALTITUDE ON CARBURETION AND COMPRESSION

Atmospheric conditions have much to do with the action of a carburetor. For example, an engine which would run satisfactorily at a low altitude, say at sea level, would lack power and would overheat at a high level, as, for instance, at Denver, Colo., where the elevation above sea level is approximately 5,280 feet, or one mile high.

This is due to the fact that at sea level, the air exerts a pressure of approximately 15 lbs. per square inch. This means that a column of air one inch square in cross-section and 50 miles high weighs approximately 15 lbs. It has been fairly well established that atmosphere blankets the earth for a depth of about 50 miles.

Therefore if we go higher, we begin to shorten this column of air responsible for this pressure; we therefore have not so much weight of air above us, and consequently the pressure corresponding to the reduced weight is also reduced.

Thus, if, at Denver, the height above sea level is 1 mile, there would be only 49 miles depth of air in the column to establish this pressure, and a column of air 49 miles high weighs less than a column 50 miles high, so that we find the atmospheric pressure at Denver is just a trifle over 12 pounds per square inch. As we go still higher, the pressure begins to fall off.

The drop in pressure amounts to approximately one half-pound per square inch for each rise of 1,000 feet. This, however, is not strictly accurate, nor is there a distinct and invariable relationship between the two, for it depends upon barometric variations, the amount of moisture in the air, etc., which, as we know, will cause the barometer to vary even though it remain in one place.

This reduction of air pressure as a result of increasing altitude has an effect on the power of the engine.

First it affects the compression, reducing it at a rate corresponding to the reduction in atmospheric pressure, as explained above. Thus at sea level, an average Ford engine would have a compression pressure of 64 lbs. per square inch, as measured by a pressure gauge, and after ignition, the explosion pressure would be 256 lbs. per square inch; while in Denver, owing to the low atmospheric pressure, the compression pressure would be only 48.5 lbs. per square inch, and after ignition, the explosion pressure would rise to only 194 lbs. per square inch. It is the latter pressure which determines the power of the engine, and since it has decreased from 256 lbs. per square inch to 194 lbs. per square inch, the engine will deliver much less power.

Second, we know that at sea level the composition of the air by weight is approximately 25 parts of oxygen to 75 parts of nitrogen, and the combination is a mechanical mixture, not a chemical one.

It is the oxygen that we rely upon to support combustion of the gasoline. Thus if the oxygen is reduced in value to that of the fuel, the mixture is affected.

The higher we go, the less the percentage of oxygen in the air. Therefore, unless the carburetor is readjusted to suit the changed conditions, we get an over-rich mixture, slow combustion, and overheating.

The point, then, is to open up the air intake, giving more air, rather than to cut down on the needle valve of the carburetor, reducing the gasoline supply.

Where carburetors are fitted with adjustable air valves, then the air-valve adjustment should be opened wider for altitude work.

Where carburetors have no air adjustment, use smaller jets for altitude work. To increase power, increase compression by fitting pistons slightly longer than the standard.

At the top of Pike's Peak, which rises to an altitude of 14,000 feet above sea level, the atmospheric pressure of the air is only 8.5 lbs. per square inch; therefore the compression pressure will drop to 30 lbs. per square inch (as measured by a gauge), and the explosion pressure will be only 120 lbs. per square inch, thus causing a very great loss of power.

Furthermore, water boils at a lower degree (Fahrenheit) at higher altitudes, for example at 14,000 feet above sea level water boils at 185° F., owing to less atmospheric pressure, whereas at sea level, water boils at 212° F.

Altitude	Atmospheric Pressure	Boiling Point of Water	Compression Pressure (as measured by a Gauge) on Engine with Compression Ratio of 3.6
Sea Level	15 lbs.	212° F.	64 lbs.
1,000 feet	14.1 lbs.	210° F.	59.5 lbs.
2,000 feet	13.6 lbs.	208° F.	57 lbs.
3,000 feet	13.1 lbs.	206° F.	55.4 lbs.
4,000 feet	12.5 lbs.	204° F.	51.2 lbs.
5,000 feet	12.3 lbs.	203° F.	49 lbs.
6,000 feet	11.6 lbs.	201° F.	46.5 lbs.
7,000 feet	11.2 lbs.	199° F.	44.3 lbs.
8,000 feet	10.8 lbs.	197° F.	42.1 lbs.
9,000 feet	10.4 lbs.	195° F.	40 lbs.
10,000 feet	10 lbs.	193° F.	37.9 lbs.
14,000 feet	8.5 lbs.	185° F.	30 lbs.

Note. The Ford model "T" engine compression ratio is 3.6–3.98.

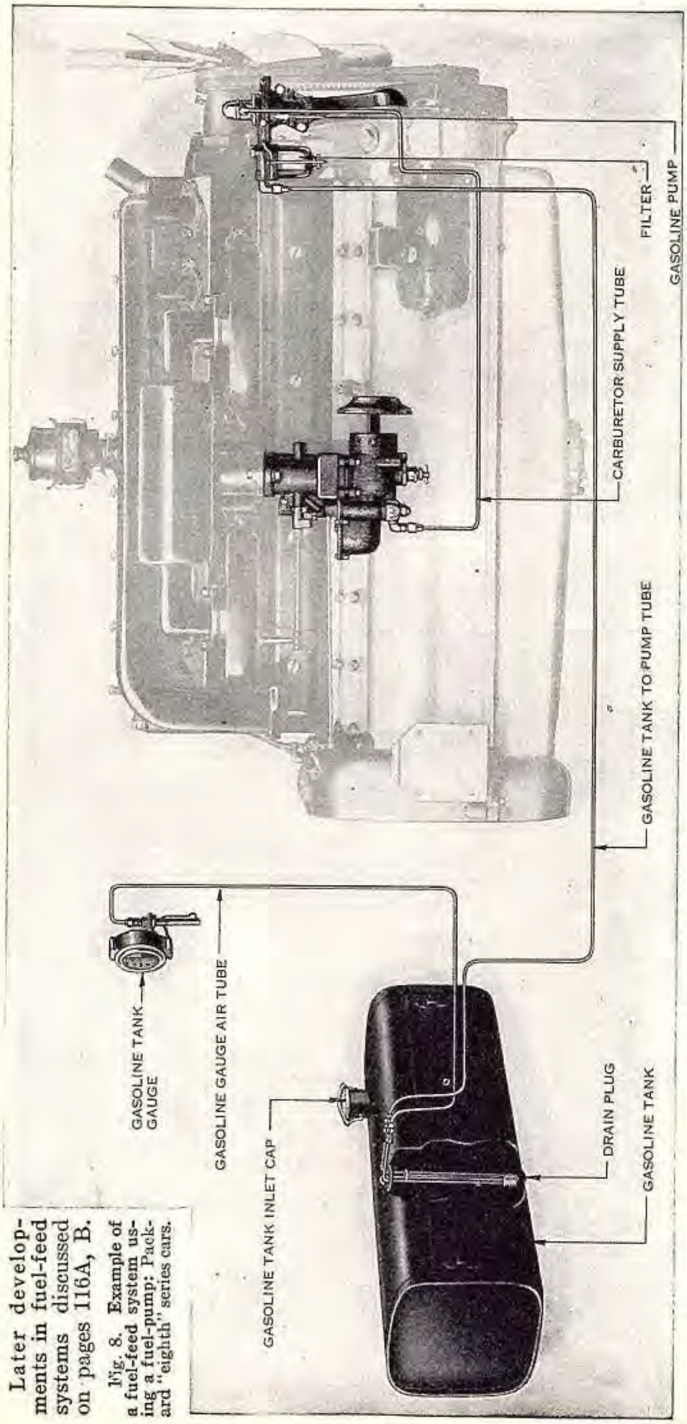
FUEL-FEED SYSTEMS

Fuel Pumps

Purpose of the fuel pump is to promote constant pressure at the carburetor under all operating conditions and all rates of discharge. The fuel is pumped from the fuel tank in the rear of car direct to the carburetor, or to a gravity feed tank close to the carburetor.

There are three types, the **piston, diaphragm** and the **electric** type. The piston and diaphragm type are mechanically operated and the electric is magnetically operated.

Piston type, for example, used on the Cadillac V-16 car is mechanically operated by an eccentric on the rear of the camshaft. It delivers the vacuum to the vacuum tanks which receives the fuel from the fuel tank at the rear of the car. The two vacuum tanks are mounted above and close to the carburetors, and have valves and parts as usual, but are not connected with the intake manifolds of engine; instead, the vacuum pump serves the same purpose as the suction (vacuum) in the intake manifold.



Later developments in fuel-feed systems discussed on pages 116A, B.

Fig. 8. Example of a fuel-feed system using a fuel-pump; Packard "eighth" series cars.

Diaphragm type is mechanically operated and pumps the fuel from the fuel tank at rear of car direct to the carburetor. It can be driven by any method that will give reciprocal motion of from 3/16" to ¼" maximum. It can be operated from the push rods, tappets or eccentrics. It can be located on the camshaft or any other rotating shaft such as generator, oil pump, etc. In the example, Fig. 8, the stroke is controlled by a bell crank, one end resting upon a push rod actuated by an eccentric on the front end of the engine camshaft and the other attached to the rod operating the pump diaphragm.

Electric type. The Autopulse magnetic fuel pump (patented) is an example of the electric type. It is connected directly to the carburetor suction line, and a wire terminal from the device is installed on battery side of ignition switch. Thus contact is made as soon as the ignition switch is turned on. A metal bellows is expanded by magnetic pull, created by an armature and magnet. This forms the suction stroke.

Stewart-Warner Fuel Pump

An example of a mechanically-driven diaphragm type of fuel pump is shown in Fig. 9.

Operation during suction stroke: As the high point of cam A pushes lever B toward the pump, the lever fulcrums at point C, thereby pulling the pump diaphragm D down. A vacuum or suction is thereby created in chamber E. This opens the inlet valve F, pressed downward by a spring, and draws gasoline from the glass reserve bowl G through screen H. The glass bowl G is connected to the rear tank by inlet line J. In operation the glass bowl will always be full of liquid. The outlet valve K is also pressed downward by a spring. Chamber L is always open to the atmosphere through breather hole M. This prevents back pressure or vacuum in this chamber and ventilates it.

Operation during delivery stroke: The low point on cam A would now be on the side nearest the pump. Pressure is exerted on lever B by the lever spring N. This causes the lever to follow the cam. The other end of the lever is engaged with the bronze spool that is free to slide on the diaphragm piston rod T.

On the end of the delivery stroke the lever is up as high as it will go, permitting the diaphragm spring O to push the diaphragm up, thereby forcing the gasoline in chamber E through the outlet valve K. On this stroke inlet valve F is held closed by its spring.

The purpose of the air dome Q is the same as on other hydraulic pumps. It not only relieves the diaphragm and carburetor float bowl valve of excess pressure when the carburetor float bowl valve is closed, but utilizes this pressure to increase the delivery rate about twenty-five per cent.

Note: Some of the models do not have this high delivery air dome; however, the dome used on these pumps is satisfactory on the cars for which these models are specified.

When the carburetor float bowl valve is closed, or partially closed, the full stroke pressure and stroke of the diaphragm is utilized to store gasoline in the air dome by compressing the gasoline vapor in it as the baffle plate is perforated. On the down stroke of the diaphragm this compressed vapor expands and maintains a pressure on the gasoline in the line to the carburetor and a constant flow, so long as the carburetor float bowl valve is open.

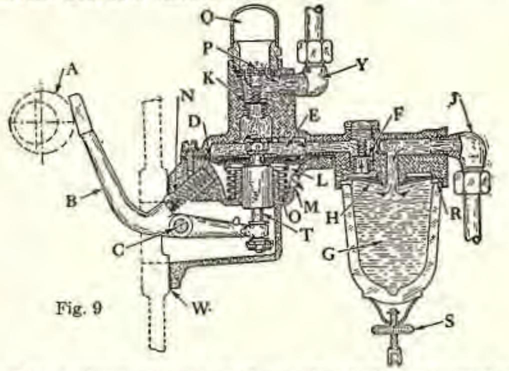


Fig. 9

The maximum pressure on the gasoline to the carburetor is two and one-half pounds per square inch.

Control of delivery: The actual delivery to the carburetor is controlled by the carburetor float bowl valve, as this shuts off the flow of gas when the carburetor float bowl is full. When this occurs and the air dome pressure reaches two and one-half pounds per square inch the pump diaphragm automatically stops pumping and remains in the down position. This is because the pressure in the gasoline line to the carburetor equals that of the diaphragm spring O.

The lever, however, continues moving with the engine camshaft, and the spool on the piston rod T with which the lever is engaged, slides up and down.

The down stroke is cushioned by the rubber washer under the bronze spool. As soon as the back pressure at the carburetor needle valve is relieved the diaphragm is forced up by spring pressure and pulled down by the lever.

Service Hints

Test on engine: If no gasoline to carburetor, first check as follows: (1) learn if there is gasoline in the fuel tank; (2) note if gasoline has been coming out of breather hole M. This indicates a leak due to a fractured diaphragm or leak at the piston; (3) examine sediment bowl G and screen H. Although bowl may be full of gasoline, pump will not operate properly if screen is dirty or inlet valve F is clogged. Clean. Do not break cork gasket when replacing bowl; a leak will cause erratic action of pump and delivery. When using new gasket, first soak it in lubricating oil; (4) check for loose connections and broken lines; (5) disconnect pump at the line to the carburetor; (6) while someone steps on starter, observe if gasoline spurts out of the pump outlet. When gas spurts out and carburetor bowl is empty it indicates that the line to carburetor, or carburetor float needle valve, is clogged; (7) disconnect gasoline supply line at both ends and blow through it to see if clogged.

Test of pump off of the engine: When the previous tests fail to show the trouble, remove pump and take it to the work bench for test and examination as follows: (1) attach two pieces of rubber hose to the outlet and inlet of the pump, and move pump lever in and out. Gasoline should spurt out of hose attached to outlet opening in approximately fifteen strokes; (2) if not, examine check valves F and K, Fig. 9. Clean the valve seat and the springs, and replace the disc valves, glossy side down. Be careful not to scratch or mar valve seats while cleaning. Use new gaskets under valve retaining nut U, and air dome Q. Draw them up tight; (3) examine vent hole M; (4) test the pump with two pieces of hose and a pail of gasoline, as previously described; also by holding a wet finger alternately on the inlet and delivery openings while working the lever.

When pump cannot be made to operate properly after the tests described, it is best to take it to one of the Stewart-Warner authorized service stations.

AC Fuel Pump

Another example of a mechanically driven diaphragm type of fuel pump is shown in Fig. 10. This is the AC fuel pump, series "B." See also Insert No. 2 for another type of AC fuel pump.

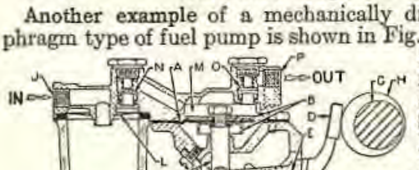


Fig. 10

Stewart-Warner Constant Suction Vacuum Tank

This series of tanks, while embodying the same general principles explained on pages 112 to 115 has but one valve (air valve), one lever and one spring. The vacuum valve is eliminated. It is claimed that there is no intermittent enriching of the mixture above the carburetor when the tank trips, and smoother operation of the engine when idling.

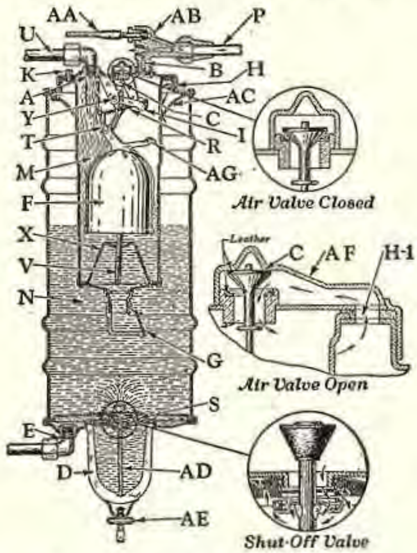


Fig. 11. Stewart-Warner constant suction, lever type vacuum tank, model 377. Name of parts: A, fuel inlet; AA, windshield cleaner connection; AB, booster; AC, baffle; AD, shut-off valve; AE, clamp; AF, valve cover; AG, float tee; B, vacuum opening; C, air valve; D, sediment bowl; E, outlet; F, float; G, flapper valve; H, air inlet; H-1, air valve opening to outer shell; I, valve yoke; K, vent; M, vacuum chamber; N, reserve chamber; P, booster line; R, spring; S, strainer screen; T, float lever; U, supply line; V, float stem.

Description: The inner or vacuum chamber M has four openings, namely: the fuel inlet A, which is connected to the main fuel tank through line U; the vacuum opening B, which is connected to the intake manifold through the booster and line P; the air valve opening to the outer shell through H-1; flapper valve G.

The outer or reserve chamber N has three openings, namely, through vent K and air inlet H, which are open to the atmosphere at all times; fuel flows through hole in false bottom of outer tank into glass sediment bowl D, up through strainer screen S, and from there through outlet E to the carburetor.

The booster AB operates somewhat on the principle of the injector to force water into steam boilers with their own steam. It forces the air from the inner chamber M into the engine manifold and thus creates in chamber M a higher vacuum than that in the manifold. This causes fuel to be forced into the vacuum tank under conditions that would make it inoperative without the booster. The booster increases the vacuum in M from two hundred per cent to three hundred per cent. AA is the windshield cleaner connection. The funnel-shaped baffle AC prevents fuel splashing out air inlet H.

The principle of operation, troubles and remedies otherwise are very similar to the vacuum tank previously discussed.

As-ke Fuemer

An electric heater constructed of high-grade resistance wire, about the size of a spark plug, which vaporizes or fumes a portion of the fuel supplied in the carburetor air-horn the instant the starter pedal is applied to start the engine.

The model E magnetic valve fuemer is for up-draft carburetors. Upon application of the starter, the magnetic valve contained within the fuemer assembly opens and permits fuel to flow into the fuemer plug from the fuel pump or vacuum tank. When the fuel touches the fuemer it is instantly vaporized and exploded in the engine cylinders. Advantages claimed are that engines equipped with this device are not only easy to start in cold weather, but last longer because of less piston wear through the winter months (As-Ke Fuemer Co., Minneapolis, Minn.).

INSTRUCTION No. 14

CARBURETOR ADJUSTMENTS: Mixture; Troubles and Remedies; Float Adjustments; Tools for Repairing Carburetors; Examples of Principle and Adjustments of Carburetors

The principle of carburetion is treated in instruction No. 13. It will be advisable to start at the beginning of the subject and master the fundamental principles before taking up the subject of adjustments.

Kerosene carburetors are treated under the subject of "Tractors." See Index.

The first and most important thing to learn about any carburetor is to let it alone as long as it is working properly. Never tamper with the carburetor until you are quite sure that it is at fault.

There are two essentials necessary before an engine will run: first, gasoline; second, a spark. The gasoline must reach the inside of the cylinders and a hot spark must be there at the proper time to ignite the gas. If you have both, something is bound to happen, even though it is but a single explosion.

Next, remember that even though you have a spark and gasoline, the engine will not run properly if the gas does not enter the cylinder at the right time and if it is not in a proper gaseous form, or a correct "mixture." See "Digest of Troubles" for various reasons why an engine will not start, etc.

MIXTURE

At low speeds the mixture should be richer than at high. At low speeds more heat is lost to the cylinder walls, more compression is lost by leakage, and the combustion can therefore be slower, thus sustaining the pressure. **At high speeds** the compression is higher, due to less leakage and less loss of heat. A lean and highly compressed charge burns faster and hence gives better pressures and fuel economy than a richer one.

The quantity of mixture an engine will take, varies greatly with the speed and pull. **At slow speeds,** the volume, at carburetor pressure, is equal to the cubic content of the cylinders multiplied by the number of intake strokes.

At high speeds of one thousand revolutions or over, the quantity may drop to less than one-half the amount, depending on the design of the valves, inlet piping, and passages. This reacts upon the compression, and hence on the mixture desired for best results.

The design of the engine has a bearing on the carburetor design, which explains the well-known but seemingly mysterious fact that a carburetor giving good results on one engine sometimes fails to maintain its reputation when applied to one of different design. **The system of ignition** used also has a marked influence on the proper working of an engine, as a hot spark is most essential (see Index for "Flame propagation").

Proportions of air and gasoline. Different mixtures of air and gasoline are needed for different engine requirements. It is no longer the belief that a uniform mixture is correct for all speeds. The new rule is, that the amount of gasoline fed into the air must be changed according to demands, and that if a 12 to 1, or rich, mixture is best for quick acceleration, a 15 to 1, or leaner, mixture may be best for pulling with the throttle wide open, and a 17 to 1, or still leaner, mixture is best for particularly high speed work. Therefore, a varying mixture must be supplied. See also page 95.

Atmospheric conditions have much to do with the action of a carburetor. An engine seems to run better at night. Taking an engine from sea level to an altitude of 10,000 feet involves using air in the engine cylinders at atmospheric pressures ranging from 14.7 lbs. down to 10.1 lbs. to the square inch. In other words, the higher the altitude, the lighter is the air, and thus more air for the carburetor is required.

To Test the Mixture

If there are doubts in the mind of the operator as to whether the mixture is too rich, one method of ascertaining **the correct proportion of air and gasoline** is to shut off the fuel at the tank and open the throttle.

If the mixture passing into the cylinder is too rich, the engine speed will increase as the level of the gasoline in the float chamber is lowered, since this operation weakens the mixture considerably.

If the mixture is thought to be too weak, the float chamber can be flooded or the "choker valve" partially closed while the engine is running, and if this causes the engine to speed up, it may be taken as an indication that the mixture is not rich enough.

The proportionate amount of gasoline to air is essential. The novice usually gives the carburetor too much gasoline by opening the adjustment valve too wide, thereby causing "too rich a mixture." Too much gasoline will not run the engine any better than not enough. It must be remembered that only a very little gasoline is required in proportion to the air needed.

Use air. It is advisable to run the engine with as much air as possible, which means a "lean" mixture. This not only means economy of gasoline, but prevents soot deposit and pitted valves (providing good lubricating oil is used).

Of course, when first starting, or when cold, more gasoline is absolutely necessary, but as soon as the engine warms up, cut down on the gasoline and run on more air. Most carburetors, now-a-days, are fitted with air regulators and heated intake manifolds for this purpose.

An engine will run on less gasoline, and more air, the warmer it gets. This accounts for the necessity of the air adjustment.

Rich and Lean Mixture

A rich mixture is one in which the proportion of gasoline abnormally exceeds the amount of air. It may be due to faulty adjustment of the gasoline needle valve, float, or air valve. The expression, "mixture too rich" means that too much gasoline is present in proportion to air, or, technically, that their is insufficient oxygen to support its combustion.

An over-rich mixture will cause an engine to overheat and thereby give rise to a number of troubles, such as preignition, accumulations of carbon on the pistons and cylinder heads, steaming water in the radiator, and loss of power and "loping" or choking up on slow speeds.

The cause of mixture being too rich may be: Too much gasoline at needle valve; punctured float; float valve not working properly, owing to bent needle, or presence of foreign matter in valve seat; too much priming; primary air passage clogged or partially obstructed; air valve not open enough, spring too strong or air opening choked.

A mixture is poor or lean when it contains too much air and not enough gasoline, a condition often due to a faulty adjustment of the needle or air-valve, float, a leak in the inlet pipe, the spray nozzle, float valve, or feed pipe partly clogged, or water in the gasoline.

A poor mixture will make the engine miss when running idle at slow speeds, and at high speeds it will not only cause misfiring, but the missing will be accompanied by coughing and "popping" in the carburetor. Both this and explosions in the muffler may also occur (see also page 461).

The cause of mixture being too weak may be: Too much air, not enough gasoline; carburetor passages or jet clogged; throttle valve out of adjustment; insufficient flow of gasoline; tank valve closed; vent hole in gasoline tank cap stopped up; break in gasoline supply; bad gasoline, originally, or from standing; water in gasoline; carburetor cold; gasoline cold and unvaporized; gasoline supply exhausted. The ignition system not working properly will also act in a manner similar to too lean a carburetor mixture.

Smoke Indications of Carburetor Mixture

If the engine is fed too much gasoline, black smoke, smelling of raw gasoline, will usually be in evidence, issuing from the exhaust. Care should be taken to distinguish this from the excess of heavy blue smoke which is indicative of too much engine lubrication.

Whenever any considerable quantity of smoke of either color comes from the exhaust, the engine may miss explosions through fouled spark plugs.

If the mixture is too rich, the engine will have a tendency to slow up and "choke" or "load up" when the throttle is opened wide, and will run at a higher speed when it is partially closed.

Another indication of the mixture being too rich will be shown in its speeding up perceptibly, if the auxiliary air valve of the carburetor is held open, or additional air is admitted in any way between the carburetor and the cylinders.

Such being the case, the exhaust gases, if ignited by holding a piece of burning paper near the end of the exhaust pipe, will burn with a large red flame, similar to that of a bunsen burner when the air is mostly cut off.

Loping. Another indication of too rich a mixture is that when **"idling,"** the engine will run in a loping manner, as if actuated by a governor; more air and less gasoline is needed.

"Loading up" when running slow or idling is due to the fact that the air comes into the carburetor so slowly that the gasoline particles are not broken up fine enough, and condensation takes place. Thus the gasoline is taken in in a more or less liquid form, and combustion is very poor. That is one reason why as much heat as possible should be applied to the air intake of the carburetor. Also, the engine should not be allowed to tick over slowly for any length of time when the car is standing idle. It not only wastes fuel, but the manifold will load up with raw fuel, and acceleration will be anything but good when you attempt to get under way.

By opening the relief cocks in the cylinder heads (if provided), while the engine is running, one can judge fairly well, by the color of the flame, when the mixture is correct. At each explosion a jet of flame will shoot out of the cylinder through this relief cock.

If the mixture is too poor (too much air for the gasoline), the flame will be light yellow.

If the mixture is too rich (not enough air for the gasoline), the flame will be red and smoky. Black smoke will also come out of the muffler, smelling of raw gasoline.

If the mixture is correct, the flame will be light blue or purple, and hardly visible.

Note. This test is not absolutely reliable, because, when the relief cock is open, air is drawn into cylinder which tends to change the mixture.

"Back Firing" or "Popping" in Carburetor

There seems to be much confusion in the use of the terms "back kick" and "back fire," the latter being very often used to describe what happens when, in starting an engine, it suddenly reverses its direction of rotation to give a "back kick."

Back-kicking is usually caused by preignition in starting the engine, which is due usually, as is well known, to too much "advance" in the spark timing.

Generally speaking, "back-firing" is caused by a weak mixture which burns so slowly that the flame continues until the opening of the admission valve again, when it ignites the incoming charge in the intake pipe and shoots back to the carburetor. While an over-rich mixture will also burn slowly, it rarely ever will cause back-firing. (See also p. 462B.)

Another cause of back-firing is, of course, the faulty timing of the valves, or, in fact, a badly leaking valve. As a general rule, back firing is due to one or more of the following causes: (1) very slow explosion or weak mixture; (2) very late explosion; (3) a spark occurring during the intake stroke; (4) the intake valve being partially open during the power stroke; (5) premature ignition.

Slow combustion is caused by a lean mixture; **late combustion** is caused by a weak or retarded spark. Nos. 1 and 2 are the usual causes, while Nos. 3 and 4 happen infrequently.

"Popping back" or "back-firing" in carburetor is quite a common occurrence with carburetors when first starting the engine on a cold day. But after the engine has been run for a brief period it will become warmed up and the gasoline will begin to vaporize properly and run without popping back.

If the "popping back" continues, then the mixture is too weak and more gasoline is required. By giving the auxiliary air-valve spring a slight increase of tension, or by opening the gasoline needle valve a notch or so, or by closing the "choker," or closing the "damper" at the air intake, more gasoline will be supplied to the carburetor until the popping stops, which it will probably do when the engine is warmed up.

Do not use the "choker" any more than absolutely necessary. It permits raw gasoline to be drawn into the engine, a part of which passes to the crank case and thins the lubricating oil. (See p. 462B.)

Never run an engine in a closed garage, because carbon monoxide, a deadly poisonous gas, is present in the exhaust of gasoline engines. Too rich a mixture increases the amount of carbon monoxide given off.

Carburetion during Cool Weather

Since, at the present day, low-gravity gasoline is being used, the engine will have a tendency to miss explosion and run in jerks or uneven explosions, especially when starting.

This is due, principally, to **insufficient heat** properly to vaporize the gasoline to prevent condensation. After the engine becomes thoroughly warmed up, the "missing" usually disappears. When the weather is warm the engine starts easier, because gasoline will vaporize more readily and is easier ignited. Therefore during cool weather three things are essential: a good **hot spark,** a **quick method of heating,** and a **choker** or primer for enriching the mixture to start on.

For starting. There are different methods employed to inject a rich mixture into the cylinder in order to start the engine at all on a cold day. The common method is to close the main air intake, which causes raw gasoline to be drawn into the cylinder, which would be termed "choking" the air supply. After the engine is started, it is then only a matter of running the engine until warm enough to vaporize the gasoline, at the same time gradually opening the choke or air valve, until the regular amount of air is being used. Never race engine when starting engine on a cold day; see page 171.

There is a disadvantage, however, in priming an engine, and that is, the raw gasoline drawn into a cool cylinder is not all utilized for combustion, but part of it forms carbon, due to lack of oxygen, which is not being supplied, as the air is choked. The result is a deposit of carbon on the head of the piston, in the combustion chamber, and on the spark plug. Therefore the air should be supplied as quickly as possible. The problem is, then, to heat the gasoline as quickly as possible, so that vapor and air are used instead of raw gasoline.

The "choker" or some method of supplying a richer mixture, however, is usually necessary for starting. If the choker principle is used, it is closed only until the engine starts, then gradually opened. In fact, by using an exhaust-heated intake manifold to heat the mixture, and also drawing warm air through the air passage of the carburetor, the amount of raw gasoline injected into the cylinders will be considerably less than if it is not heated. Therefore this system will provide a quicker vaporizing or heating of the mixture and a saving of fuel, with less carbon deposit in cylinders.

Additional Pointers on Cold-Weather Starting

Don't expect the engine to warm up in a minute any more than you expect a kettle to boil as soon as it is set on the stove. It takes time to heat.

Take into consideration the fact that cold solidifies the lubricant in the transmission, rear axle, and other parts of the car. Therefore it requires greater energy on the part of the self-starter to revolve the engine. If the clutch is in, when starting, and gears are in neutral, the transmission counter-shaft gears are directly in this oil and are revolved when cranking. After a car has been standing over night in a cold garage or sufficiently long at the curb to become thoroughly chilled, **throw out the clutch** when cranking. This eliminates the drag of the transmission gears plowing through the solidified grease.

A good hot spark is important, especially in winter. Be particular to see that the battery is always charged. A quick method of starting should be provided in order to save current. See also pages 563, 556, 462A, 462B, 286.

CARBURETOR ADJUSTMENTS IN GENERAL

The parts to adjust in the carburetor depend upon the type of carburetor. This subject is therefore best treated by giving examples of carburetors of different types, such as the air-valve type, metering-pin type, plain-tube type, etc.

Carburetors are usually adjusted to the best advantage when the engine has been run and all parts are warmed up. If a carburetor is adjusted when the engine is cold, it will be noticed that it will need readjusting when warm, that is, in order to get a perfect adjustment.

When carburetors are adjusted when warm, sometimes, especially on a cold day, the engine will not hit just right when first starting; it will miss and not run even or smooth until it has run a few moments and is heated up; then it runs satisfactorily.

Another point to remember is to be sure the ignition is right and you have a good hot spark, and the spark plug gaps set about .025". **If too close,** the engine will operate unevenly at idling speeds and miss at higher speeds; **if too wide,** it will miss when accelerating at very low speeds or hard pulls. A weak spark causes late combustion. (See Index for "Adjusting spark-plug gaps.") Also remember, that if trouble, lack of power, etc., develops with the engine missing, it is well to be sure that the trouble is in the carburetor and not due to other troubles. See "Digest of Troubles," for suggestions on how to diagnose troubles.

The best way to adjust a carburetor is to arrange so that the engine may be run loaded while the adjustment is being made. One way to do this is to adjust the carburetor while the car is in motion on the road.

To test the carburetor for adjustment, run throttled down for two blocks. When there is a clear space ahead, suddenly press the accelerator pedal down. The engine should pick up smoothly, to as high speed as you care to run at. If the engine chokes, stalls, misses or labors, or backfires at the carburetor or at the muffler explosions, it shows the carburetor is out of adjustment.

Adjusting the Air-Valve Type of Carburetor

The three principal parts of a carburetor used for making adjustments on the air-valve type are: the **auxiliary air valve,** the **gasoline needle valve,** and the **float needle valve.**

For the average carburetor, having an "auxiliary air valve" and a "needle-valve" adjustment, the following rule for adjusting will apply.

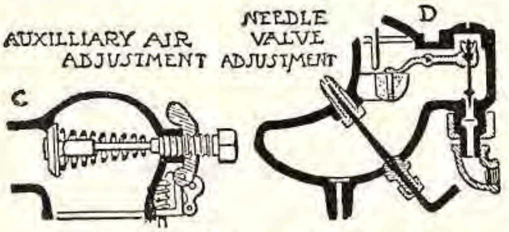


Fig. 1. Showing principal parts of an air-valve type carburetor for adjustments.

First, run the engine at what will be nearly its maximum speed in ordinary use, with the throttle open considerably and the spark rather late. This speed, of course, will be considerably less than the maximum speed of the engine when running idle.

Second, turn the main gasoline needle-valve adjustment, until the mixture is so weak that there is popping in the carburetor.

Third, note this position and then turn this adjustment until so much gas is fed that the engine chokes and threatens to stop.

Fourth, set the adjustment half-way between these two points, which will be very near the correct position. Turn the adjustment slightly in one direction and then in the other until the point is found where the engine seems to run the fastest and smoothest.

Fifth, gently and gradually cover the auxiliary air inlet of the carburetor by placing the hands partly over the valve, if necessary, in order partially to exclude the air. If the engine slows down, the spring should be weakened, since not enough air is allowed to enter the carburetor.

Sixth, next try opening the auxiliary air inlet slowly and gradually by pushing the poppet off its seat with the finger or the end of a pencil. If the engine speeds up, there was not enough air and the spring should be loosened, while if it slows down, the mixture is correct or a little too lean, according to the degree to which the speed is affected. If it is found to be too lean, the spring needs tightening.

Seventh, after the auxiliary air inlet has been adjusted, open the throttle again and adjust at high speed, as this adjustment may now require to be altered.

In the air-valve spring lies the chief difficulty in making carburetor adjustments, if the carburetor is provided with an automatic auxiliary air valve. This spring should be of such length and of such gauge wire, diameter, and number of convolutions as to provide the requisite progressively increasing resistance to opening, while at the same time exerting little or no pressure upon the valve when it is against its seat.

Adjustment: The needle valve should be set for slowest running with the air valve held lightly against its seat, and then the spring adjustment should be backed off until the slightest further increase in throttle opening causes the valve to leave its seat.

From this point on the only proper adjustment for the air valve becomes a series of tests for spring strength without alterations being made in its normal length; that is, with the adjustment backed off in accordance with the instruction just given. If the spring tension with increased throttle openings is too light, and "spitting back" in the carburetor continues in spite of the increased opening of the gasoline needle-valve adjustment, it is a pretty sure indication that the air-valve spring is too weak and that a stronger one should be obtained from the factory. These can usually be obtained in several sizes or degrees of tension to suit varying engine and climatic conditions.

Too strong a tension on the auxiliary air-valve spring will result in too much gasoline and not enough air (too rich a mixture), because the valve will be more difficult to open by suction. **Too weak a spring tension** will give too much air or too lean a mixture.

When adjusting a carburetor on a "V"-type engine, a good plan is to adjust each block of cylinders separately.

TO OBTAIN A SLOW, EVEN PULL OF ENGINE WITHOUT MISSING

Factors which, in addition to proper carburetor adjustment, assist an engine in pulling slowly and firing regularly at low speeds are:

1. **Good compression,** which includes proper clearance of pistons, good piston rings, and no air leaks at the inlet manifold, carburetor gaskets, valve caps, or spark plugs, etc. If there is an air leak in one cylinder it will affect the other cylinders.
2. **Proper valve clearance, properly seated valves, and correct valve timing** are very important.
3. **Proper ignition timing**—not too far advanced; when running slow, retard the spark.
4. **Interrupter points should be set correctly** with a clear, flat surface at the points.
5. **Be sure there is a good hot ignition spark** which will fire a charge at a wide-open throttle and also at low speed. A defective coil, condenser or resistance unit will produce a spark, but not one of sufficient volume to ignite the gas properly. See Index for these subjects, including how to test a fully charged battery.
6. **Properly set spark-plug gaps.** About .025" is the average gap. Good spark plugs are also important.
7. **Cooling water** must be at least 90° F.; 140° F. is better.

These details are essential to secure a flexible and smooth-running engine.

Indication of Correct Carburetor Adjustment

1. Run the engine until warmed up.
2. Close the throttle with spark between half advance and fully retarded position. The engine should then run evenly.
3. The car should run 6 to 7 m. p. h. smoothly on high gear.
4. Run one-quarter to one-half mile at 12 to 13 m. p. h. The engine should run evenly.
5. With the car running 7 to 8 m. p. h., open the throttle wide suddenly. The car should accelerate smoothly.

Indications of Incorrect Adjustment

The following indicate a lean mixture:

1. The engine starts hard.
2. The engine backfires through the carburetor when opening the throttle suddenly.
3. The engine refuses to idle.

The following indicate a rich mixture:

1. Spark plugs foul quickly.
2. Exhaust gas causes one's eyes to burn.
3. Black smoke issues from the muffler.
4. Engine operation is uneven, causing "loading up" or "loping," as previously explained. On a Ford, a rich mixture will cause the rear axle to have an uneven hum which is distinctly heard at 13 m.p.h.

POINTERS ON GOOD CARBURETION[1]

Good ignition, good compression and good spark plugs are necessary for perfect carburetor performance.

Valve stem guides: When the carburetor is properly installed and the engine refuses to idle, look for defective guides. To locate these defects, squirt gasoline from an oil can at the bottom of the guides while the engine is running. The tendency of the gasoline is to travel upwards through the loose guide, and each cylinder will begin firing as the gasoline takes the place of air which was previously passing through the guide.

Remedy: New valves should be installed or the valve guides should be bushed. A great deal of imaginary carburetor trouble can be traced to valve springs being weakened and to unequal tension having developed.

Air leaks in intake manifold: When the engine refuses to idle, test for air leaks, by removing the hot-air tubing from the intake and with a squirt-can apply gasoline freely around the manifold connections. If an air leak exists the engine will either speed up or choke down entirely. Air leaks are often responsible for poor mileage, loss of power, and over-heating trouble.

The cause of an engine galloping is found in unequal explosion in the cylinders, caused by leaking valves and pistons, or by leakage past the intake guides. It may also be due to improper carburetion, allowing some of the cylinders to be fed liquid gasoline. The spark-plug points should be the same distance apart; likewise there should be no partial short circuit anywhere in the distributor wiring, and all brush segments in the distributor should be cleaned so that the brush may make equal contact with all of them.

Popping back in the carburetor usually indicates a weak mixture, not enough gas; it may also indicate a sticking valve, or possibly a leaky intake valve which might be due to lack of clearance between the stem and push rod. It could also be due to improperly timed ignition or to short circuit.

Exploding of the gases in the muffler, caused by an intermittent spark, generally is due to lack of adjustment of the breaker points, to sticking of the breaker mechanism, to a loose or badly worn distributor brush, or to loose or short-circuited wires or connections.

The proper spacing of spark plugs is very essential. There are very few motors that should have a gap set closer than .025".

If gaps are set too close, the engine will not idle properly, as there will be a loping at low throttle. The action is something similar to too rich a mixture. Under these conditions the results will be the same with either a lean or rich mixture.

[1] From instruction on Master Carburetor. See also pages 462A, 462B, and 462I.

If spark-plug gaps are set too wide, the engine will have a tendency to cut out at high speed. To ascertain if it is due to the carburetor mixture, enrich the mixture by closing the damper, suddenly accelerate the engine, then open the damper for the leanest mixture, and again accelerate the engine. If the same condition exists with both the "rich mixture" and the "lean mixture" test, you will know that it is not carburetor trouble, as both rich and lean mixtures have been encountered by these operations.

If spark-plug gaps are set too close, it will cause the car to jerk at low throttle. The same condition will occur if there is a weak spark, a safety gap in the magneto set too close, or an exposed wire, which will cause the spark to jump across.

If the engine runs smooth on the level but misses on a grade or under extreme pulling conditions, it is an indication of ignition trouble, which is likely to be located in the coil or magneto, due to a defective condenser, or to a punctured armature or coil winding. This could also be traced to an improper mixture.

To determine whether the trouble is ignition or carburetion, release the clutch when missing occurs, leaving the throttle wide open. If the engine speeds up instantly and does not miss, it is ignition trouble. If the engine does not speed up readily and continues to miss, it indicates an improper mixture.

Poor compression is another cause of trouble which is often blamed on the carburetor and shows up more at low engine speeds. It will cause the car to jerk at speeds below fifteen miles an hour and make it impossible to get good idling with any mixture. The cylinders with poor compression will not draw in as much mixture as those with good compression. It will force out on the compression stroke a portion of the mixture taken in on the suction stroke. This trouble is caused by valves not seating properly, valve tappets set too high, or poorly fitting pistons or rings.

To test this out, see if the engine will rock on all cylinders by using the starting crank. This should always be tested before making a carburetor installation.

To "rock" means to have a good compression, which offers resistance to the piston when it is going up on compression stroke.

If the engine heats up excessively, look for a late spark or poor water circulation. If the magneto or distributor is set late, the engine will heat and will also cause a power loss, and you will be unable to get a spark knock with spark advance on a hard pull. Overheating could also be caused by an air leak or too lean a mixture.

When the engine backfires, it is caused by too lean a mixture. If it backfires continually and you are unable to overcome it by adjustment of the carburetor, you will know that a valve is sticking open. Exhaust valves closing too early will also cause the motor to heat.

The impression is prevalent that engine knocks are caused by a poor mixture. This is in fact very rarely the cause, as in the case of overheating, caused by a very lean mixture. When the engine knocks, look for carbon deposit, the spark being too far advanced, loose pistons causing a slap, loose bearings or wrist pins. Do not lay it on the carburetor.

Lubrication: To obtain the greatest possible mileage from an engine it is particularly essential to get the full expansion forces of the gases exploding in the combustion chamber. This is possible only when the best grade of lubricating oil is used. The perfect lubrication of an engine means considerably more than the mere elimination of friction between the moving parts.

The oil should form a perfect seal between the piston and the piston rings and the cylinder walls. This seal is all important in the saving of fuel, for it is very evident that if only a small fraction of the pressure is lost, a corresponding amount of fuel must be used to enable the engine to do the same amount of work. The fuel passing by the rings into the crank case will eventually dilute the oil to such an extent that it will be entirely robbed of its lubricating value. It is therefore essential to replace this oil with a fresh supply at least every two thousand miles.

When vacuum systems are used, there are occasional instances where trouble is experienced by gasoline being drawn direct from the vacuum tank to the intake manifold, causing the engine to load badly. This is due to a leaky check valve in the vacuum system caused either by dirt or a punctured float. The result is that the vacuum tank fills, permitting gasoline to be drawn through the vacuum tube direct into the manifold. To determine if this trouble exists loosen the vacuum tube connection at the manifold; when the engine starts loading, draw the pipe out of connection about one-eighth of an inch while the engine is running. If the valve leaks, you will notice gas being drawn through the tube. If there is an air leak existing at the vacuum-tank connection, the tank will not supply enough fuel to the carburetor under heavy pulling conditions. See also page 1041.

In making carburetor installations it is often necessary to use elbow fittings, which will necessitate tapping the flange for vacuum connections. In such cases do not tap the intake manifold too close to the outlet of the carburetor throttle, as this will reduce the vacuum in the manifold when the throttle is suddenly opened to such an extent as to interfere with the proper functioning of the vacuum tank. The bottom of the vacuum tank should be at least two inches higher than the gasoline level in the float chamber of the carburetor.

Vacuum tanks should be drained and cleaned at regular intervals. The carburetor is blamed quite often for vacuum-tank trouble. However, do not lay your trouble to the vacuum system until you have proved that it lies there.

When the car runs perfectly at low throttle or ordinary speeds and will accelerate quickly without backfiring, **but will backfire at high engine speeds** or on hills with wide-open throttle, look for some restriction in the flow of fuel from the tank to the bowl of the carburetor (providing you are sure the spark-plug gaps and ignition are all right). If the line is free from restriction, remove the screen and wash with gasoline. If there is no restriction up to this point, see that the vent hole in the main gas tank filler cap is not plugged up and trapping the flow of gasoline in the line. See also pages 114, 115, 1041.

FLOAT TROUBLES AND ADJUSTMENTS

When a carburetor drips, it usually indicates that the float or float-valve mechanism is out of adjustment. This prevents the float needle valve from properly closing. For instance, the float may be loose at the float screw; the gasoline then reaches a higher level than the spray nozzle or jet, with the result of an overflowing at the spray nozzle.

There are several causes for a dripping carburetor: either the float needle valve does not seat, due to sediment under it, or worn.

If sediment is the cause, the needle valve can be turned a few times on its seat and will probably clear the obstruction. On some carburetors, the float needle valve is in the form of a rod (needle valve) running through the float (see (20), page 462H).

If the leak is not in the float needle valve, then it is probably due to the float being set so that it does not cut off in time to prevent overflowing at the jet. Or, in the case of a **metal float,** there may be a small hole in it, preventing it from properly floating; if a **cork float,** it may have become **gasoline soaked or logged** (see pages 123 and 1132); another cause may be that the mechanism is loose.

A simple method of testing a carburetor float mechanism is shown in Fig. 1.

In making this test, unscrew that part of the carburetor which will permit access to the float and float mechanism. Then prepare a device consisting of a can with a wire handle, a piece of copper tubing soldered to the bottom of the can to form an inlet, a piece of rubber tubing, and a nipple or short piece of metal tubing with a coupling adapted for attachment to the carburetor. The gasoline flows to the carburetor from the can, when it is held above the carburetor. By watching the float chamber fill with gasoline, the height the gasoline reaches at the time the float valve cuts off can be ascertained. If the height of gasoline in the carburetor is not sufficient, then the float must be raised slightly so that it will cut off later; if the height is too great, which can be determined by the gasoline flowing out of the jet, then the float must be slightly lowered, so that it will cut off earlier.

Owing to the variation in the suction of different engines on a carburetor, it is often found that a slight variation of the fuel level or a slight change in the size of the spraying nozzle will add greatly to the efficiency of the engine. The first thing to do, then, before attempting the adjustment of a float is to learn whether or not the float needs adjustment, by seeing if the gasoline is at the proper height in the jet when the float cuts off the gasoline.

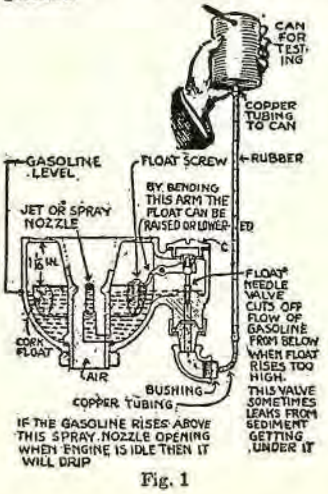


Fig. 1

To locate a suspected leak in a float of the hollow metal type: If the float is immersed in very hot water, the gasoline will be vaporized sufficiently to force its way out through a puncture and the spot may be located by watching the bubbles. The float should, of course, be removed from the water the instant bubbles cease appearing. The remedy is to solder the hole, but use solder sparingly, otherwise it will cause the float to become too heavy.

Cork floats are coated with varnish, but after long periods of time this coating may come off and the cork may become gasoline soaked, making it heavy and thus causing the float needle valve to fail to cut off properly. A mixture for coating is as follows: 1 lb. of glue, 1 teaspoon glycerine, 1 quart water. Let this come to a boil and add formaldehyde for quick drying. When coated, suspend the float by a string until dry.

Testing the Float Height

On most makes of carburetors, the float needle valve is intended to cut off the gasoline when the level of gasoline in the float chamber reaches a level of about 1/8" below the top of the nozzle or jet tube. Therefore the **height recommended by the manufacturer** ought to be maintained.

Float adjustment: There is usually an adjustment provided directly above the gasoline float needle valve, which will regulate the height of the float. If not, then on some makes of carburetors (see Fig. 1) the float arm can be bent up or down, which will regulate the height of the float, and this in turn governs the float needle valve cut-off.

If the leak is due to a faulty seating of the float needle valve, then it will be necessary to put in a new needle valve or to reseat it.

Gasoline Level in the Jet

It is advisable to not tamper with the float unless you know positively that it is out of adjustment. This can be determined, if continually leaking, by making the test suggested above. Carburetors with floats similar to the Stromberg type "H" are provided with float adjustments. A Zenith carburetor is used as an example.

Zenith (Fig. 2): The level of the gasoline is maintained in the float chamber so that the gasoline stands 3 millimeters below the top of the jet, or about 7/64". To regulate the level, note the washers (L), Fig. 2.

Master: The float weights are set about 1/32" from the bottom of the float lid.

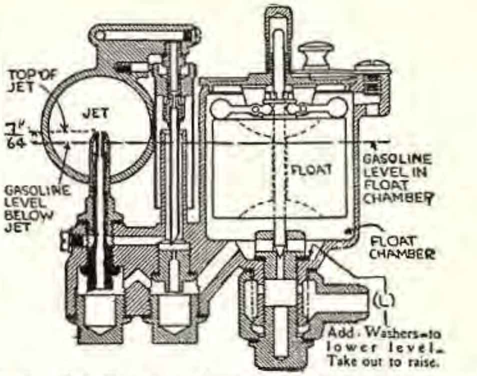


Fig. 2. This illustration shows the level of gasoline in the float chamber and in the jet of the Zenith carburetor. If the float level was above the jet, the gasoline would run out of the jet.

Schebler: In model "L," the top of the cork should stand 1 1/16" from the top of the bowl in the 1-inch, 1¼-inch, 1½-inch and 1¾-inch. In the 2-inch model "L" carburetors this measurement is 1⅛" and in the 2½-inch model "L," 1¾". These measurements should be made when the float valve is seated. In the Model R, the height of the cork float should be 23/32" from the top of the bowl when the float valve is seated. In models D and E, the cork float should be level and rest 1/16" above the top of the nozzle in the ½-inch, ¾-inch, and 2-inch sizes, and 1/32" on the 1-inch, 1¼-inch, and 1½-inch sizes. Model H is 19/32".

Note: When changing the float level, great care must be taken to bend the arm in such a manner that the float will be at the proper height, yet perfectly level.

Stromberg: Note the level of gasoline in the float chamber in Fig. 2. This illustration will give the reader an idea as to the relation of the level of the gasoline in the float chamber to that in the jet. On the Stromberg models "H," "L" and "M," the fuel level in float chamber should be about one inch below the top machined surface of the float chamber. This can be adjusted by removing the dust cap and loosening the nut; if the gasoline is too low, screw adjustment up; if the gasoline is too high, screw adjustment down.

The adjustment on the Stromberg "K" type can be adjusted only by "bending the arm," as previously explained, which governs the float level.

Rayfield: The float level is correctly set at the factory and does not ordinarily require adjustment; but if it should, then the correct gasoline level should be maintained in the middle of the window in the side of the float chamber.

TOOLS REQUIRED FOR REPAIRING CARBURETORS

A few of the tools generally used for repairing carburetors are given below. Special service tools, such as wrenches, gauges, etc., also parts, may be obtained of the various carburetor manufacturers, or their authorized distributors.

Some of the small hand tools required are: 2 oz. hammer; long, thin 3/16" wide point screw driver; 1/4" and 1/2" screw drivers; flat and box type socket wrenches 5/16", 3/8", 7/16", 1/2", 9/16", 5/8", 3/4"; hand drill; very small drills; feeler gauges; regular and long nose pliers; flexible 6" scale; 6" and 8" mill file; special wrenches for removing and inserting jets and float needle valve seats; seating tool for inlet needle valve; float gauge and adjusting tool. **Other equipment:** gasoline mileage tester (explained in *Dyke's Carburetor Book*); compression and vacuum gauges (see Addenda, pages 40-44 and 481); battery tester. An exhaust gas analyzer is recommended for those doing regular carburetor work. See *Dyke's Carburetor Book.*

Before proceeding with carburetor adjustments the engine should be checked for "tune-up." This involves checking the spark plugs, ignition interrupter points, ignition timing, valve clearance, compression, manifold and carburetor gaskets and choker operation, etc. See page 1054B.

Carburetor Repair Bench

A space should be set aside for testing and repairing the carburetor, and no greasy or dirty tools should be used, as it is important that no dirt gets into the assembly.

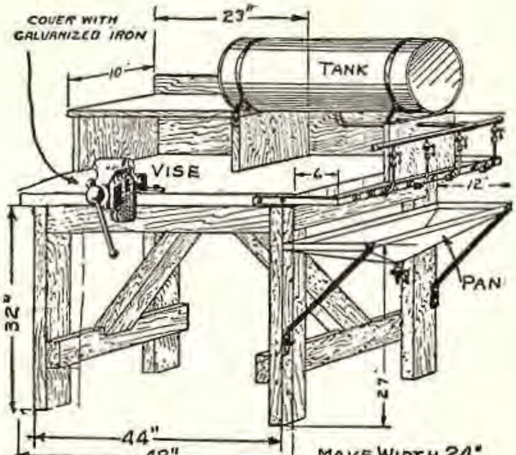


Fig. 3. Carburetor repair bench.

A suggestion for a repair bench is shown in Fig. 3. A bracket is provided to hold the carburetor in a level position. A tank 6" above the level of the bracket is connected to the carburetor by means of a series of standard feed pipes. Note the four gasoline pet cocks and connections which permit four carburetors to be tested at one time. Below the bracket a pan is provided to catch any drippings.

To guard against fire due to static electricity, the bracket should be connected to the drip pan by some metallic connector.

The carburetor is secured to the bracket and the feed pipe is attached to the carburetor from the connections (shown on the right) in the regular way. Here the gasoline level may be checked and the carburetor may be watched to see that it does not leak at the float valve.

A 4" machine vise with jaws opening 5¼" should be provided to hold the carburetor during the repair operations.

CARBURETORS—PRINCIPLE AND ADJUSTMENT

Owing to the fact that innumerable improvements are constantly being made in carburetor construction, it is impossible in this instruction to describe all the actual adjustments of all carburetors.

Repairmen are advised to secure instructions for adjustment of all the leading makes of carburetors from the manufacturers and to keep them on file (see Index for "Addresses of carburetor manufacturers").

Schebler Model "R" Carburetor

This carburetor may be termed an air-valve type of carburetor, with an automatically operated gasoline needle valve controlled by the auxiliary air valve.

Note that the gasoline needle valve (metering pin I) is operated automatically by movement of the auxiliary air valve. A concentric-type cork float is used.

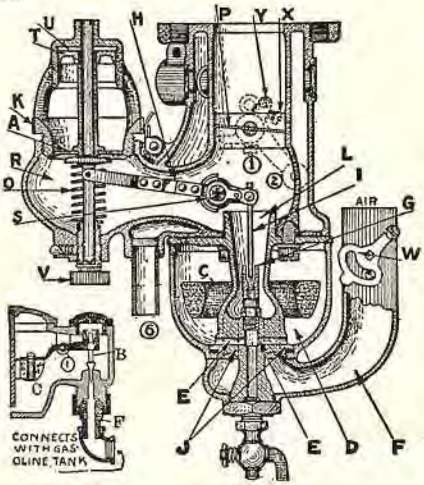


Fig. 1A Fig. 1

Fig. 1. Schebler model "R" carburetor.

Fig. 1A. Showing how the float gasoline needle-valve (B) cuts off and opens the gasoline passage (F) by the rise and fall of the float (C).

The parts consist of a float chamber (D), the cork float (C), and a float needle valve (B). These three parts control all flow of gasoline into the carburetor as it is needed by the engine.

That part of the carburetor where the gasoline and air are mixed consists of a mixing chamber (L), a spray-nozzle (G), and a needle valve (I).

The parts which automatically regulate the amount of gasoline required from the float chamber to provide the proper mixture consist of an auxiliary air valve (A) and lever (H), connected with needle valve (I).

Principle of operation: Gasoline flows from the tank through the gasoline pipe into the float chamber (D).

As the gasoline rises in the float chamber (D) it raises the cork float (C) with it, which, through a lever connection, automatically closes the needle valve (B) and shuts off the flow of gasoline from the tank to the carburetor. Of course, as the gasoline is drawn from float chamber (D), the float (C) drops and raises valve (B), admitting more gasoline.

The suction of the pistons draws the gasoline from the float chamber (D) through the passages (E) into the nozzle well (G), and past the needle valve (I) into the mixing chamber (L). As the needle valve (I) is raised and lowered, more or less gasoline is allowed to spray into the mixing chamber (L). At the same time the suction of the pistons draws from the warm-air intake (F) and the passages (J) warm air into the mixing chamber (L). As the suction of the swiftly moving pistons is very strong, the air is drawn through the mixing chamber (L) with great velocity, and there, coming into contact with the gasoline spray from the nozzle well (G), it vaporizes the gasoline.

This vaporized mixture is then drawn by the suction of the pistons past the throttle valve (P) into the cylinders. The quantity of combustive vapor flowing past the throttle valve (P) is regulated by the position of this throttle valve, and the position of this throttle valve is regulated by the driver either from a pedal called the "accelerator" or a throttle lever on the steering post. Opening the valve (P) admits more combustive vapor to the cylinders, and consequently increases the speed and power of the motor. Closing it has the reverse effect.

At high speed it is obvious that the suction through the mixing chamber (L) and the warm air passages (J) greatly increases, and as it increases beyond the capacity of these passages to supply air, a strong suction is brought to bear upon the auxiliary air valve (A). At a certain speed this suction is sufficient to draw this valve down against the coil spring (O). As the valve is drawn down, air rushes into the auxiliary air passage (R), and thence past the mixing chamber (L) into the cylinders.

Auxiliary air valve: To take care of this extra supply of air there must be an extra supply of gasoline automatically furnished. This is taken care of as follows: As valve (A) is depressed against the spring (O) it operates the lever (H), which is hinged at the point (S). As the lever (H) is depressed by the valve (A) it opens needle valve (I) admitting more gasoline to the mixture. It will be seen that this extra supply of gasoline is always directly in proportion to the air supply through the valve (A).

Dash-pot action: It is obvious that if means were not taken to prevent it, the valve (A), which is under the tension of the spring (O), would close very

NOTE: Although these carburetors are early models, the reader should study their principle of operation. With these fundamental principles in mind he can then more readily understand the modern carburetors, such as on Insert No. 6 and 7.

abruptly if the speed of the engine was suddenly checked. It would also tend to open very abruptly if the speed of the engine was suddenly increased, as, for instance, if the accelerator was suddenly opened. Furthermore, the suction of the cylinders is to a certain degree intermittent between the strokes of the pistons, and this intermission between the strokes would ordinarily tend to cause the valve (A) to flutter or vibrate if means were not taken to prevent it. The fluttering or vibratory action of the valve (A) would result in an unsteady flow of gasoline vapor to the cylinders, which would cause a vibratory or jarring effect in the engine. Any such action is prevented by a device (U) called a dash pot. Its function is automatically to insure a steady and stable supply of gasoline vapor to take care of varying engine speeds under all circumstances. To hold the valve (A) steady and to check its sudden closing or opening and to overcome its tendency to vibrate, it is attached directly to a plunger (T), which operates on a cushion of air in the dash pot (U).

To adjust the carburetor (Fig. 1): Turn the auxiliary air-valve cap (K) clockwise, or to the right (right means "rich") until you can turn it no farther. Then turn to the left or counter-clockwise (left means "lean") through one complete turn. Start the engine and then continue to turn (K) to the left or counter-clockwise until the engine hits perfectly on all cylinders, at the slowest speed possible. Advance the spark lever two-thirds or three-fourths the way on the sector and then suddenly open the throttle lever or accelerator wide. If the engine back-fires on this quick acceleration, turn the spring adjusting screw (V) up until the carburetor works perfectly.

By turning the screw (V) up or inward, it is turned against the spring (O), which increases its tension, thus preventing valve (A) from admitting air into the carburetor too freely.

Turning (K) to the right, or clockwise, lifts the needle valve (I) out of the nozzle well (G) and permits more gasoline to spray into the mixing chamber.

When (K) is turned to the left, or counter-clockwise, it lowers the needle in the nozzle and shuts off the gasoline. It should be remembered that it is desirable, from both points of economy and power, to drive the car with the leanest mixture possible.

The throttle valve should be adjusted so that when the hand throttle is closed, the engine will idle and run evenly on all cylinders. This can be ascertained by the regularity of the impulses in the exhaust when both the spark and throttle levers are set at their lowest positions. If the engine, however, should run too fast, or should stop when the throttle is at lowest position, adjustment is necessary. Directions for this are as follows:

Adjusting carburetor throttle idling screw: Loosen the set screw (Y) which locks the adjusting screw (X) where the throttle shaft enters the carburetor. Place throttle in lowest position. If the engine runs too fast, unscrew adjusting screw (X) so that the butterfly throttle valve (P) is closed a little tighter. If the engine runs too slow, screw in the adjusting screw so that the valve is held a little more open. Lock adjusting screw (X) with set screw (Y) after adjustment. About .005" clearance of throttle valve (P) is usually allowed when closed.

Schebler Model "L" Carburetor

This carburetor may be termed an "air-valve type" of carburetor with a mechanically operated gasoline needle valve. Note that the gasoline needle valve (B) is raised and thus opened mechanically by movement of the throttle lever which is connected with a cam arrangement (C). As the throttle lever is opened, the cam action raises the arm (J) connected with the gasoline needle valve, thus raising the needle valve from its seat (S) and admitting more gasoline at the jet.

To adjust the carburetor: First, make adjustments on the auxiliary air valve (A) so that it seats firmly, but lightly; then close the needle valve by turning the adjustment screw (B) to the right until it stops. Do not use any pressure on this adjustment screw after it meets with resistance. Then turn it to the left about a turn and a half and prime or flush the carburetor by pulling up the priming lever (C) and holding it up for about five seconds. Next, open the throttle about one-third, and start the engine; then close the throttle slightly and retard the spark and adjust the throttle-lever screw (F) and needle valve adjusting screw (B) so that the engine runs at the desired speed and hits on all cylinders.

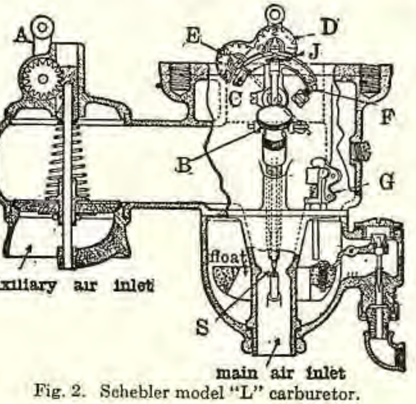


Fig. 2. Schebler model "L" carburetor.

After getting a good adjustment with the engine running idle, do not touch the needle valve adjustment again, but make intermediate and high-speed adjustment on the dials (D) and (E). Adjust pointer on the first dial (D) from figure No. 1 toward figure No. 3, about half-way between. Advance the spark and open the throttle so that the roller on the track running below the dials is in line with the first dial. If the engine back-fires with the throttle in this position and the spark advanced, turn the indicator a little more toward figure No. 3; or if the mixture is too rich, turn the indicator back or toward figure No. 1 until satisfied that the engine is running properly with the throttle in this position, or at intermediate speed. Now, open the throttle wide and make adjustment on dial (E) for high speed, the same as adjustments for intermediate speed on dial (D).

Note: In the majority of cases, in adjusting this carburetor, the tendency is to give too rich a mixture. In adjusting the carburetor, both at low, intermediate, and high speed, cut down the gasoline until the engine begins to back fire, and then increase the supply of fuel, a notch at a time, until the engine hits evenly on all cylinders. Do not increase the supply of gasoline by turning the needle valve adjusting screw more than a notch at a time, in low-speed adjustment, and do not turn it after the engine hits regularly on all cylinders.

In making the adjustments on the intermediate and high-speed dials, do not turn the pointers more than half-way at a time between the graduated divisions or marks shown on the dials.

Stromberg Model "H"

This carburetor would be termed a compensating-type carburetor, because, as previously stated, an auxiliary full jet comes into action as the throttle is opened.

For low speeds the gasoline is taken from the spray nozzle (C), in a venturi tube, through which hot air passes. Regulation of amount of gasoline is by needle valve (A) (Figs. 3 and 4).

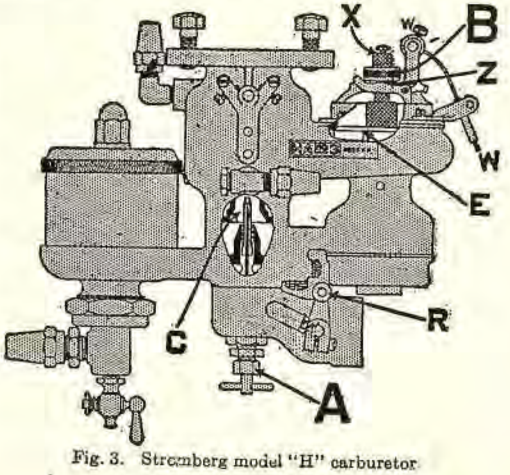


Fig. 3. Stromberg model "H" carburetor.

For high speeds, the nozzle in the center of the air valve is automatically regulated by opening of the air valve thus supplying the necessary volume of gasoline for high speed.

Adjustment for high speed is by (**B**), which controls the amount of flow of gasoline on high speed by regulating the time when the needle valve begins to open. The needle valve opens only when (**B**) comes in contact with (**X**). (**B**) is raised by a throttle opening at high speed. There is usually about 1/32″ clearance between (**B**) and (**X**).

Low-speed adjustment is controlled by the needle valve (**A**). If too rich, as indicated by the engine "rolling" or "loading," turn (**A**) up, thus admitting less gasoline and making the mixture leaner. If the mixture is too lean, turn (**A**) down, thus admitting more gasoline and a richer mixture.

High-speed adjustment: Advance the spark, open the throttle. If the mixture is too lean on high speed, screw (**B**) up until desired results are obtained. If the mixture is too rich, screw (**B**) down.

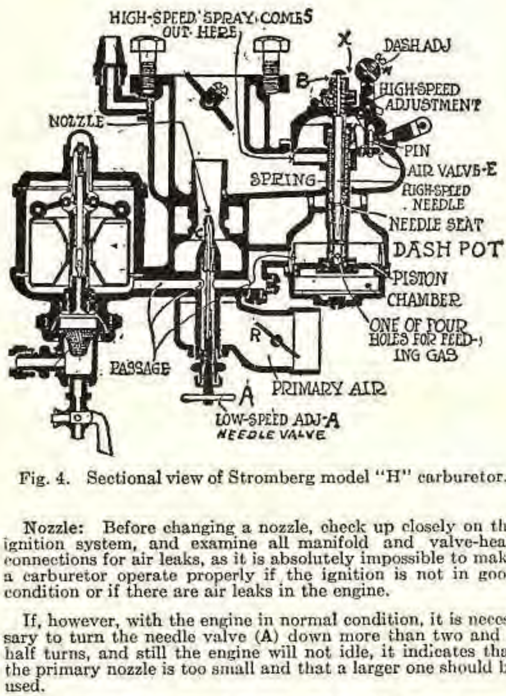


Fig. 4. Sectional view of Stromberg model "H" carburetor.

Nozzle: Before changing a nozzle, check up closely on the ignition system, and examine all manifold and valve-head connections for air leaks, as it is absolutely impossible to make a carburetor operate properly if the ignition is not in good condition or if there are air leaks in the engine.

If, however, with the engine in normal condition, it is necessary to turn the needle valve (**A**) down more than two and a half turns, and still the engine will not idle, it indicates that the primary nozzle is too small and that a larger one should be used.

If it is impossible to get enough gas on high speed except when nut (**B**) is so high that there is no clearance at (**X**) on idle, a higher number needle valve should be used.

If there is too much gas on high speed when nut (**B**) is turned down as far as it will go, a lower number needle valve should be used.

To change the primary nozzle (**C**), take out the needle valve (**A**) and remove nozzle with a regular screw driver. To remove the taper valve on high speed, pull up the steering post control, unscrew nut (**B**) all the way, and lift valve out. This valve and nut (**B**) are assembled together and should be ordered in that way. Do not attempt to take these apart or to change the taper.

Never change the nozzle more than one size at a time. The nozzle opening gets smaller as the number gets larger; thus a No. 59 is smaller than a No. 58.

High-speed needle valves deliver more gas as the number gets larger; thus a No. 7 will give more gas than No. 6.

Always install the carburetor with the float chamber towards the radiator.

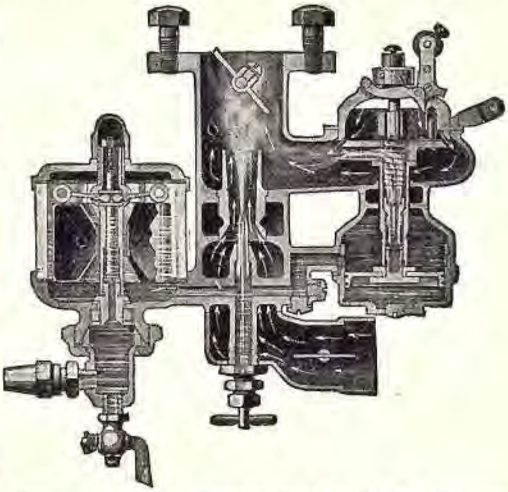


Fig. 5. Phantom sectional view of model "H" Stromberg carburetor, showing high-speed needle and primary nozzle in action. Note the path of the gas.

Marvel Model "E" Carburetor

The Marvel model "E" is a double jet, "compensating type" of carburetor, with the application of exhaust heat to a jacket surrounding the throttle chamber and venturi tube, the amount of heat being automatically controlled by the throttle opening. Outside the float mechanism this carburetor has but one moving part, the auxiliary air valve. (See Figs. 6 and 7.)

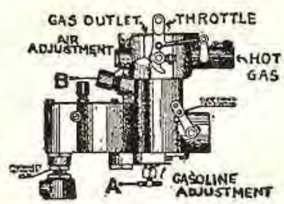


Fig. 6. Marvel model "E" carburetor.

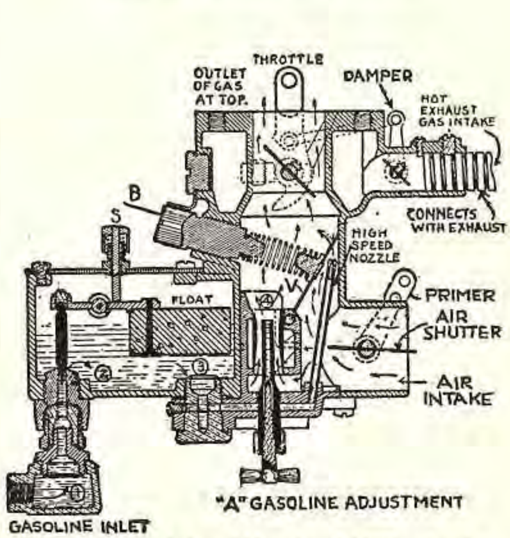


Fig. 7. Sectional view of Marvel model "E" carburetor.

Two jets are used, a primary low-speed jet and a secondary high-speed jet which is brought into action by the opening of the auxiliary air valve.

When the engine is idling, the hinged auxiliary air valve (V) (Fig. 7) rides on its seat against the bore of the mixing chamber, thus closing off the air passage past the tall high-speed nozzle jet, rendering it ineffective. At this time the air passes up through the small venturi surrounding the low-speed jet.

As the suction of the engine increases the auxiliary air valve is opened against the spring pressure, and the second jet (high speed), comes into action.

A choker valve (see air shutter) in the main air intake allows a rich mixture to be obtained for starting. This device may be controlled from the dash, so that when the engine is cold it may be closed to prevent back-fires, and may be gradually opened up as the engine warms up.

The feature of this carburetor, previously mentioned, is the **exhaust-heated jacket.** The heat is controlled by a damper connected to the throttle lever, which damper can be set to give any degree of heat desired. This is of particular importance, as the quality of gasoline is yearly becoming heavier and heavier. This heat damper, therefore, can be set to admit sufficient heat to secure good vaporization of heavy fuel on low throttle, and then, as the throttle is opened, the heat is automatically cut off, thus insuring maximum power at the higher speeds where heat is not necessary to good carburetion. By such an application of heat the entering air is not preheated, and this naturally results in greater thermal efficiency and power due to a maximum cylinder filling at each stroke of the pistons.

Adjustment: start by turning needle valve (A) to the right until it is completely closed. Then adjust the air adjustment (B) until the end of the screw is even with the end of the ratchet set spring above it.

Next, open (A) (gasoline needle) one turn, start the engine as usual, using the strangler button (S) to get a rich mixture at first. Allow the engine to settle and warm up; then gradually cut down on (A) until the engine runs smoothly.

Next, turn air screw (B) to the left, a little at a time, until the engine begins to slow down. This indicates that the air-valve spring is too loose. Turn it back to the right just enough to make the engine run well.

To test the adjustment, advance the spark and open the throttle quickly. The engine should "take hold" instantly and speed up at once. If it misses, or "pops back" in the carburetor, open needle valve (A) slightly, turning to the left. If this does not give results, the air screw (B) may be tightened a little by turning slightly to the right. It should be borne in mind that the air valve should be carried as loosely as possible, and that the adjustment for "pick-up" may be obtained by carrying more gas with needle valve (A), rather than to tighten up the air valve too much.

The best possible adjustment is secured when air adjustment (B) is turned as far as possible to the left and needle valve (A) to the right, providing the engine runs smoothly and picks up quickly when the throttle is open. The speed of the engine is governed by the small set screw in the throttle stop. If the engine runs too fast, turn the screw to the left; if too slow, turn the screw to the right.

The auxiliary air valve spring (V) after long use may lose its tension due to heat.

Marvel Carburetor Connected to a Buick

The illustration (Fig. 8) is that of the gasoline system of the Buick six-cylinder, enclosed-model car. Note the vacuum gasoline feed system connected with the intake manifold and carburetor.

The Buick exhaust heating method of the mixture, by means of the exhaust manifold surrounding the intake manifold is shown.

A gasoline gauge is shown on the dash, the purpose and explanation of which is as follows:

A visual gasoline gauge is located on the dash of the closed models only and is a mechanically operating device which registers at all times the quantity of gasoline **remaining** in the main gasoline tank attached to the rear of the car.

It consists of a cork float, a piano wire, and a graduated registering dial. The cork float (F) is fastened to the tank base extension by means of an arm bent at the proper angle, which rises and lowers as the gasoline level changes.

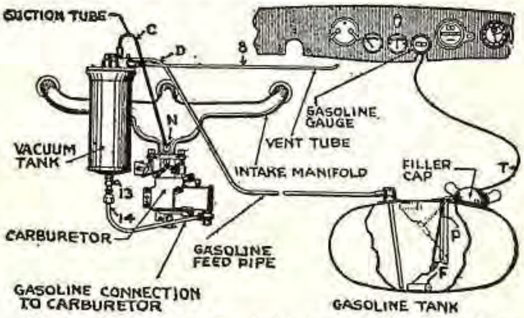


Fig. 8. Fuel system of the Buick in which the Marvel carburetor is used.

The piano wire (P) is attached to the float arm by means of a clip, and as the float rises and lowers it forces the wire to oscillate in and out of the tank through an aperture in the tank base which is fastened to the tank, from which a flexible tubing or casing (T) extends to the gauge on the dash inside of which the piano wire oscillates (see also page 650).

The graduated dial or drum is enclosed in a housing which fastens to the instrument plate, and the gasoline level is registered by the longitudinal motion of the wire. The drum is supported by pivot pins, and a constant tension is maintained with a hair-spring adjustment, set in such a manner as to permit the drum to rotate. The registering figures are placed on the outside of the drum and show through a small aperture in the face of the instrument conveniently located on the dash.

Rayfield Models "G" and "L" Carburetor

Rayfield carburetors are made in two types: model "G" and "L," the difference being that model "G" has a water-jacket.

In both models the **air-valve adjustment has been eliminated,** high and low-speed adjustments being made through the control of the fuel.

Both models are of the **two-jet type,** one jet feeding at low speed and both at high speed. The principle of this carburetor is explained in Fig. 24 and on page 102.

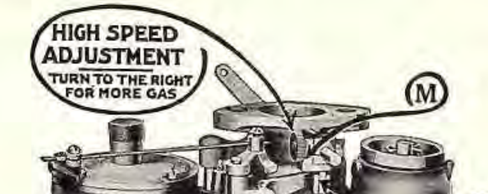


Fig. 9. Side view of Rayfield model "G" carburetor.

There are three air openings, one fixed and operating in conjunction with the low-speed nozzle and the other two having automatic valves linked together and operating simultaneously.

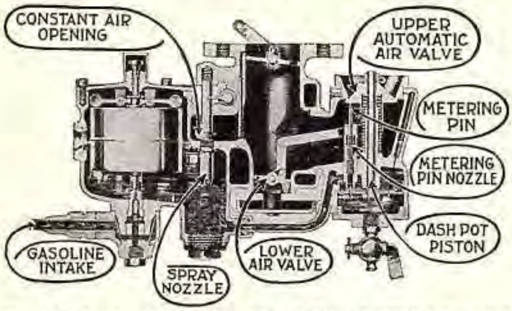


Fig. 10. Sectional side view of Rayfield model "G" carburetor.

The high-speed nozzle is controlled by a metering pin actuated by the upper automatic air valve. The stem of the valve is connected to a piston working in the dash pot, from which a passage communicates with the float chamber; the dash-pot chamber has direct connection with the high-speed nozzle.

When the throttle is opened, the tendency of the air valve to open suddenly and excessively, and to flutter, is checked by the dash-pot piston, which at the same time forces an extra supply of fuel into the nozzle and enriches the mixture for acceleration; the slow opening of the air valve increases acceleration by causing strong suction on the nozzles.

When adjusting a Rayfield, bear in mind that **both adjustments are turned to the right for a richer mixture,** as indicated on the adjustment screw heads.

The Rayfield dash control connects with the carburetor by a wire. When properly used, this will render starting easy, furnish a richer mixture when the engine is cold, and maintain a correct mixture under extreme atmospheric changes.

Raising the dash control lifts the spray needle and supplies a richer mixture. When it is raised full distance, a direct passage is opened, permitting raw gasoline to be drawn from the fuel chamber of the carburetor to the engine. The control button (or lever) should be down for running, except when a richer mixture is desired.

The automatic air valve should be closed when the engine is not running, or when throttled down.

The low-speed adjustment is to be used only when the engine is running idle and positively must not be used in adjusting high speed. Never adjust a carburetor unless the engine is hot and the water jacket of the carburetor warm.

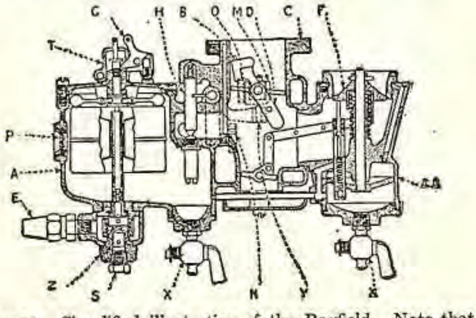


Fig. 11. Simplified illustration of the Rayfield. Note that two air valves, with a dash pot for acceleration, are used. (A), float chamber; (AA), dash pot; (B), stop screw; (F), automatic air valve; (H), nozzle needle; (N), low-speed adjustment; (M), cam; (O), high-speed adjustment; (S), drain cock; (Y), block

Adjusting low speed: With the throttle closed and the dash control down, close the nozzle needle by turning low-speed adjustment to the left until block (U) (Fig. 9), slightly leaves contact with the cam (M). Then turn to the right about three complete turns. Start the engine and allow it to run until warmed up. Then with retarded spark, close the throttle until the engine runs slowly without stopping. Now, with engine thoroughly warm, make final low-speed adjustment by turning low-speed screw to the left until the engine slows down and then turn to the right a notch at a time until the engine idles smoothly. If the engine does not throttle low enough, turn stop arm screw (A) (Fig. 12) to the left until it runs at the lowest number of revolutions desired.

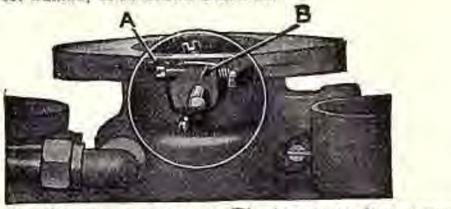


Fig. 12. **(A)** stop arm screw; **(B)** stop arm; turn screw **(A)** to left to throttle engine lower.

Adjusting high speed: Advance spark about one-quarter. Open the throttle rather quickly. Should the engine back-fire, it indicates a lean mixture. Correct this by turning the high-speed adjusting screw to the right about one notch at a time, until the throttle can be opened quickly without back-firing. If "loading" or choking is experienced when running under heavy load with throttle wide open, it indicates too rich a mixture. This can be overcome by turning the high-speed adjustment to the left.

To start the engine when cold: First close the throttle and pull the dash control all the way up. Second, when the engine starts, open the throttle slightly and push the dash control one-quarter of the way down. Third, as the engine warms up, push the control down gradually; when thoroughly warm, push the control all the way down. When the engine is warm it is necessary to pull the dash control only part way up for starting.

Hot-water connection is connected with the suction end of the pump (between radiator and pump). The connection on the other side connects with the water jacket of the engine or upper water pipe. A shut-off cock is provided for hot weather. See that these connections are made so that water will be drained out of the carburetor jacket when the system is drained.

Attach a hot-air stove to the exhaust pipe and connect to the constant air elbow of carburetor by a flexible tube. Connections are 5/16" outside diameter tubing for gasoline and water connections.

Rayfield Model "M" Carburetor

The model "M" Rayfield (Fig. 13) is a smaller type incorporating the features of the Rayfield model "G" without the dash pot. Fig. 14 shows the principle of the primer incorporated within the carburetor.

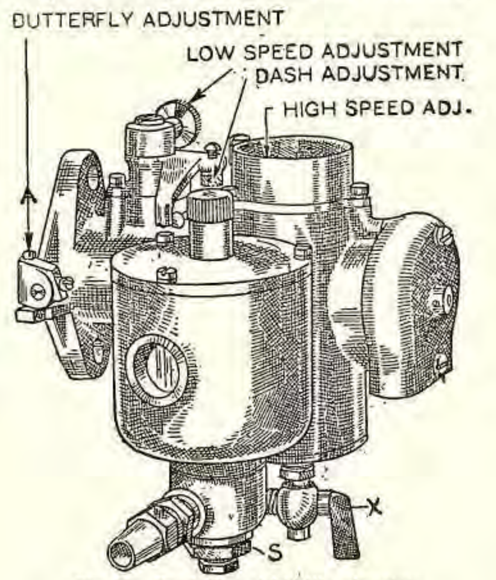


Fig. 13. Rayfield model "M" carburetor.

To adjust this carburetor, bearing in mind all the precautions cited previously, proceed as follows: The **low-speed adjustment** is turned to the right for a rich mixture, to the left for a lean.

With the engine running idle and the dash control down, turn the low-speed screw to the left one notch at a time. Between each movement of the thumb screw, the engine should be accelerated and allowed to come back to its idling speed. In this way a very exact adjustment can be obtained. If the slow-speed adjustment is obtained by turning the screw down all at once, a very accurate setting will not be obtained. When this screw has been turned down until the engine manifests a marked falling off in speed, it is a sign that the correct position has just been passed a notch or two. During the accelerating periods, the engine will commence to miss and spit back when the lean mixture is reached.

The intermediate and high speed is made accessible by removing the hot-air elbow from over the main air valve. It is well to observe a little precaution at this point. The high-speed screw should not be moved more than one-eighth turn at a time. This screw produces very effective results in the action of the carburetor, and its movement should therefore be correspondingly regulated. The economy of the engine is affected in a very pronounced manner by turning this screw.

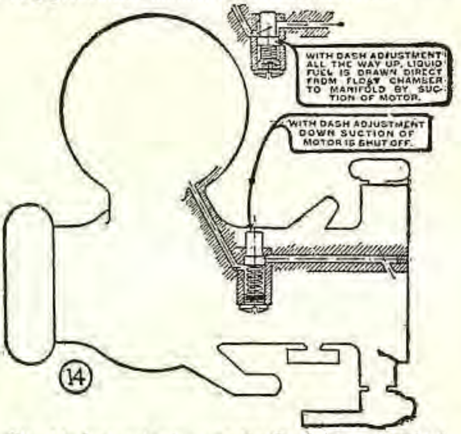


Fig. 14. Internal primer on the Rayfield model "M."

Johnson Carburetor

The Johnson is a "gravity air-valve type," with a single concentric jet, in which an air valve is made up of a sleeve rising and falling by suction and gravity in a cylindrical passage above the jet.

There are **three stages of vacuum:** one is the space between the throttle and strangle tube; the second, in the strangle tube itself; the third, in the space below the plate on the bottom of the air-valve sleeve. By removing the location of the idling adjustment (in Fig. 15) the gasoline flow (for idling) is brought in a zone of greater vacuum and hence better idling.

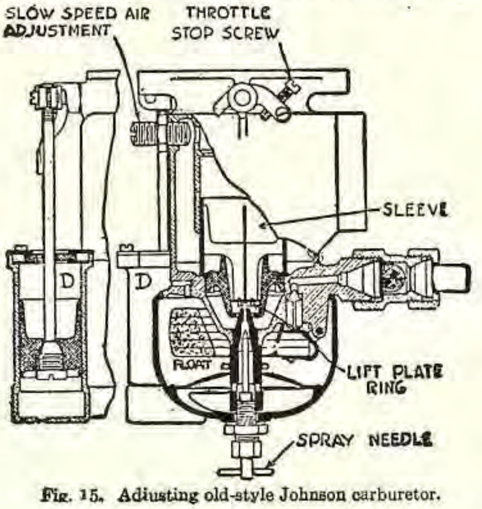


Fig. 15. Adjusting old-style Johnson carburetor.

Indications of incorrect adjustment: (A), lean mixture; **(B)**, engine difficult to start; **(C)**, "popping back" on quickly opening throttle; **(D)**, engine knocks when throttle is opened quickly; **(E)**, engine will not idle.

Many mechanics can adjust this carburetor for high speeds, but sometimes find difficulty in adjusting for low speeds or idling. The correct procedure of **adjustment is as follows:** (1) retard spark; (2) close the slow-speed air-adjustment screw (Fig. 15); (3) warm engine; (4) see that the intake pipe manifold, where it connects to the carburetor flange, does not leak air; (sometimes a water-jacketed intake manifold will become "air-locked" and water will not circulate, depriving it of heat; open "plug"); (5) accelerate the engine by opening and closing the throttle rapidly; if the mixture is too rich, acceleration will be sluggish; if too lean, it will "pop back" considerably; the spray needle adjustment should be set between these two points; (6) retard the spark and close the hand throttle; adjust the throttle stop screw until the engine runs very slowly, regardless of whether it operates evenly or not; (7) open the slow-speed air adjustment until the engine idles evenly, if possible; if it runs too fast, close down the throttle stop-screw; the adjustments on the stop-screw and the low-speed screw should be made simultaneously; (8) it may be found that the low-speed air adjustment cannot be opened at all; in this case the low-speed mixture is too lean; possibly the low-speed air adjustment can be opened more than 3½ turns, when the mixture is too rich; do not touch the spray-needle setting, but **proceed as follows:**

Disassemble the carburetor: A small ring, shown in Fig. 15, is attached by two lugs to what is known as the lift plate. This ring is somewhat curved, and if the slow-speed air adjustment can be opened more than 3½ turns without obtaining good idling, the curve is excessive and the ring should be slightly flattened. If on the other hand the air adjustment cannot be opened, the ring is too flat and should be slightly curved. The standard setting is 3/32" from the edge of the ring to the lift plate to which it is attached.

Adjusting (Model "A"): (1) Turn both idle screw and high-speed needle (Fig. 16) to their seats, and set the throttle stop in approximately the correct position for closed throttle; (2) open the high-speed needle 1½ turns. This permits the engine to be started. Warm the engine up by running a few minutes; (3)

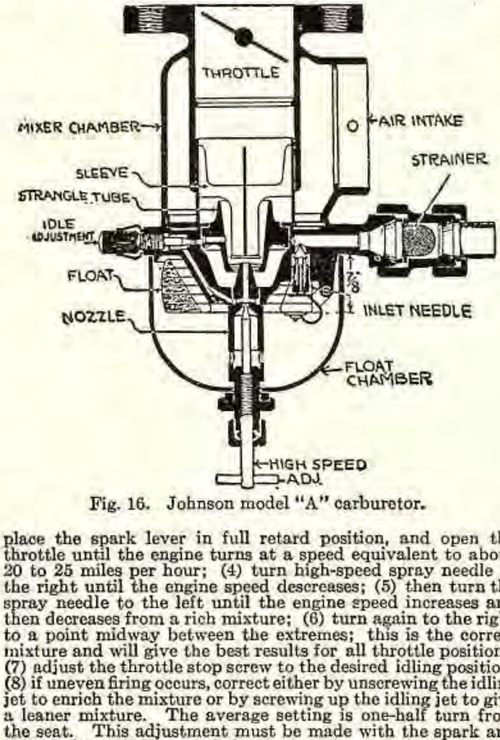


Fig. 16. Johnson model "A" carburetor.

place the spark lever in full retard position, and open the throttle until the engine turns at a speed equivalent to about 20 to 25 miles per hour; (4) turn high-speed spray needle to the right until the engine speed descreases; (5) then turn the spray needle to the left until the engine speed increases and then decreases from a rich mixture; (6) turn again to the right to a point midway between the extremes; this is the correct mixture and will give the best results for all throttle positions; (7) adjust the throttle stop screw to the desired idling position; (8) if uneven firing occurs, correct either by unscrewing the idling jet to enrich the mixture or by screwing up the idling jet to give a leaner mixture. The average setting is one-half turn from the seat. This adjustment must be made with the spark and throttle levers fully retarded.

The float should set evenly all around, the bottom being ⅞" **from the float-chamber seat, as shown in Fig. 16.**

Principle of the Zenith Plain Tube or Compensating Type Carburetor

In order to understand the principle of the Zenith carburetor we shall first consider *a simple type of* "*single jet" carburetor*, then a "compensating jet," then a "compound jet."

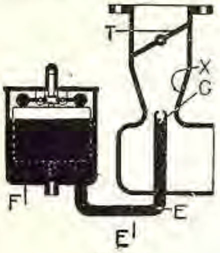


Fig. 17

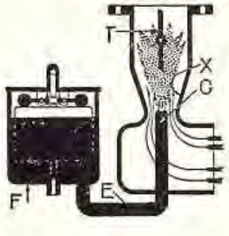


Fig. 17 A

Fig. 17. **The illustration shows a simple type of "single jet" carburetor at rest.** Note that the gasoline in the jet (G) is level with the gasoline in the float chamber (F). Throttle (T) is closed. The more we close the throttle, the more we prevent the cylinder from filling with gas.

Fig. 17A. **Single jet action: On a level road we "open up" the throttle (T). The more we open, the faster we go.** Assume that the throttle (T) is full open and the engine running at **1600 r.p.m.**; the cylinders fill with gas as freely as possible and a large quantity of air (see long arrows) passes through the carburetor, while the gasoline jet delivers its maximum.

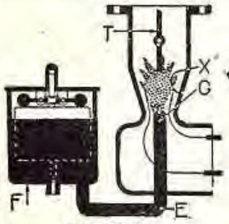


Fig. 17 B


Fig. 18


Fig. 18 A

Fig. 17B. **Now we come to a hill, and although we keep throttle wide open, the speed slows up to, say, 400 r.p.m.** The air does not pass through the carburetor with the same rush as before; the **suction** is much reduced. There is also a lessened gasoline discharge at jet (G). How will this simple carburetor work under varying degrees of suction dictated by the throttle, load, and speed? Under increased suction more air will be drawn up and also more gasoline.

The law of liquid flow tells us that the flow of gasoline from the jet increases under suction faster than the flow of air. This spoils our simple type of carburetor; for the desired ratio of 15 to 1 between air and gasoline **cannot be maintained constant under varying suction.**

Baverey, the inventor of the compound nozzle, readily saw that if, with the ideal simple carburetor, this mixture grew rich as suction increased, the only logical thing to do was to find another simple type which would work the **opposite** way, that is, a jet which would **ignore** suction and produce a mixture which would grow **poorer** as the suction increased, thus combining the two; the result being a **compound** which would hold its correct proportions under any conditions. This was Baverey's idea, upon which all Zenith carburetors are based. The principle of the jet which **ignores** suction is explained as follows.

Fig. 18. **Take a full glass of liquid.** Suck this liquid through a straw. **The harder we suck the more we get.** This is the **principle of the single jet (G) in Figs. 17, 17A, 17B.**

Fig. 18A. **Take an empty glass.** Let a tiny stream pour in from a bottle at a constant rate of flow, and again apply the straw. This time there is a difference; **we may suck as hard as we can, but we get only what the tiny stream allows us.** The bottle **ignores** the suction. This is the **principle of the compensating jet (I)** in Figs. 18B, 18C.

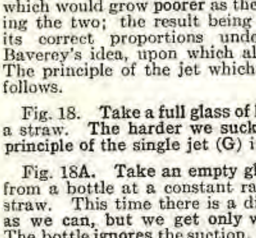


Fig. 18 B

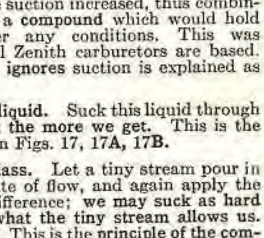


Fig. 18 C

Fig. 18B. and 18C. **The jet which ignores suction, or the constant flow device that Baverey invented, is on the same principle as the bottle, glass, and straw.** It is shown in Figs. 18B, 18C. Gasoline (as from the bottle) flows through the measuring hole (I) in a tiny stream into the open well (J) (the glass), and is drawn out through nozzle (H) (the straw), by suction. The size of the measuring hole (I), which controls the rate of flow into well (J), may be so chosen that the suction at (H) (at a certain engine speed and load) will be just sufficient to keep well (J) emptied. Once well (J) is emptied, **no more fuel can be drawn from (H) than is supplied by the constant gravity flow** through the calibrated hole (I). The mixture therefore grows **poorer** as the suction increases.

Fig. 18B. **We assume the engine is under a heavy load with wide-open throttle, running at 400 r.p.m.**, as when climbing a hill. Note that only a relatively small quantity of air is being drawn through the mixing chamber, as shown by two arrows, because the suction is not very strong, because of the engine speed being reduced, but the mixture is **fairly rich**—assuming the opening (I) is of the correct size—because we have less air.

Fig. 18C. **Assume that the engine is speeding on a level road with wide-open throttle, running at, say, 1600 r.p.m.** Note that the air has greatly increased in quantity, as indicated by the four arrows (because the speed of the engine has been increased), yet the gasoline flow remains the same as in Fig. **18B** because the tiny stream at (I) **ignores** the suction at (H). This mixture is much **leaner** than before, because we have more air, and the engine could not run under these conditions alone. It is directly opposite to the single-jet action shown in Fig. **17A**.

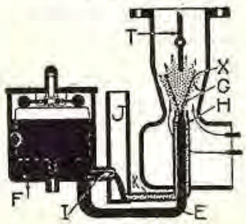


Fig. 19

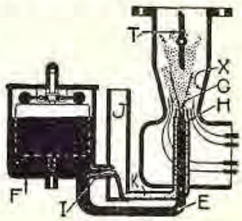


Fig. 19 A

We will now apply both principles, the "single jet (G)" with its "variable flow," and the "compensating jet (I)," with its "constant flow" to a carburetor (Figs. 19 and 19A), **and we have the Zenith "compound nozzle."**

Fig. 19. **Assume that the engine is under a heavy load with wide-open throttle, running at 400 r.p.m.** The suction is not very strong, but is lifting gasoline from nozzle (G) which feeds from float chamber (F), through channel (E), and also from nozzle (H), which feeds from (I) to open well (J), through channel (K). The arrows indicate but a moderate flow of air and at low suction the mixture is **richer than in Fig. 18B** because we have the combined action as shown in Figs. **17B** and **18B.**

Fig. 19A. **Assume that the engine is speeding on a level road with wide-open throttle, running at 1600 r.p.m.** The suction has greatly increased, as shown by the arrows, and with it the flow of gasoline from nozzle (G). Nozzle (H), however, still gives the same measured amount of gasoline as in Fig. 19, because its flow is held in check by **compensator (I).** Here we have the combined action of Figs. **17A** and **18C,** producing a **richer mixture** in jet (G) because we have more suction, and a **poorer** mixture in jet (H), because we have more air, or the desired proportion of air to gasoline.

The compound nozzle receives its gasoline from two sources. At any speed both sources of supply are in action. The main jet (G), controlled by suction, is selected of the proper size to give just about enough gasoline at high suction; at low suction the flow will be quite deficient. The compensator (I) lends its strongest support to the main jet (G) at low suction when it is most needed, and withdraws it gradually as the main jet (G) gathers in strength with increasing suction.

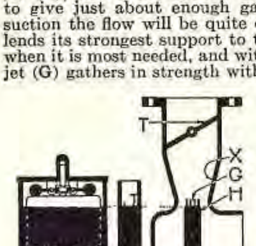


Fig. 20

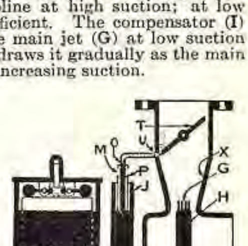


Fig. 20 A

Fig. 20 **shows carburetor at rest** with throttle (T) closed, and shows the gasoline at the same level in the float chamber (F), well (J), and nozzles (G) and (H).

Fig. 20A **shows the idling and starting jet.** Note the addition of an idling tube (P) in the well (J), explained on page **131.**

Zenith Model "U" Carburetor

There are four measuring parts to meet the exact requirements of any particular engine as follows:

1. **The choke tube (X, Fig. 21) measures the amount of air taken into the engine. The flow of air increases as the engine speed increases.**

2. **The main jet (G) acts exactly like the jet in the simple carburetor (Fig. 17). It varies in flow with the suction.**

3. **The compensating jet (I).** The flow from this jet **is constant, regardless of the amount of suction, or the speed of the engine.**

4. **The idling jet (N)** operates only when the throttle is barely cracked open. Further opening of the throttle automatically puts the idling device out of operation because the fuel in the well (J) is then all drawn through the cap jet (H).

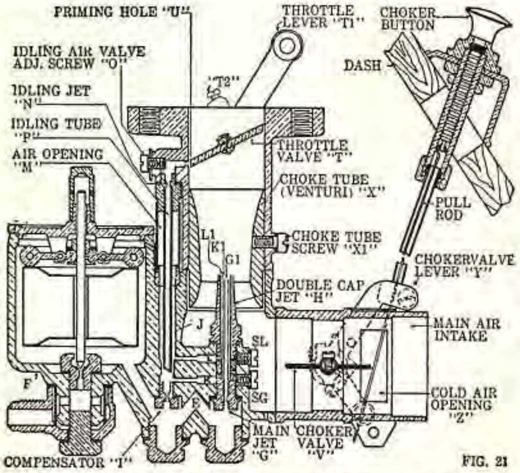


Fig. 21. Model "U" carburetor. Differs from the early model "L" Zenith in that there is a double cap jet (H), or three jets or spray nozzles (L1, K1, G1) instead of two, and the calibrated opening of idling jet (N) is placed above the top of tube (P) instead of at the bottom.

From the float chamber (F) to the engine, gasoline flows through three different channels **(E, K, L),** in various quantities and proportions according to the size of the nozzles, the speed of the engine and the degree of the throttle opening.

With throttle (T) fully open, most of the gasoline flows through channel (E) and main jet (G); some flows through compensator jet (I), which is located at the bottom of well (J), which is open to the atmosphere through (M) from the outside of the carburetor. It then passes through channel (K) to cap jet passage (K1) which surrounds the main jet (G). The main jet and cap jet work together and furnish the proper mixture, whatever the speed of the engine.

The influence of this third jet (L1), (also jet K1), is greatest when accelerating from idling position, when the gasoline in well (J) is level with the gasoline in float chamber (F), (figs. 20, 20A), thus giving an additional rich mixture in connection with the main jet (G). As the throttle is opened and suction is increased, the level of the gasoline in atmospheric well (J) drops, and gasoline is then fed only from (G) and compensator (I) through passage (K) to (K1), the third nozzle (L1 and its passage L) being practically cut out of action.

The idling tube (P) has a calibrated jet opening (N) at its top, and is fixed and not adjustable.

Air choker connection. The air intake on the Zenith carburetor is provided with a choker valve (V) (Fig. 21), which is operated through the air shutter lever (Y) connected with a choker button on the dash, for use in starting and warming up a cold engine. Usually a piece of tubing connects the main air connection with a stove on the exhaust pipe for preheating the air before it enters the carburetor. The air shutter (or choker valve) lever (Y) is fitted with a spring which normally holds the choker valve (V) in a wide-open position (as now shown).

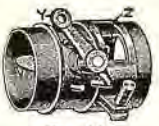


Fig. 22

The air connection is supplied with a temperature regulating band around an air opening (Z) (Figs. 21, 22), which can be adjusted so as to admit cold air in warm weather or shut off all cold air in cold weather.

Idling. At low or idling speed, when the throttle (T) is nearly closed, the main jet (G) and cap jet (H) give little or no gasoline, but there is considerable suction at (U) (Fig. 21). Gasoline from compensator (I) flows into well (J) and is then drawn through the idling tube (P), through the calibrated idling jet hole (N) at the top of (P), which in turn is adjustably open to the air, through idling adjusting needle valve (O). The suction lifts the gasoline through tube (P) and, in combination with the air passing the throttle (T), forms the idling mixture.

Idling adjustment. The throttle (lever) adjusting screw (T2) will regulate the opening of the throttle (T) for slow speed or idling, and the position of the screw (O) will regulate the quality of the mixture at that speed; screwing **(O) in,** increases the effect of gasoline, making the mixture richer, and unscrewing it diminishes the effect of the suction in idling tube (P), making the mixture leaner.

This adjustment varies the **idling mixture only and has no effect upon the high-speed action.** Be sure the engine is warmed up when making the idling adjustment (see also "Slow Speed Adjustment," page 132).

Starting the engine: Open throttle (T) "just a crack," and close the choker valve (V) tight, by pulling out choker button. This will create a very strong suction on the priming hole (U) and will raise the gasoline through tube (P) and jet (N), into the opening (U) and thence to the manifold. Immediately the engine is started, open the choker valve (V), adjusting its position until the engine runs smoothly and without backfiring through the carburetor. As soon as the engine has thoroughly warmed up, the choker valve (V) **should be opened wide.** Leaving the choker valve partially closed will greatly increase the fuel consumption.

Adjusting the Zenith Carburetor

In the Zenith, the quality of the mixture is fixed, once for all, by the choosing of the three variables: Choke tube, Main jet, and Compensator, as indicated below.

The size number of these three parts constitute what is called the "Setting." The size number is stamped on the end of each part.

The chokes are numbered in millimeters according to the size of the smallest inside diameter.

The jets and compensators are numbered in hundredths of a millimeter. A "100" jet has a one-millimeter hole and is smaller than a "105" jet. The sizes vary regularly by steps of five one-hundredths of a millimeter.

When cars are regularly equipped at the factory with the Zenith carburetor, it is seldom necessary to change the "factory setting." This has been determined by experts after exhaustive tests, and as there are no moving parts in the Zenith in any way affecting the mixture, it is reasonable to assume that any trouble that might arise can be caused only by **dirt and water** in the carburetor, or by the disarrangement of some adjustment of the ignition, valve-operating mechanism, etc., which troubles are often erroneously blamed on the carburetor.

The following tests should be made with method, first determining the **Choke,** then the **Main jet,** then the **Compensator.**

Choke tube (X). This is really an air nozzle (Venturi), of such a stream-line shape as to allow the maximum flow of air, without any eddies, and with the least resistance. It is held in place by a screw (X1) (Fig. 21) and can easily be changed when the butterfly throttle (T) has been removed. If stuck, remove the cap and jet at the lower part of the carburetor and drive it out with a brass rod.

Choke tube too large. The pick-up will be defective and cannot be bettered by the use of a larger compensator. Slow-speed running will not be very smooth. The engine will have a tendency to "load up" under a hard pull, and at high speed the exhaust will be of an irregular nature. (This "loading-up" will be much worse if the manifold is too large or too cold.)

Choke tube too small. The effect of a small choke tube is to prevent the engine from taking a full charge with the throttle opened fully. The pick-up will be very good, but it will not be possible to get all the speed of which the car is capable.

Bear in mind that when the choke is increased more air is admitted and the mixture is correspondingly thinned, and vice versa.

Main jet (G). The main jet is easily removed after unscrewing the lower plug. **The influence of the main jet is mostly felt at high speed.**

Main jet too large. At high speed on a level road it will give the usual indications of a rich mixture: irregular running, characteristic smell from the exhaust, firing in the muffler, sooting up the spark plugs and low mileage.

Main jet too small. The mixture will be too lean at high speed and the car will not attain its maximum. There may be back-firing at high speed, but this is not probable, **especially if the choke and main jet are according to the factory setting.**

This back-firing is more often due to large air leaks in the intake or valves or to defects in the gasoline line.

Compensator (I). The compensator is easily removed after unscrewing the lower plug.

From the explanation of the Zenith principle given on page 130, it is readily noted that the influence of the compensator is most marked at low speeds. The compensator size is best tried out on a hill, as regular as possible and as long as possible, and of such a slope that the engine will labor rather hard to make it on high gear. A long, even, hard pull of this sort taxes the efficiency of the compensator to the utmost, and will indicate readily the correctness of its size.

Compensator too large. Too rich a mixture on a hard pull. It will give the same indications as rich mixtures at high speed on the level.

Compensator too small. Too lean a mixture. Liable to miss and give a jerky action to the car on a hard pull.

Slow-speed adjustment (see also "Idling Adjustment," page 131). This adjustment is made on the floor, with the engine properly warmed up. It must be remembered that many factors may prevent a good idling, such as: poor gaskets, loose valve stems, pitted valves, leaky valve caps, leaky plugs or priming cocks, all of which create air leaks. Spark-plug points too close together, flywheel too light, too much spark advance, late spark.

The idling device differs somewhat with each model. The size of the gasoline orifice is stamped on each idling jet in one-hundredths of a millimeter. In the case of vertical carburetors, models "L," "U," "T," and "O," it may be said in general:

If the idling device is too small, it will be impossible to obtain a satisfactory mixture except by turning the idling—adjusting—screw (O) all the way in. In this event put in a larger idling device.

If the mixture is too rich, it will be indicated by the engine running in a surging and irregular manner. Open the throttle to clear the passages of the rich mixture, and then bring it back to the idling position, and screw out the idling adjusting screw (O) until regular running is attained. If it is necessary to screw this out more than four or five turns from the seat, put in a smaller idling device.

If the mixture is too lean, it will be indicated by the engine running in a jerky manner, missing will occur, and in extreme cases the engine will stop altogether. Screw in on the idling adjusting screw (O) until this condition is remedied. In case it is necessary to screw the valve in to within ¾ to 1 turn from its seat, put in a larger idling device.

Water in the gasoline will sometimes lodge in tube (P) and prevent proper idling. Remove the nut under the compensator and clean. This is a common trouble unless a strainer is used.

If the engine does not slow down or idle, or if it "lopes," that is, speeding up and slowing down as if fitted with a governor, it is evidently getting too much gasoline. (1) adjust air screw (O); (2) look for air leaks at manifold and other joints; see that jets are tight on seat; (3) look for water accumulation in the passages; remove plugs under the carburetor and clean (I), (P) and (G).

If the engine does not pull properly, going up hill: (1) the engine may be cold or insufficiently heated; (2) the mixture may be too lean or too rich (irregular running results in the latter case); try a larger or a smaller compensating jet (I), using the one which gives best results; try this also with jet (G) and adjust the choke tube to a corresponding size.

If the car does not attain its proper speed: (1) the mixture may be too lean; try adjusting slow speed (O); if the trouble is chronic, try larger main jet (G); (2) if the mixture is too rich, try regulating air intake at (Z) (Fig. 21); if the trouble is still chronic, try a smaller-size main jet (G).

When trying a new jet, it is not necessary to change the choke tube (X).

Zenith Duplex Carburetor

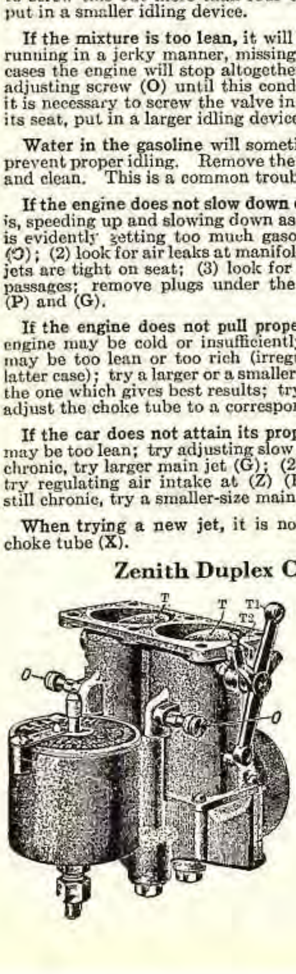


Fig. 23. **The Zenith (Model "OD") duplex carburetor** is so named, because there are two carburetors combined into one unit, both using the same float. This type of carburetor is designed for "V"-type engines.

Stromberg Type "OE" Plain Tube Carburetor (Vertical Outlet)

This carburetor is of the plain tube type, so called because, having no air valves or metering needles, both the air passages and gasoline jet are of fixed size for all engine speeds.

This model has been particularly developed for the use of low grade gasoline fuels and **contains the following special features:**

A gasoline feed above the throttle, with separate adjustment, for idling the engine.

An **accelerating well,** which gives an extra supply of fuel just for a moment as the throttle is opened.

An **economizer,** which permits the carburetor to operate on a very lean and economical mixture at the closed throttle positions of average driving but automatically shifts to the needed richer setting when the full power of the engine is called for.

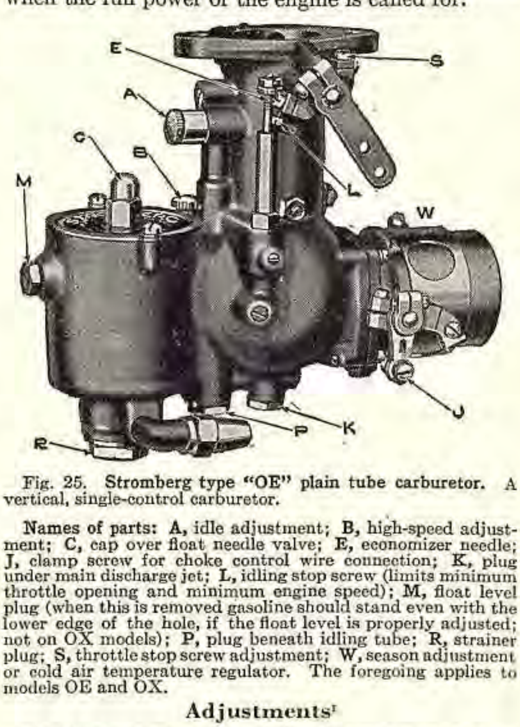


Fig. 25. **Stromberg type "OE" plain tube carburetor.** A vertical, single-control carburetor.

Names of parts: A, idle adjustment; **B,** high-speed adjustment; **C,** cap over float needle valve; **E,** economizer needle; **J,** clamp screw for choke control wire connection; **K,** plug under main discharge jet; **L,** idling stop screw (limits minimum throttle opening and minimum engine speed); **M,** float level plug (when this is removed gasoline should stand even with the lower edge of the hole, if the float level is properly adjusted; not on OX models); **P,** plug beneath idling tube; **R,** strainer plug; **S,** throttle stop screw adjustment; **W,** season adjustment or cold air temperature regulator. The foregoing applies to models OE and OX.

Adjustments[1]

The idling mixture and closed throttle running up to about eight miles per hour are controlled by the knurled button, or idle adjustment screw (A). This operates on the air, so that screwing it in, clockwise, gives a richer mixture, outward a leaner one.

When engine is **idling properly** there should be a steady hiss in the carburetor. If there is a weak cylinder or a manifold leak the hiss may be unsteady. For an engine to idle steadily on present fuel the spark plug gap must not be less than .022.

If, after adjusting the low speed needle as above described, the engine idles too fast, turn the small throttle stop screw (L) to the left or counter clockwise until the proper idling speed is reached. If engine idles too slow and stops, turn screw (L) to the right or clockwise until proper speed is reached.

The high speed and main driving adjustment are regulated by the high speed needle (B): Turning down, clockwise, gives less gasoline; up, counter-clockwise, more.

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[1] Applies to types OE, OX, OT and O which are all vertical models. Outside of minor arrangement of the parts the above mentioned vertical types of Stromberg carburetors function internally very much the same, and the adjustments explained under the type OE will apply to other vertical models except type M.

The horizontal models, types OS and OC differ from above.

The following is a good way to obtain an exact adjustment: Advance spark lever to normal driving position; set throttle lever on steering wheel to a position which will give about twenty-five miles per hour speed on a smooth road; then adjust high speed needle to the minimum opening that will give smooth running, and the maximum engine speed for that throttle opening; this should give a good average adjustment.

Several notches less opening may give best economy for continuous driving or touring; and one notch more may be best for short runs in cold weather, when the engine does not get up to normal heat.

The economizer device (E) operates to automatically lean out the mixture at speeds from ten to forty-five miles per hour. The economizer needle is properly set at time carburetor is installed on the engine and no adjustment is needed.

In all cases the adjustments should be made when the Motometer shows a temperature of higher than 140 degrees, and the richer adjustment necessary for a cold engine obtained by using the driving control.

Use of Choke Control

For starting and warming up with the present-day fuel, it is absolutely necessary to use the choke control until the proper operating temperature is attained. Ordinarily the engine will start readily with the control closed one-half to three-quarters of the way. In very cold weather it may be necessary to pull the control up all the way, but this should be done only for an instant, as this cuts off all the air and delivers raw gasoline only.

In starting with electric starter, the throttle should be nearly closed, or better still, it may be successively opened part way and closed while the starter turns the engine over. Never keep this control up more than a moment at a time.

For hand cranking choke control should be only one-half to three-quarters up and throttle should be just barely open. In cold weather choke control can be pulled all the way up with the throttle barely open, for two or three turns of the crank, then the choke control should be set at one-half or three-quarters open and the crank given several more turns when the engine should start.

When the engine is cold it is best not to open the throttle so far that the engine misfires, as this is a frequent cause of sooted spark plugs and gasoline (really kerosene) in the crank case.

Season or Cold Air Adjustment

In the warm months of the year the engine will show more power and run cooler with the cold air shutter (W) open; **in cold weather** this shutter (W) should be closed to feed the carburetor warm air only.

Float Level Adjustment

The proper float level with engine not running is one inch from the top surface of float chamber casting or just even with the bottom of hole in which plug (M) (Fig. 25) is inserted.

Should the level be more than one-sixteenth of an inch higher or lower than bottom of hole the float needle should be readjusted. Remove valve cap (C, Fig. 25) and upper end of float needle stem will be seen.

If level is too high, loosen lock nut, hold needle sleeve from turning by putting small wrench on flat sides and screw needle down clockwise one turn which should lower level about three thirty-seconds of an inch, if too low, a full turn of needle upward will raise level same distance.

The float level described above applies to O, OE, OX, OS and M, but not to OT.

The float level of OT is adjusted by slightly rotating screw under cap (C) (Fig. 25 A). It is an eccentric adjustment on the float pivot. By unscrewing cover the adjustment can be observed. The correct level is 1¼" below top of float chamber with cover removed.

Cautions

Note: Never adjust the carburetor to a cold engine. Start the engine and allow it to run a short time until it is warm. Not until then should the adjustment of the carburetor be attempted.

In starting engine on a cold day it may begin "popping." Do not blame this on the carburetor and begin to adjust it. Wait until the engine has warmed up thoroughly, and then if the popping continues it is time to consider an adjustment.

If engine, after running, suddenly ceases to perform properly, look over carburetor connections, etc., but do not start to change the adjustments until other causes of trouble have been investigated. Carburetor adjustments should only be necessitated by changes in fuel or seasonal changes in weather.

There are many other things on the engine subject to derangement besides the carburetor. Ninety per cent of the so-called carburetor trouble is due to fouled spark plugs, spark plug or ignition breaker points improperly spaced, intake manifold leaks, or lack of compression in the cylinders, due to valves not seating tightly.

If engine regularly refuses to start, see whether valve operated by choker closes securely; and always be sure that it is fully open, and the control all the way down, for normal driving.

To find whether gasoline is feeding to the carburetor, remove nut (C) and feel if needle plunger inside is all the way down. If up, gasoline is not reaching the float chamber. Gasoline can also be seen when plug (M) is removed.

The present low-grade gasolines contain a large percentage of kerosene elements which do not evaporate in the intake manifold but remain in liquid form; after shutting off the engine, particularly in cold weather, this kerosene which has been held in the intake manifold, will drain back out of the carburetor. This is unavoidable and should not be taken as an indication that the carburetor is "flooding" or "leaking." These gasolines sometimes contain heavy lubricating oil components which creep up the walls of the carburetor and spread over the outside surface; the only remedy for this is the purchase of a **better grade** of fuel.

The internal specifications of the carburetor and the adjustments given above have been selected for the use of gasoline 56 to 60° Baumé, with end boiling point 400 to 450 degrees Fahrenheit.

Information regarding the adjustments for very light high grade gasolines or benzol mixtures may be obtained at the Strömberg Carburetor Service Stations in the sections of the country where these fuels are sold.

Stromberg Type OT, OX, and O Carburetors (Vertical Outlet)

The types OT, OX, and O carburetors are vertical types as OE. They all have "single control" except O, which has "double control."

Single control means that there is one pull button on dash which connects with the air choke lever (J) (Fig. 25) to enrich the mixture for starting.

Double control means that in addition, there is another pull button which operates an "auxiliary gasoline needle valve" to further enrich the mixture and warm engine up more quickly.

Outside of minor arrangement of the parts these vertical types of Stromberg carburetors OE, OT, (OX, and O) function internally very much the same, and the **adjustments explained under type OE** will apply to the other vertical models except type M. The horizontal models, such as OS, OC, differ considerably.

The OE is made in sizes 1", 1-¼" and 1-½". The OT is made in 1¼", 1½" and 1¾". The OX is made in 1¼" and 1½" sizes.

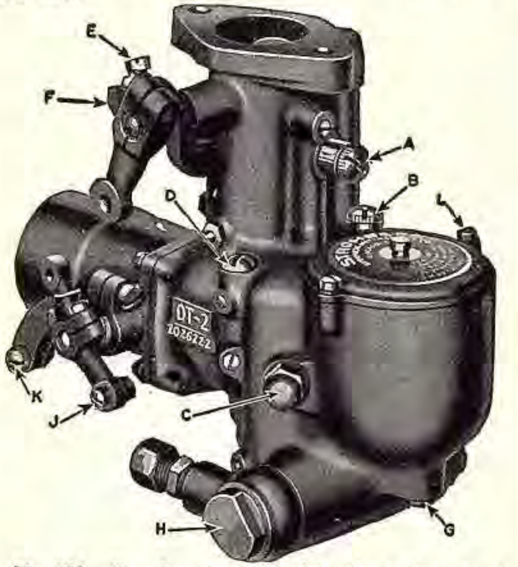


Fig. 25A. Stromberg type **OT** plain-tube carburetor. A vertical, single control carburetor.

This type differs slightly from the OE and OX. As a rule, there is no "economizer needle" as on OX and OE, and instead, a "high-speed air bleeder" (D) is used, similar to the horizontal type OS; this type is also of a much heavier construction and is used for heavy-duty work, such as on heavy trucks, motor coaches, etc.

Names of parts: A, idling adjustment; **B,** high-speed adjustment; **C,** cap over float fulcrum and float-level adjustment; **D,** high-speed air bleeder; **E,** throttle stop screw; **F,** clamp for throttle stop screw; **G,** float chamber drain; **H,** plug holding strainer and gasoline connection; **J,** screw for clamping control wire; **K,** control tube clamp screw; **L,** float chamber cover screw.

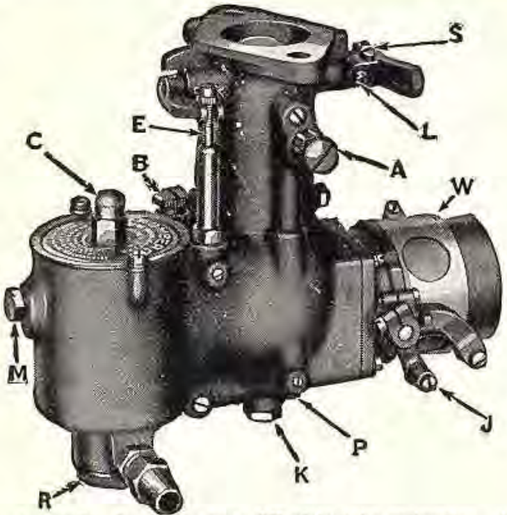


Fig. 25B. Stromberg type **OX** plain tube carburetor. A vertical, single control carburetor. This type differs from the OE principally in the arrangement of flange. The **names of the** parts are the same as in the OE (Fig. 25).

Stromberg Type "M" Plain Tube Carburetor (Vertical Outlet)

To reduce the number of fuel passages, the emulsion column for the air-bleed jet is made concentric with the idling tube and the fuel emulsion passes through a horizontal drill to a groove around the small venturi, into which it discharges through a number of small holes.

No air bleeds are used in the idling tube, while the idle discharge jet, instead of being slotted as in the model O has a recessed round orifice.

The accelerating well is of the type used on the models OS and OC, and two forms are commonly used; the "single" and the "compensating." The **M** has no economizer action.

Fig. 26. Stromberg type **M:** intended for truck heavy-duty service and small four-cylinder engines, marine and stationary use. It is made in sizes from ¾" to 3".

Principle of Operation

The level of the gasoline in the float chamber of the carburetor is maintained constant by the float and the valve which is operated by it. From the float chamber the gasoline flows to the accelerating well (M) through the needle valve (F) (Fig. 28) which is adjustable.

There are two tubes in the accelerating well, one a sort of standpipe (H), and the other a smaller one that is inside of the standpipe and which connects with the idling jet (K). The latter tube has a small opening in the bottom that connects with the bottom of the well (M), but otherwise has no connection with the well.

The top end of the standpipe (H) **connects with a cross-passage** (N) **that feeds the gasoline to the eight discharge holes in the small venturi tube** (I), which is located just below the main venturi tube (note that there are two venturi tubes).

A **rich** mixture and not raw gasoline is fed through passage (N), because of the small air intake opening (G), which enters the top of the well (M), and supplies a certain amount of air with the gasoline that is drawn up the standpipe to the passage (N).

Holes in the side of the standpipe, below the level of the fuel, feed gasoline into the standpipe, while **holes above** the fuel level add air from the top of well (M), thus making a rich mixture to discharge into the small venturi passage.

At low and idling speeds, practically no fuel is drawn through the small venturi, because of the closed throttle. At this time the gasoline is through the hole in the bottom of the small tube (J), up to the idling needle valve (B), and through the passage (K), into the intake manifold above the throttle valve. This gives a **rich mixture for idling** and slow-speed running, but is cut out at about eight miles per hour when the throttle is opened more, and thus does not affect the running mixture at all.

Adjustments

The idling mixture and low-speed closed throttle running are controlled by the upper knurled button or idle adjusting screw (B). This operates on the air, so that screwing it in gives a richer mixture and out a leaner one.

Turn screw (B) outward until engine slows down, then turn (B) in notch by notch until the proper idling mixture is reached. When engine is idling properly there should be a steady hiss in the carburetor. If there is a weak cylinder or a manifold leak the hiss may be unsteady.

For an engine to idle steadily on present heavy fuel the spark plug gaps must not be less than .022 inches.

If, after adjusting the low-speed needle as above described, the engine idles too fast, turn the small throttle stop screw to the left or counter clockwise until the proper idling speed is reached. If engine idles too slow and stops, turn stop screw to the right or clockwise until proper speed is reached.

The high speed and main driving adjustment is regulated by the high-speed needle (A), which regulates the opening through which the fuel flows to the jets. Turning (A) to the left, counter clockwise, gives more gasoline, to the right, clockwise, less gasoline.

To make the proper high-speed adjustment, advance spark lever to normal driving position; set throttle lever on steering wheel at a position which will give about twenty-five miles an hour speed on a smooth road—on trucks throttle should be one fourth open—then adjust the high-speed needle to the minimum opening that will give the greatest engine speed fo that throttle opening.

This should give a good average adjustment, for **continuou driving** or touring. Several notches to the left may be best for **short runs** in cold weather when the engine does not get up to normal heat.

To prevent a wrong high-speed adjustment from giving a harmful rich mixture, a gasoline nozzle **reducer** is inserted beyond the high-speed needle opening, inside the plug (D) (Fig. 26). The reducer placed in the carburetor at the factory will permit about 20 per cent more gas to pass through than is generally needed. However, under some conditions a larger reducer may be needed in order to secure a richer mixture. **These reducers can be obtained** from the Stromberg factory or the nearest Stromberg service station

Instructions for the use of dash control, etc., of OE on page 133 will apply here.

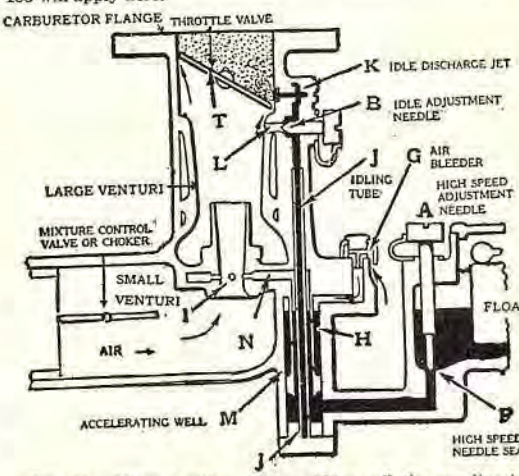


Fig. 28. **Idling position.** When idling, all the gasoline is drawn up the tube (J), through the idling jet (K) and sprayed above the throttle valve (T).

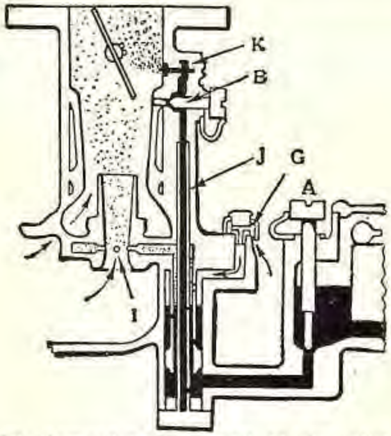


Fig. 29. **Low and medium speed:** At intermediate speeds the gasoline is drawn past the low-speed adjusting screw (B) from the tube (J). As the throttle is opened, more mixture is drawn through the small venturi tube (I) and augments that drawn from the idle discharge jet (K).

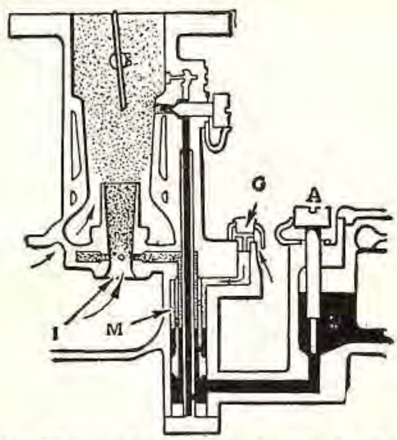


Fig. 30. **High speed:** At high speed practically all the gasoline is drawn through the small venturi tube (I) mixed with air, drawn through the air-bleed opening (G) above the well (M).

Stromberg Type "OS" Plain Tube Carburetor (Horizontal Outlet)

This carburetor is of the plain tube type, so called because, having no air valves or metering needles, both the air passages and gasoline jet are of fixed size for all engine speeds.

This model has been particularly developed for the use of low grade gasoline fuels and **contains the following special features:**

A gasoline feed above the throttle, with separate adjustment, for idling the engine, an "accelerating well," which gives an extra supply of fuel just for a moment as the throttle is opened.

An "economizer," which permits the carburetor to operate on a very lean and economical mixture at the closed throttle positions of average driving but automatically shifts to the needed richer setting when the full power of the engine is called for.

Adjustment for idling mixture and closed throttle running up to about eight miles per hour is controlled by the idling adjusting screw (B) (Fig. 31). This operates on the air, so that screwing it in gives a richer mixture and out a leaner one.

Turn the screw outward until the engine slows down, then turn in notch by notch until the proper idling mixture is reached. When the engine is idling properly there should be a steady hiss in the carburetor. If there is a weak cylinder or a manifold leak, the hiss may be unsteady. For an engine to idle steadily on present-day heavy fuel, the spark gaps must be set not less than .022".

If, after adjusting the low-speed needle as described above, the engine idles too fast, turn the small throttle stop screw (L) (Fig. 31) to the left, or counter-clockwise, until the proper idling speed is reached. If the engine idles too slow and stops, turn the screw to right, or clockwise, until the proper speed is reached. Before adjusting with throttle stop screw, it will be necessary to loosen the lock screw.

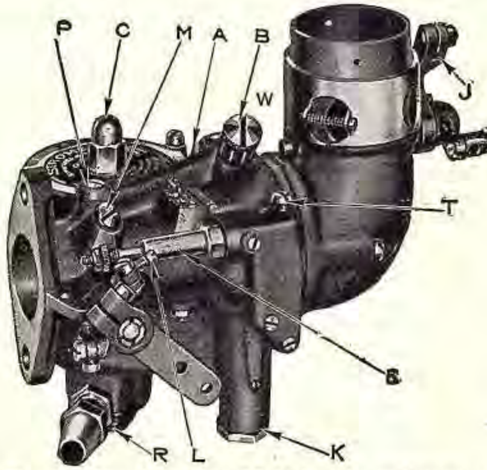


Fig. 31. Stromberg type **OS** plain tube carburetor. A horizontal, single control carburetor. Made 1" and 1¼" sizes.

Name of Parts: A, high speed needle adjustment; **B,** idle adjustment screw; **C,** cap over float needle valve; **E,** economizer needle; **J,** control tube holder; **K,** plug for removing accelerator well; **L,** throttle stop screw; **M,** vacuum tank connection[2]; **P,** plug to reach idling discharge jet; **R,** gasoline inlet; **T,** air bleeder to accelerating well; **W,** season temperature regulator.

Adjustment for high speed and main driving adjustment is regulated by high-speed needle (A), which regulates the opening through which fuel flows to the jet. Turning counter-clockwise, gives more gasoline; clockwise, less gasoline.

To make proper high-speed adjustments, advance the spark lever to normal driving position, set the throttle lever on the steering wheel at a position which will give a speed of engine corresponding to a car speed of about 25 miles an hour on smooth road. Then adjust the high-speed needle to minimum opening that will give greatest engine speed for that throttle opening. This should give a good average adjustment. Two or three notches less may give best economy for continuous driving or touring, and two or three to the left may be best for short runs in cold weather when the engine does not reach normal heat.

To prevent a wrong high-speed adjustment from giving a harmful rich mixture, a gasoline nozzle reducer is inserted beyond the high-speed needle opening, in a passage-way closed by a reducer jet plug. The reducer placed in the carburetor at the factory will permit about 20 per cent more gas to pass through than is generally needed.

The economizer device (E) (Fig. 31) operates to lean out the mixture automatically at speeds of from 10 to 45 miles per hour. The economizer needle is properly set at the time the carburetor is installed on the engine and no adjustment is needed.

When starting the engine, first open the carburetor butterfly valve slightly by means of the hand throttle lever on the steering-gear sector, then pull the choke button out all the way, turn the ignition switch to "on" position and depress the starter switch. As soon as the engine starts, push the choke button in about one-third of the way or to the point where the engine runs smoothly. Do not leave the choke button pulled out fully after the engine starts as this will flood the engine with gasoline and cause it to stop. As the engine warms up, the choke button should be pushed in gradually, the normal position for running being all the way in. The choke button should be out the shortest period of time possible, as running with an over-rich mixture tends to foul the engine, dilute lubricating oil, and use an excessive amount of fuel.

Engine should start after five or ten seconds of cranking. If not, it may be that the choke valve does not entirely close.

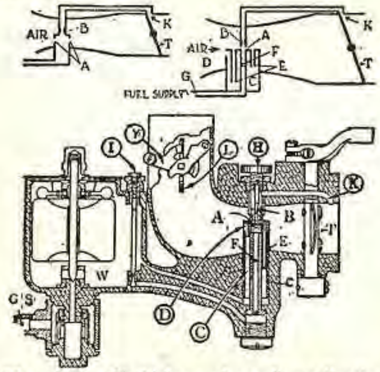
The normal position of air temperature regulator (W) is closed. Only in extremely hot weather should it be open.

The proper gasoline level in float chamber with engine not running is one inch from the top surface of float chamber casting. Remove valve cap (C) and upper end of float needle stem will be seen. If level **is too high** loosen lock nut, hold needle sleeve from turning by putting small wrench on flat sides and screw needle down clockwise one turn which should lower level about three thirty-seconds of an inch, **if too low,** a full turn of needle upward will raise level same distance.

[1] For the **Pitot principle,** formerly explained on this page, see page 102. The **Schebler carburetor,** model (AH), formerly on this page is on next page. [2] This carburetor is used on engines where the carburetor is fit close to cylinder and where inlet manifold is cast in, therefore the suction for operating the vacuum tank is connected at (M).

Schebler Model "AH" Plain Tube Carburetor

This carburetor is a horizontal outlet type and functions similar to model **A**, which is a vertical outlet type. Model **A** is used on autos, marine engines, fire engines and large engines where flexibility is required.



Figs. 35 and 36. (I), high-speed gasoline adjusting needle; (H), low-speed gasoline adjusting needle; (L), choker valve; (T), throttle valve; (K), idle and low-speed by-pass; (D), Pitot opening.

The Pitot function is simply to provide air at sufficient pressure to force fuel from well and to be inclosed in carburetor.

The principle of a "pitot tube" is explained on page 102.

Tillotson Carburetor[1]

This carburetor as illustrated is an early model where a uniform partial vacuum is maintained at the

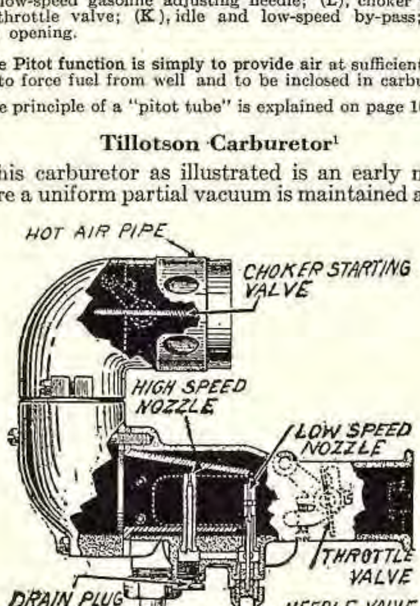
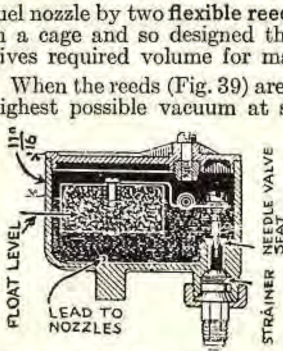


Fig. 37. The Tillotson carburetor.

fuel nozzle by two **flexible reeds,** which are mounted in a cage and so designed that maximum opening gives required volume for maximum speed.

When the reeds (Fig. 39) are closed, they cause the highest possible vacuum at slower engine speeds.



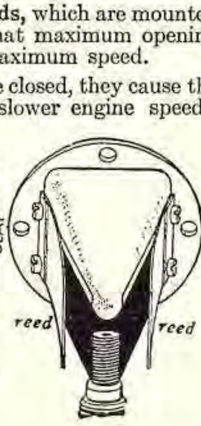


Fig. 38 (left). Float mechanism.
Fig. 39 (right): The reeds.

The reeds open and close according to the speed of the engine. These reeds are so placed that as they move they form a virtual variable venturi. A secondary nozzle comes into operation at higher speeds and is not in use at the lower speeds.

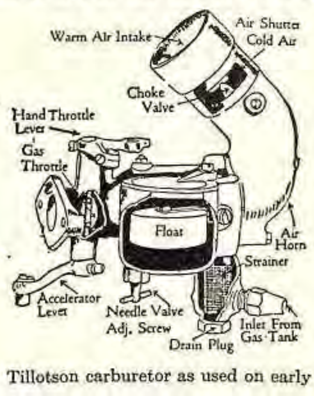


Fig. 40. Tillotson carburetor as used on early model Overland 4.

To adjust the carburetor, set the choke valve in full open position, after running the engine until it is warm. Push in the throttle-control button to its lowest operating point and pull out the spark lever about three notches. Slowly close the needle valve, by turning to the right, cutting down the amount of gasoline, until the engine starts to miss because of too lean a mixture Then open the needle valve slightly, so that the engine begins to fire regularly. Push in the spark-control button and accelerate the engine either by hand or foot controls. If the engine backfires, or pops in the carburetor, increase the amount of gasoline by opening the valve slightly. Continue this until the engine fires regularly when suddenly accelerated. The engine should always be allowed to run for half a minute after it is slowed down before another attempt is made to accelerate it. In cold weather it will be found advisable to close the air shutter, insuring warm air for the gas mixture.

The Hudson Carburetor[1]

The Hudson carburetor operates upon the pneumatic principle and may also be termed the "metering-pin" type, and the "measuring-pin" type of carburetor. A glance at the sectional view of the carburetor (Fig. 41) will show clearly the operation. When the throttle is opened with the engine running, the suction is communicated to the air chamber by way of the pneumatic control passage (Fig. 42). This causes the piston to rise and with it the metering pin (**A**, Fig. 41).

The metering pin has a V-shaped slot cut in it, and as the pin rises or falls, according to the engine's requirements, it changes the area of the slot at the gasoline feed regulator, and consequently controls the amount of fuel passing through.

The proportioning of the mixture is automatic at all speeds, the piston giving instant response to the demands made on the engine.

Adjustments can be made entirely with the dash controls. The air-control adjustment is used only for starting the engine in cold weather, or after it has been standing for any length of time. Once the engine is running, it should be operated with the air-adjustment valve open.

The gasoline adjustment enables the driver to have the mixture as rich or lean as desired, by varying the amount of fuel allowed to pass the metering pin. This is done by raising or lowering the gasoline feed regulator which surrounds the metering pin. This regulator is actuated by the "Gas" button on the dash.

[1] The construction and principle of later models varies from this model.

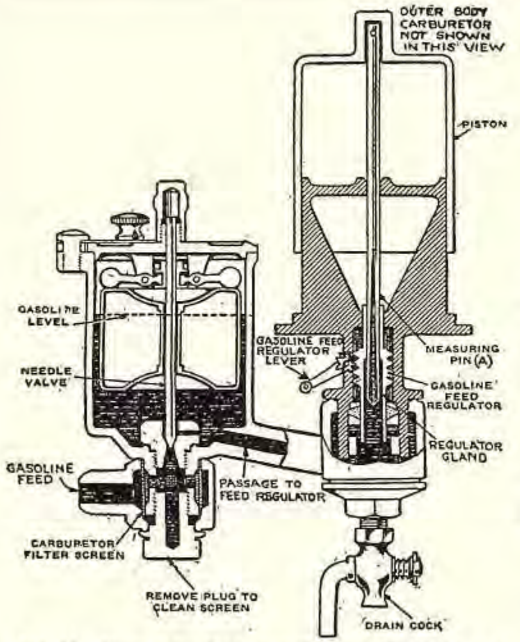


Fig. 41. View of the Hudson carburetor. Note the gasoline level.

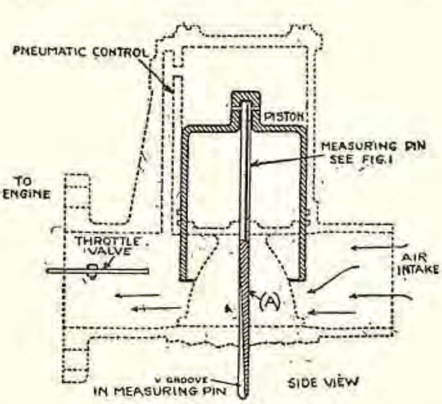


Fig. 42. Pneumatic control.

When the radiator shutter (see Index under "Radiator shutter") has been adjusted, so that the motor temperature maintains the red fluid in the motometer (see Index for meaning of "Motometer"), at the center of the circular opening, the engine will operate very economically on a lean mixture. Of course, heavier duty placed on the engine, such as hill climbing, pulling through sand, high speed, etc., places proportionate demands upon the amount of fuel, but in ordinary driving at speeds of 20 miles per hour upwards, the **carburetor should be adjusted as lean as possible.**

Too rich a mixture results in carbonization and misfiring; too lean a mixture gives less power and acceleration at low speeds. The entire range of adjustments is convenient to the driver.

Carburetor attention: Make sure, periodically, that the piston is clean and that the packing gland is tight. A sticking piston will seriously interfere with the action of the carburetor[2] and a loose packing gland will permit excessive gasoline consumption with its attendant troubles.

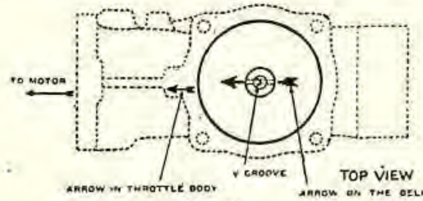


Fig. 43

Instructions for assembling measuring pin and piston: When assembling the metering pin and also the air bell to the throttle body (Fig. 43), be sure the arrow on the bell points in the same direction as the open end of the V-groove, and that the arrow on the bell also points in the same direction as the arrow in the throttle body.

Stewart Carburetor (on the Dodge)[1]

On the Dodge the carburetor (Figs. 44, 45) is on left side of the engine, and is fed from a Stewart vacuum tank. The carburetor is supplied with a hot-air attachment which draws air from around the exhaust manifold to the air inlet.

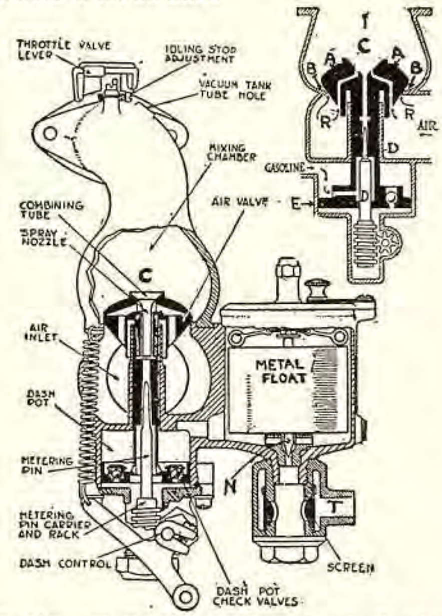


Fig. 44 (upper). How the metering pin **D** varies the mixture in the Stewart. Air passes through the passages **R** around the nozzle.

Fig 45 (lower). There is only one adjustment and that is the metering pin, which is interconnected with the dash control. Ordinarily the metering pin should be two-thirds the way through.

Principle (Fig. 44): The automatic metering valve (**A**) rests on the valve seat (**B**) when the engine is not running. As the engine begins to rotate the suction of the pistons raises the valve (**A**) from the seat drawing in air (**R** to **B**) as indicated by arrows. The suction also draws gasoline up within the valve stem which mixes with incoming air in chamber (**C**).

The one adjustment of the Stewart is that of proportioning the volume of gasoline to the air admitted. The air being always a fixed factor, it is only necessary to adjust or regulate the volume of gasoline

[1] The construction of the later models varies from this model, but the fundamental principles are similar.

[2] If engine stops after an acceleration or after releasing clutch due to a sticking piston, the trouble may be remedied by applying a few drops of light oil to inside surface of the bell.

admitted which is controlled by means of the tapered metering pin (**D**).

This adjustment is made when the engine is running at idling speed. Turning the adjusting screw (on "dash control," see lower part of Fig. 45), either to the right or left, raises or lowers the position of the tapered metering pin, thereby allowing an increased or decreased supply of gasoline to be drawn up into the mixing chamber. When the proper proportion has been determined at slow speed, it will be seen that as the speed of the engine increases, the automatic metering valve (A) will rise higher from the seat (B) and away from the tapered metering pin (D), which will allow a greater supply of both gasoline and air, in exactly the same proportion, to be admitted to the cylinders.

On the Dodge (Fig. 45) the tapered metering pin is subject to control within fixed limits by means of the "dash control" ratchet (see lower part of Fig. 45 for connection), for the purpose of obtaining a rich mixture for starting. Should there be any reason for **changing the fixed adjustment** of the tapering metering pin (D), it can be done by turning the stop screw adjustment on the "dash control" (see lower part of Fig. 45). Turning it to the right lowers the position of the metering pin and allows more gasoline to be admitted to the spray nozzle, enriching the mixture. Turning it to the left raises the pin and decreases the supply. **The throttle valve** is in the top of the carburetor.

Ball & Ball Model "SV-29" Carburetor

This carburetor is termed a two-stage type. In Fig. 47, the first and second stage throats are indicated.

Prior to making carburetor adjustment the following points should be thoroughly covered: (1) See that the spacing of the points in the spark plugs are set properly, or to .025". (2) See that the breaker points on the interrupter are set to .020". (3) See that the cylinders have good compression. It may be that some of the tappets are holding the valves partly open.

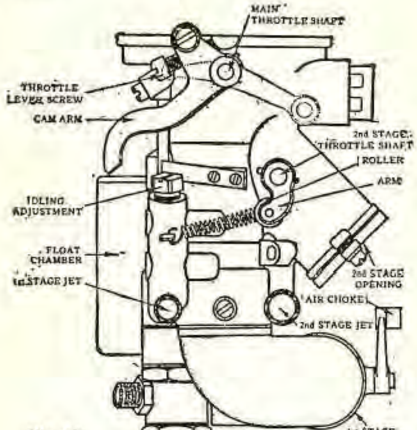
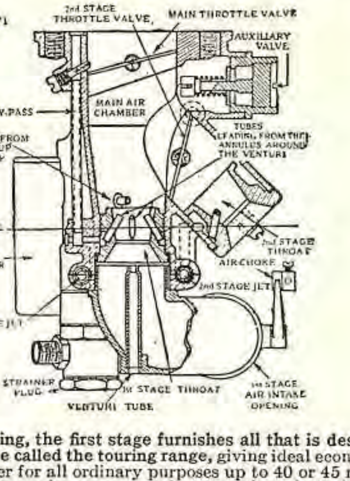


Fig. 46

Operation: Through a given range of throttle-opening all the gas is drawn through the **first stage** throat. The capacity of the first stage is sufficient to take care of all level road speeds up to approximately 40 or 45 miles per hour.

Fig. 46 shows clearly how the **second stage** is brought into action by opening the main throttle to its extreme position. The cam arm, integral with the main throttle shaft, coming into contact with the roller on the arm of the second stage throttle shaft causes the second stage throttle to open under additional pressure. The resultant action is to draw an additional or secondary supply of gas mixture through the second stage throat, Fig. 47.

Fig. 47[1]



Briefly speaking, the first stage furnishes all that is desired in what might be called the touring range, giving ideal economy and ample power for all ordinary purposes up to 40 or 45 miles per hour. The secondary stage supplies everything desired over and above the first stage in the form of added acceleration, power, and speed.

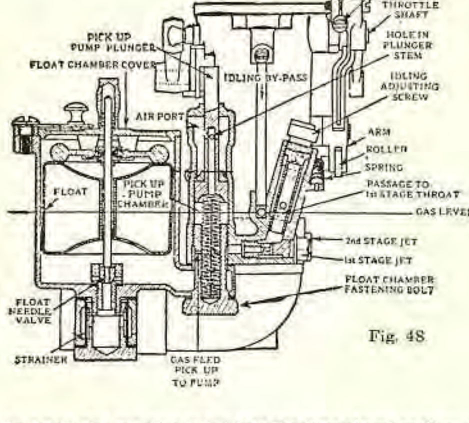


Fig. 48

In detail, the gasoline is fed into the float chamber through a removable cylindrical strainer (Fig. 48). From the float chamber the gasoline is fed separately to both first and second stage jets of the fixed orifice type (Fig. 47). In Fig. 48, the gasoline feeding to the first stage throat after leaving the first stage jet, passes through a tube, adjustable in height, known as the **idling adjustment screw.** By raising this screw the idling mixture becomes leaner; by lowering the screw, the mixture is made richer. **This is the only adjustment on the carburetor,** aside from the throttle stop.

The pick-up device consists of a spring-operated plunger pump (Fig. 48) which receives a supply of gasoline directly from the float chamber through a small hole in the float-chamber fastening bolt. The gasoline fills the pump chamber to the level of that in the float chamber. In opening the main throttle, the "pick-up plunger" is depressed, which results in gasoline being forced out through holes in the plunger stem and carried into the main air chamber of the carburetor along with the air drawn through ports at the top and side wall of the pump chamber. **The resultant action is to supply additional gasoline required for quick get-away.** This construction, on account of the time required to fill the pump, is such that the engine cannot be flooded by excessive repeated opening and closing of the throttle.

[1] **Note:** The auxiliary valve (Fig. 47) is now fitted with a damper to give easier starting. The damper is connected to and controlled by the air choke lever. When assembling, it is important that this be assembled so that the damper be closed when the air choke valve is closed.

The idling by-pass consists of a tube through which a sufficient amount of gas mixture is taken in above the throttle valve to keep the engine running when the throttle is closed.

The choke valve is located below the first stage throat for the purpose of starting, and also may be used in a partially closed position to enrich the gas mixture until the engine warms up.

The only adjustment that can be made is the idling adjustment previously explained. This produces no effect whatever on the running of the car except when the throttle is closed to the idling position. The richness of mixture at all speeds above idling, is determined by calibrated orifices in the first and second stage jets respectively.

The possible troubles that might interfere with carburetion are insufficient gasoline supply or obstructions lodging in the carburetor passages.

To test for insufficient gasoline supply, remove the float chamber cover (see Fig. 48) and float, and note if gasoline flows freely. The gasoline strainer at the bottom of the float chamber may have become clogged.

In looking for obstructed passages in the carburetor, remove the first and second stage jets and carefully examine the jet orifices, keeping in mind that an almost imperceptible obstruction will reduce the jet capacity. Blowing through the orifice is generally effective, or, in addition, the opening may be cleaned out by means of a small wire. Attention is called to the footnote at the bottom of page 138.

Ball & Ball Duplex Carburetor

This carburetor is used for V-type multi-cylinder engines.

It is a two-stage carburetor: the first, or **primary stage** being used when starting and under usual running conditions and the **second stage** when throttle is wide open for full power.

It is classified as an air valve type of carburetor at speeds below 15 m.p.h., and at that speed, or approximately, the air valves are fully opened and then the carburetor automatically becomes of the **fixed nozzle and air-valve type.**

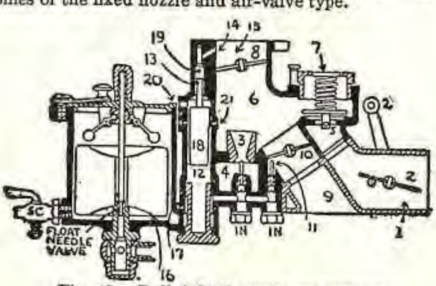


Fig. 49. Ball & Ball duplex carburetor.

Packard Carburetor[1] (Six Cylinder Cars Models 116–126–133–226–233–326–333)

Gasoline system: The gasoline supply of 21 gallons is carried in the main tank at rear of frame. From there it is drawn to a vacuum tank on the dash, by suction from engine. From the vacuum tank it flows to the carburetor by gravity (this applies to 6- and 8-cylinder cars). This carburetor is an **automatic air valve type.**

Construction and operation: The **primary air intake** (30, Fig. 50) is at the front end of the carburetor.

An air shutter (28) is normally open and not in use when running. This shutter is operated by the "carburetor control" on the instrument board, which also operates the **auxiliary air valve** (34).

By pulling the control on instrument board all the way out, the primary air intake is completely closed, allowing a very rich mixture to be drawn into the cylinders. The control should be pushed in, at least part way as soon as the engine has started firing.

The **auxiliary air valve** (34) is in a housing (42) and is controlled by the tension of two springs, one of which is within the other.

[1] See footnote next page.

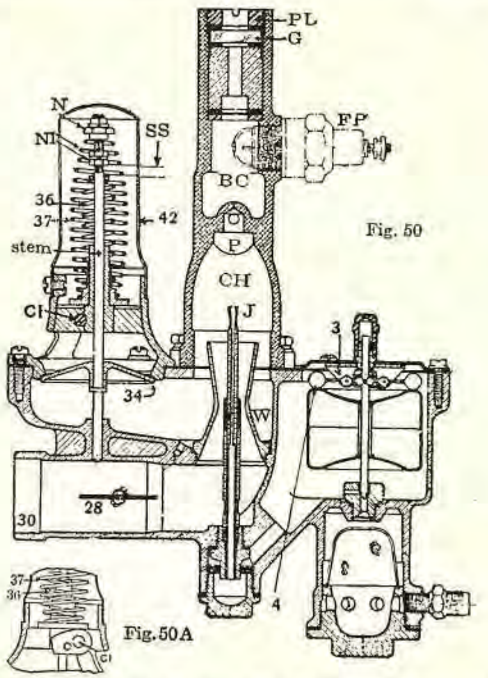


Fig. 50. Sectional side view of the Packard carburetor and fuelizer used on the six-cylinder engines on cars, models 126–333.

Fig. 50A. Action of the cam (C) which is controlled by pull button on instrument board. It will be observed that if cam is turned, the tension of springs of the auxiliary air valve will be increased or decreased.

At low engine speed most of the air is admitted through the **primary air intake** (30) around the spray nozzle.

To prevent too rich a mixture at a greater throttle opening, the **auxiliary air valve** (34) is opened by the increase in the vacuum, admitting the right proportion of air to meet all conditions.

Carburetor Adjustment

There is only one carburetor adjustment which directly affects the mixture, and this is the auxiliary air-valve adjustment.

Permanent adjustment is made by changing the tension of the air-valve springs (36, 37).

These springs which control the action of the valve are, in addition, adjusted for temporarily varying operating conditions by means of cam (C) (Fig. 50A) on cam shaft (C1) (Fig. 50). Raising the cams increases the pressure of the springs, and lowering the cam decreases the pressure. Increasing the pressure produces a richer mixture, and decreasing the pressure makes a leaner mixture.

The cam (**C**) is controlled and operated by the air-valve control on the instrument board through levers **C**4, C3, C1, C2 (Figs. 51, 52).

Note that **C1** controls the action of cam (**C**), and (**B**) (Figs. 51, 52) controls the air shutter or choker (28) in the primary air intake (30). Both are connected to lever (C4) thence to air valve control on dash.

The proper adjustment for normal running conditions with engine warm is obtained when the carburetor control is against the instrument board. To enrich the mixture pull the control out.

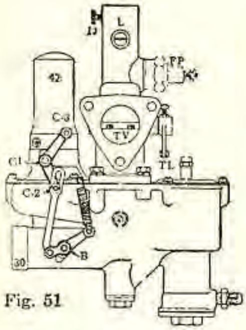


Fig. 51

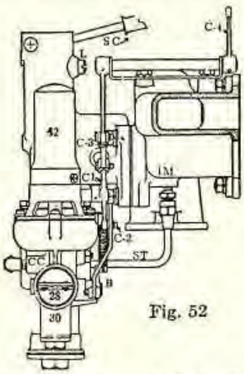


Fig. 52

Fig. 51. Side view showing the control levers C1, C2, C3.

Fig. 52. End view showing the control levers and connection of suction tube (ST) from carburetor (CC) to inlet manifold (IM).

The auxiliary air valve (34) should be adjusted to the leanest possible mixture at which the engine will idle properly when hot. The carburetor control on instrument board should be pushed all the way in and the valve, when depressed to the point where it touches the inside spring (see **SS**, Fig. 50), should have a drop of $\frac{3}{32}$" from its seat ($\frac{11}{64}$" on the eight cylinder engine).

To check, proceed as follows: Push the carburetor control in instrument board all the way in. Measure height of top of air valve stems from some fixed point on the engine. Depress air valve until it strikes inside spring. Measure height of top of stem as before. The difference in these two measurements is the air valve drop. A special gauge is made for this purpose.

The outer spring (37) should be adjusted so that the auxiliary air valve (34) just touches its seat when the carburetor control is against the dash. Then with engine warm, reduce compression of spring as much as possible, retaining smooth operation.

The large outer spring (37) is at all times under tension, but smaller inside spring (36) is not normally under pressure until valve (34) opens a little.

The other adjustment of the springs is made by changing the position of the nuts (**N, N1**) on the stem of the valve. There are two sets of nuts, one for each spring, and they allow individual adjustment of the springs.

Make sure that on adjusting connecting rod clevis (C2), (Figs. 52, 51) is so adjusted that air shutter (28) completely closes when carburetor control on instrument board is pulled all the way out.

Caution: In warm weather, or if the engine is warm, the mixture may be so rich, if the knob is pulled out, that the charge will not ignite and the surplus of unburned gasoline may interfere with the proper lubrication of the cylinder walls.

For idling, the throttle valve is held very slightly open to allow a very small amount of mixture to go to the cylinders. If the engine races or stalls when the throttle is closed all the way, the stop screw of throttle lever **(TL)** (Fig. 51) needs adjusting.

A suction tube (**ST**) (Fig. 52) leads from the base of the spray mixing tube, or nozzle at (**CC**) (Fig. 52) around the carburetor into the intake manifold (**IM**).

Purpose is to prevent loading of engine when idled, or driven by car in coasting with clutch engaged. The tube removes gasoline which collects in carburetor body due to condensation. It also prevents loading under continued **low-throttle driving** and aids in **quick acceleration.**

Failure of suction tube to function properly is evidenced usually by gasoline dripping from the carburetor and by loading up, not idling properly, and uneven running at low throttle.

Cause of failure: air leakage into tube or connections, or, more frequently, clogging of the passage way either in the tube elbow, or carburetor body.

Remedy: Remove tube and blow it out, together with the lower elbow connection and the drilled leads in the carburetor, with compressed air.

Throttle valve (TV) (Fig. 51) is of the butterfly type and is located in the fuelizer elbow above the spray tube or nozzle (J).[1] It is controlled by a hand lever on the steering wheel and by the accelerator pedal.

The air valve (28) **and choker valve** (34) should be tested for tight fitting. When closed must be tight within .0015" at top and .004" at bottom.

Float needle valve (Fig. 50) must have, not less than $\frac{1}{64}$" movement. Solder collar and needle valve after adjusting. With **gasoline level** $\frac{1}{8}$" below top of well surrounding jet J (about in line with W), float weights must be approximately horizontal (position as now shown).

Fuelizer

Purpose: The fuelizer heats the gasoline and air from the carburetor, so that the mixture enters the cylinders as a dry gas rather than a combination of air and liquid particles.

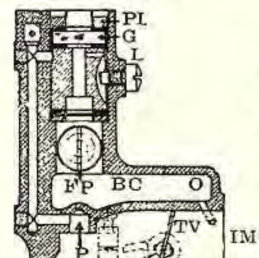


Fig. 53. Packard fuelizer, sectional view. **Names of parts: J,** spray tube or nozzle; **CH,** mixing chamber of carburetor; **TL,** throttle lever; **TV,** throttle valve; **IM,** to inlet manifold; **P,** passage to fuelizer which leads to burning chamber of fuelizer; **G** inspection glass of fuelizer; **PL,** plug and gasket retaining inspection glass; **L,** retaining plug set screw; **FP,** fuelizer spark plug; **BC,** fuelizer burning chamber; **O,** passage of superheated exhaust from fuelizer burning chamber to intake manifold.

Note: A screen is provided in the bottom of retaining plug just above fuelizer spark plug **FP,** for the purpose of preventing carbon from obscuring the glass.

This is accomplished in the following manner: A small fraction of the gasoline and air mixture passing to the engine is **shunted** into passage (**P**) (Fig. 53) in the intake elbow (on the eight-cylinder engine it is shunted through the throttle valve shaft into a passage in the manifold) which leads to the burning chamber of the fuelizer.

This mixture is ignited by the fuelizer spark plug (**FP**) in the side of the fuelizer burning chamber (**BC**) and burns with a steady flame, which can be viewed through the inspection glass (**G**) on top of the fuelizer.

The flame heats the burning chamber walls and then the hot burned gas mixes with the charge going to the engine cylinders from the carburetor.

The application of heat to the ingoing mixture greatly improves its gasification, which is particularly important at the lower throttle openings, at which time the fuelizer supplies its maximum heat.

[1] On later models the spray tube or nozzle (J) (Fig. 50) extends only about half-way up the spray mixing tube. On models 426–433, 336–343, the throttle valve is directly above the spray mixing tube. The carburetion mixture is heated and vaporized by means of an exhaust heated intake manifold. Otherwise, the principle and construction are practically the same.

The fuelizer mixture when ignited, **burns** instead of exploding and so heats the intake manifold so as to dry the main flow of gasoline and air.

After the charge in the fuelizer is ignited and burns, it circulates through the fuelizer chamber (**BC**) and spurts through two tiny holes (one shown at **O**, Fig. 53) into the main intake manifold (**IM**), further drying the flow of mixture from the carburetor mixing chamber (**CH**) on its way to the engine cylinders.

By the time the mixture in the main intake manifold (**IM**) has passed through the heat created by the fuelizer chamber and also has absorbed the superheated exhaust (from **O**) from the fuelizer, it is so dry that it is as near to perfect fuel as has been created.

The suction from the pistons that draws gas into the cylinders from the carburetor also keeps a steady flow of gasoline and air moving through the fuelizer.

As the circulation of gas through the fuelizer begins at (**P**) ahead of the butterfly throttle valve (**TV**) and exhausts beyond it (at **O**), the degree to which the fuelizer heats the main gas and air mixture in the intake manifold is regulated by the way the throttle valve (**TV**) is operated.

How the Fuelizer Automatically Stops Functioning

When the throttle valve is closed or nearly so, as when engine is starting or idling (low throttle openings), **engine suction is heavy** through the fuelizer, which then receives a maximum of gas and gives off its maximum of heat.

The farther the throttle valve is opened, the less is the engine suction through the fuelizer because it is easier for the engine to suck in mixture through the main manifold.

Thus heat given off by the fuelizer is **automatically increased or decreased** in proportion to the increasing or decreasing need of the engine for heat. This is especially true in cold weather.

In normal operation the fuelizer uses about 3 per cent of the engine's consumption of gasoline. Its automatic character prevents waste of fuel in warm weather or under favorable engine conditions.

Fuelizer Indications and Care

The color and condition of the flame is the index to the operation of the fuelizer. It should be observed with the engine idling.

A steady bluish-green flame indicates a good mixture.

If at any time an improper mixture is obtained, adjustment can be made by admitting either more or less air to the burning chamber by means of the small needle valve (**IJ**) (Fig. 51) at the top.

If the operation is still unsatisfactory, remove the inspection plug (**PL**) above the inspection glass (**G**), the glass and screen retainer which is held by a set screw (**L**) at the rear; clean the screen (at bottom of retainer just above spark plug **FP**) and glass (**G**), and also the fuelizer spark plug (**FP**) and replace parts carefully.

The **color of flame** given off from a petcock **on the engine** while running would be **different** from that of a fuelizer flame, because the flame given off from the engine has been compressed and ignited, whereas the fuelizer flame is a thoroughly vaporized gas, ignited by a spark and merely **burned.** It is not compressed, and the action could be likened to a blow-torch.

The fuelizer secondary ignition current (SC) (Fig. 52) leads directly from the terminal "Fuelizer" on the ignition coil (see pages 420, 407) to the fuelizer spark plug (**FP**)

The fuelizer spark plug (FP) is of an entirely different type than used for engine ignition, and the two types should never be interchanged except that in an emergency a cylinder spark plug with a widened gap may be used in the fuelizer until the proper replacement can be made. Rapid depreciation of the plug and faulty fuelizer action must be expected in a short time under this condition, however.

The difference in the designs of the two spark plugs is due to differences in operating temperatures, mixtures and pressure conditions in the fuelizer and cylinder combustion chambers.

The fuelizer spark plug functions in the same manner as the ignition plugs and should receive same attention. **The gap,** however, is 1/8".

The gap on spark plugs for engine (six and eight) is 1/32". This gap gives a good spark for slow running and for hard pulling, and is the best all-around adjustment obtainable.

An electric ground or cut off on the eight-cylinder engine (not on the six) is provided in order to cut off the secondary circuit leading to the fuelizer spark plug at approximately 30 m.p.h.

This attachment is placed on the fuelizer adjacent and connected to the throttle lever. At almost full opening of the carburetor throttle the fuelizer spark plug is grounded and thus its functioning ceases. The **purpose** of this is to intensify the ignition to cylinders at wide throttle opening.

Miller Carburetor

The Miller "H" is a "multiple-jet expanding carburetor" of the rotary or barrel throttle type.

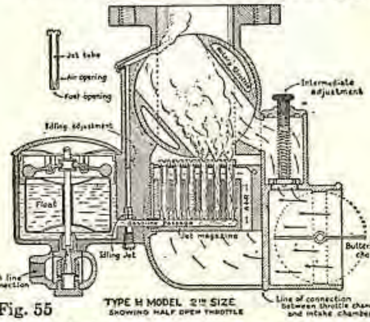


Fig. 55

Four to six main jet tubes are used, depending on the size of the carburetor, and these tubes, having each the fuel jet in the bottom and four small air holes a little above, are placed in a row in a removable magazine. This magazine has a fuel passage which supplies the jet in the bottom of the tubes and provides an air jacket which surrounds the main portion of each tube; these jacket spaces have a passageway near the top o the magazine above the float level that connects them with each other and with the outside air. **When not in action the tubes and surrounding air-jacket spaces are filled with fuel,** which provides a succession of puddles as the throttle is opened and the tubes brought into action one after another. Each tube, when the puddle has been drained, begins to function as a miniature carburetor with fuel entering at the jet in the bottom and air being supplied through the four small air holes just above.

By this design the fuel goes through a "two-stage" atomization process: the first in the bottom of the tubes, where a heavy spray is formed, and the second in the venturi of the carburetor, where the spray unites with the main air column. The main feature of this construction is the fact that the fuel flows through the jets by gravity from the float chamber and combines with the air of the first stage at a point below the float level. This brings the partially atomized fuel out of the tube and into the venturi for the second stage without the choke restriction necessary to create a depression at this point.

Carter carburetor (formerly on this **page**) is also a multiple-jet type carburetor but of a different **construction.**

Two exterior adjustments are provided. The first is for **idling** and is a control of the idling speed air by means of a screw in the passage. The second adjustment is for **intermediate speeds** and has its principal effect on the first third of the throttle range. It amounts to a control of the spring tension on a poppet valve which admits a certain amount of air during the first part of the throttle opening when the vacuum is at a relatively high point. This adjustment has its greatest effect as a control for pick-up, and consequently is also an adjustment for economy.

The air intake is made in two sections, with an adjustable clamping ring at the joint. The second section can be supplied as a vertical elbow which can be set at any angle required for the hot-air tubing. At the intake connection a butterfly valve is provided as a choker or strangler for starting; this is operated by a flexible wire control from the dash.

The carburetor here described is the same in all respects except for the two exterior adjustments as the instrument which the Miller company has been making in large sizes only for marine and aeronautical engines in past years.

Franklin Carburetor (Series 10)
(Series 10C to 11 uses Stromberg carburetor)

The carburetor used on the Franklin is of Franklin design and manufacture. It consists of a **carburetor** (Fig. 56), with **starting devices, air cleaner** (N), and a **gas heater** (Fig. 56C). The **choke** (L), although shown and described below, has been found unnecessary.

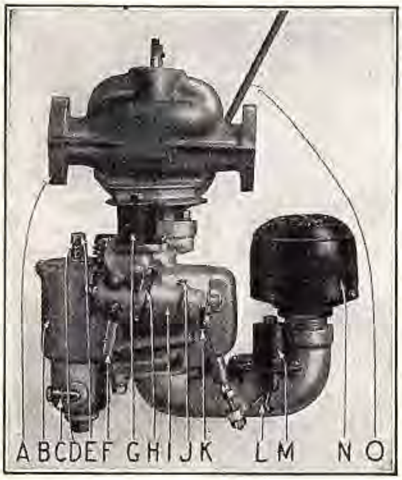


Fig. 56. **Franklin carburetor:** (A) gas heater; (B) float chamber; (C) gasoline inlet; (D) float chamber priming button; (E) float valve guide screw; (F) auxiliary air intake to electric vaporizer; (G) electric primer valve magnet; (H) throttle; (I) electric vaporizer; (J) air intake to electric vaporizer; (K) auxiliary air valve; (L) choke; (M) choke magnet (choke and magnet not now used); (N) air strainer; (O) needle valve.

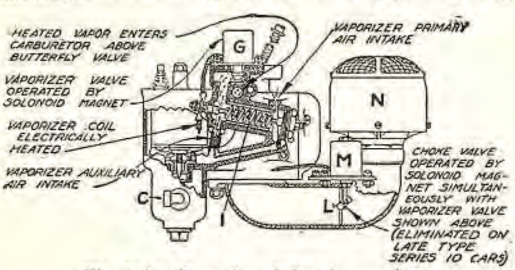


Fig. 56A. Operation of electric vaporizer.

Starting: How to obtain a rich, warm vapor for starting is shown in Fig. 56A.

Closing the switch on the instrument board sends electric current to the carburetor, where part goes to heat the vaporizer coil (I), and part to operate solenoid magnets (G) and (M). The solenoid (M) closes the main air passage by means of choke valve (L), and (G) opens a valve which permits the engine to draw fuel from the vaporizer chamber (I) through an opening above the throttle valve. Gasoline is drawn from the float chamber through the small passage shown below the vaporizer chamber, then into vaporizer chamber through the small metering hole, and mixes with air coming in at the primary air intake. The mixture passes over the red-hot electric coil, after which it is further diluted by air coming in at the auxiliary air intake. The hot mixture then passes into the cold cylinders in the form of vapor and can be readily ignited.

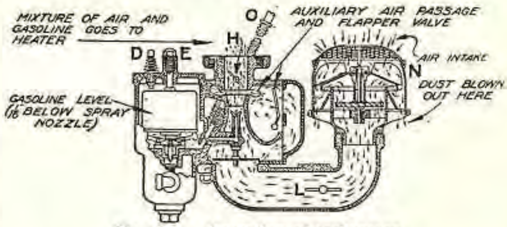


Fig. 56B. Operation of carburetor.

Running: Having started the engine, the carburetor functions as in Fig. 56B. Gasoline is drawn from the float chamber past needle valve (O), through a short passage to the spray nozzle shown directly below throttle valve (H).

Air cleaner: The air entering the carburetor is cleaned of dust by passing through air cleaner (N).

The action of the cleaner depends upon centrifugal force. Passage of air through the cleaner operates a small fan. This fan rotates four vertical vanes, which throw off any particles of dust. Cleaned air enters the carburetor through the lift valve shown at the extreme left of the air passage. The lift valve moves up and down on a pin through its center. The greater the suction of the engine, the farther the lift valve rises, thereby allowing more air to pass by the valve. After passing the lift valve, the air divides, part going directly past the spray nozzle tubes where it mixes with gasoline, the remainder passing to the right, through a curved passage, thence through an auxiliary air valve.

The shape of the air passage around the spray nozzle is such that a high velocity of air is obtained past the spray nozzle. This is necessary in order completely to break up the gasoline particles. When the mixture leaves this passage it is too rich for use, which is the reason for adding the auxiliary air.

The amount of opening of the auxiliary air valve against the action of spring (left of M, Fig. 56), depends upon suction of the engine. The auxiliary air joins the main mixture just below butterfly throttle valve (H).

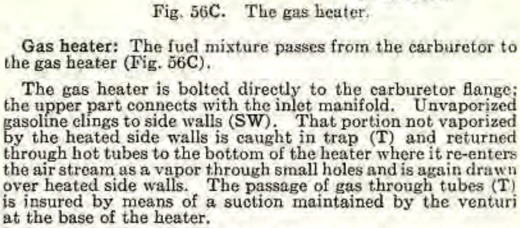


Fig. 56C. The gas heater.

Gas heater: The fuel mixture passes from the carburetor to the gas heater (Fig. 56C).

The gas heater is bolted directly to the carburetor flange; the upper part connects with the inlet manifold. Unvaporized gasoline clings to side walls (SW). That portion not vaporized by the heated side walls is caught in trap (T) and returned through hot tubes to the bottom of the heater where it re-enters the air stream as a vapor through small holes and is again drawn over heated side walls. The passage of gas through tubes (T) is insured by means of a suction maintained by the venturi at the base of the heater.

The mixture which leaves the heater is uniform, absolutely dry, and readily combustible. Its temperature is warm enough to prevent condensation, but cool enough to allow a large amount, **by weight,** to be introduced into the cylinder, thus giving maximum power. This temperature is automatically maintained constant, within a very few degrees, regardless of running conditions and of outside temperature. That part of the mixture which is **liquid** does not go into the cylinders, but clings to the side walls of the heater and is vaporized.

Adjust tension of spring of auxiliary air valve (K) just enough to bring the valve back to its seat when the engine is not running. If the tension is too great, the engine will load up; if too weak, backfiring will result.

Adjust needle valve (O) by turning to the right or left to a point where the engine runs best. In this position, set the pointer at the center of "run," and fasten the set screw. The valve can then be turned from this position to "lean" or to "enrich" mixture.

The Claudel Carburetor

Claudel carburetor, widely used in Europe, is manufactured by Claudel Carburetor Co., Long Island City, N.Y.

This carburetor was used on the Sunbeam engines of the British dirigible R-34, which made the first round trip across the Atlantic; also on the Rolls-Royce engines of the Vickers-Vimy aeroplane, which was the first plane to make a non-stop trip across the Atlantic; also used by Sadi Lecointe, the French aviator, who set a world's record of 232 m.p.h.

It is a "plain-tube" automatic compensating unit which has no moving part. **The principle used** is that of breaking up the gasoline by a swift current of air which makes an emulsion inside the jet itself before delivering it to the carburetor proper.

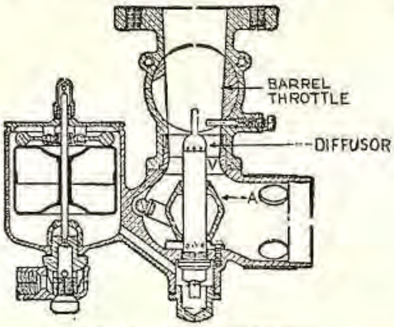


Fig. 57. Claudel carburetor.

In the American type of Claudel shown in Fig. 57, an improvement has been incorporated for strangling the air by means of a sliding air cone (A) which, when in strangling position, fits snugly into the venturi entry (V). This cone is controlled from the dash. This device assures quick starting and warming up in cold weather. The streamline air cone, concentric with the **diffusor,** may be raised into contact with the venturi, shutting off the air supply and putting the full suction on the diffusor.

Master Carburetor

A sectional side view is shown in Fig. 58.

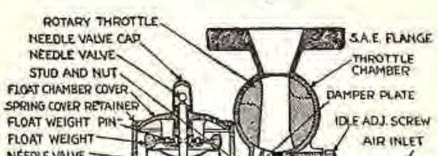


Fig. 58. Master Carburetor.

The fuel distributor (Fig. 59) is placed across the mixing chamber, the number of its jets varying from 11 to 19, according to its size. Each of these tiny jets occupies a different position in the path of the inrushing air, thus forming a perfectly atomized fuel that is instantly and thoroughly mixed with the air, the two elements being merged into one.

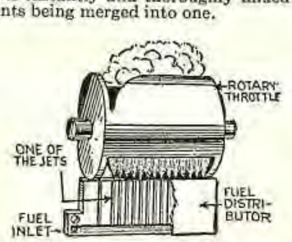


Fig. 59. Master fuel distributor.

When the **throttle is closed,** a single hole remains uncovered to admit a supply of fuel that is ample for idling or for slow running. As the **throttle is opened,** the additional holes are uncovered, one by one, and the fuel supply increased.

The rotary throttle eliminates the butterfly throttle which is extensively used on other makes.

As stated above, the fuel openings are fixed, but the air opening can be varied through the use of the positive control which operates the **damper** in the carburetor. The changing of the damper position, which increases or decreases the volume of the air passing the distributor, increasing or decreasing suction on the jets, gives the widest possible mixture range.

The air supply is constricted by the damper at the outlet, like a variable venturi. When the lever on the steering-post control (which is connected to the damper), is pulled to "rich" position, the venturi (or opening) paralleling the row of 11 to 19 jets is very small and the pure gas rushes to the engine under tremendous suction, thus enriching the mixture so that quick starting is easy and certain. As the engine picks up speed, the mixture may be modified by decrease to any mixture required.

Rapid acceleration. Do not open the throttle suddenly. A gradual opening will give quicker get-away and save wear and tear on the motor.

Idle adjust-screw. For perfect idling of the engine set the control lever in center position. If the engine rolls or gallops at idling speed, back out on idle adjust-screw. If the engine seems not to have sufficient gas at idling, screw the idle adjust-screw in. Turning it to the right enriches the mixture coming from the idle hole only.

Fuel distributors of various capacities are available for each size carburetor. Should the engine run and pull best with control in rich position at ordinary speeds, you should have a distributor of greater fuel capacity. Should the engine take all the air possible to give it at idle speeds, you should then have a distributor of less fuel capacity. The letter on the end of distributor designates its fuel capacity. See below for sizes.

Control centers are numbered at the base of the lever and those stamped No. 1 are for 1" and 1¼" JR carburetors. Those stamped No. 2 are for 1¼" STD and 1½" JR carburetors. Those stamped No. 3 are for 1½" and all larger sizes. Manufacturers are the Master Carburetor Company, Box 444 Sta. C., Los Angeles, Cal.

Eagle Carburetor

The Eagle carburetor used on the Maxwell engine is an "air-valve" type of carburetor.

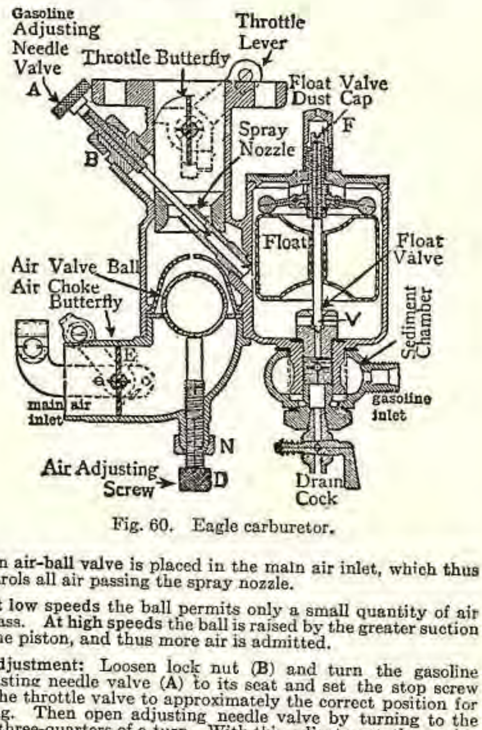


Fig. 60. Eagle carburetor.

An **air-ball valve** is placed in the main air inlet, which thus controls all air passing the spray nozzle.

At low speeds the ball permits only a small quantity of air to pass. **At high speeds** the ball is raised by the greater suction of the piston, and thus more air is admitted.

Adjustment: Loosen lock nut (B) and turn the gasoline adjusting needle valve (A) to its seat and set the stop screw on the throttle valve to approximately the correct position for idling. Then open adjusting needle valve by turning to the left three-quarters of a turn. With this adjustment the engine can be started.

When starting with a cool engine, it is absolutely necessary to have choker butterfly (E) closed. This is operated from the dash and should be opened gradually as the engine warms up.

The engine should be run long enough to be warmed up to service condition. Be sure that the choker butterfly valve (E) is open when making adjustment.

Then retard the spark control, open the throttle until the engine is running at average driving speed. Next turn gasoline adjusting needle (A) to the right until the engine speed decreases from lean mixture. Then turn to left until the speed increases and again starts slowing up, which is as rich a mixture as engine can be run on. By turning again to the right to a point half-way between the two, when the engine speed is highest, the correct mixture for general driving will be obtained. Tighten lock nut (B), and the adjustment is complete.

The air-adjusting screw (D) is provided only for the purpose of controlling the air supply to the carburetor when running at low speeds. It may be possible that the adjustment on the gasoline adjusting needle is slightly too rich for idling purposes and will cause the carburetor to choke. By loosening lock nut (N) and turning the air adjusting screw (D) to the right, admitting more air, this condition will be eliminated. Tighten the lock nut, and the adjustment is complete.

Adjust the throttle-lever stop screw until the desired idling speed is secured. Adjustments should be made with spark and throttle fully retarded.

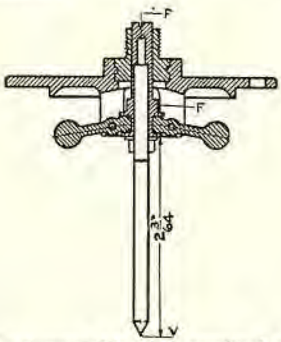


Fig. 61. If carburetor drips, it is usually due to dirt under the float needle valve (V). Remove the float dust cap, place a screw driver in the end of float collar (F) and turn gently back and forth, thus seating the float needle valve. Eagle Carburetor Co., Cleveland, Ohio.

Marvel Carburetor Heating System

The Marvel carburetor used on the Buick, Nash, and Oakland (1923) varies slightly in construction, but is similar in principle, by which the air drawn into the main air inlet is heated and controlled by the choker valve, and the mixture is heated by the exhaust gases passing around the jacket of the carburetor.

Refer to Fig. 62 and note a damper body holding a valve in the main exhaust line. This valve is inter-connected to the throttle and forces **all the exhaust gas to pass around the jacket of the carburetor when the throttle is closed and** partly closed for town driving. As the throttle is opened up however, the damper too is opened, allowing more and more heat to pass out the main exhaust, thus preventing over-heating. It takes but a few explosions to warm the jacket of the carburetor

Crank-case dilution, or thinning out of the engine oil, comes from excessive use of the choker in cold weather in getting the car up to normal operating temperature. This is prevented by the quick application of heat requiring the use of the choker for starting only, and but a very short time thereafter. See also G.M.C. manifold on page 917.

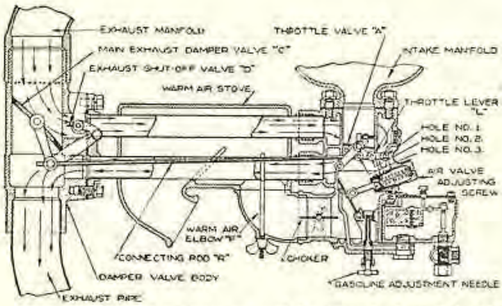


Fig. 62. Marvel carburetor and heat control used in the Nash (1923).

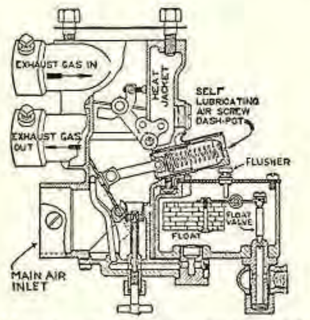


Fig. 63. Marvel carburetor showing the intake and outlet of exhaust gases around the jacket of the carburetor.

ADDRESS OF CARBURETOR MANUFACTURERS

"Air-Friction": New Air-Friction Co., Dayton, Ohio.
"Ball and Ball": Penberthy Injector Co., Detroit, Mich.
"Carter": Carter Carburetor Corp., St. Louis, Mo.
"Duff": Duff Engineering Co., Nebraska City, Neb.
"Ensign": Ensign Carburetor Co., Los Angeles, Calif.
"Holley": Holley Carburetor Co., Detroit, Mich.
"Juhasz": Juhasz Carburetor Corp., New York, N.Y.
"Kingston": Kingston Products Corp., Kokomo, Ind.
"Marvel": Marvel Carburetor Co., Flint, Mich.
"Miller": Harry A. Miller, Inc., Los Angeles, Calif.
"Schebler": Wheeler-Schebler Carburetor Co., Indianapolis, Ind.
"Solex": American Carburetor Co., Detroit, Mich.
"Stokes": Stokes Carburetor Co., Hampton Bays, N.Y.
"Stromberg": Stromberg Motor Devices Co., Chicago, Ill.
"Swan": Swan Carburetor Co., Cleveland, Ohio.
"Tillotson": Tillotson Mfg. Co., Toledo, Ohio.
"Vis-A-Gas": See Stromberg Motor Devices Co.
"Winfield": Winfield Carburetor Co., Glendale, Calif.
"Zenith": Zenith-Detroit Corp., Detroit, Mich.

For make of carburetor used on various cars, see Index under "Specifications of passenger cars."

Note: **Carburetors described in this instruction are selected as examples in order to explain the different principles of operation and construction.** Carburetor manufacturers are changing their models from time to time. It is not our intention to attempt to show all the different models, as space would not permit. See pages 1055–1062 for "*Passenger Car Specifications*," which will give the make of carburetor used on late model cars; see also page 966 for "*Truck Specifications*," and page 996 for "*Tractor Specifications*."

By writing to carburetor manufacturers, no doubt they would forward printed matter explaining their later models.

—Continued from other side

will lift rocker arm **D**, which is pivoted at **E** and which pulls the pull rod **F**, together with diaphragm **A** held between metal discs **B** downward against spring pressure **C**, thus creating a vacuum in pump chamber **M**.

Fuel from the rear tank will enter at **J** into sediment bowl **K** and through strainer **L** and suction valve **N** into pump chamber **M**. On the return stroke, spring pressure **C** pushes diaphragm **A** upward forcing fuel from chamber **M** through pressure valve **O** and opening **P** into the carburetor.

When the carburetor bowl is filled the float in the float chamber will shut off the inlet needle valve, thus creating a pressure in pump chamber **M**. This pressure will hold diaphragm **A** downward against the spring pressure **C** and it will remain in this position until the carburetor requires further fuel and the needle valve opens. The rocker arm **D** is in two pieces split at **R** and the movement of the eccentric **H** is absorbed by this "break" **R** when fuel is not required.

Spring **S** is merely for the purpose of keeping rocker arm **D** in constant contact with eccentric **H** to eliminate noise.

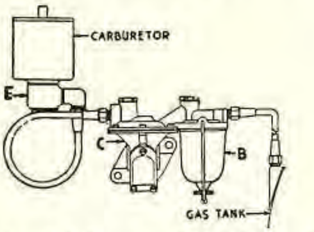


Fig. 26. **A typical diagrammatic installation of the AC fuel supply system.** Note that only one line is required from the rear gas tank to strainer **B** and another small line connects pump **C** to float chamber of carburetor **E**.

Service Hints on the AC Fuel Pump

Service is available through United Motors Service branches and authorized AC service stations who are prepared with parts and fixtures for repairing all types of pumps. There are some service operations on this fuel pump that can, if necessary, be done without referring to the service station, as given below.

Lack of fuel at the carburetor, check as follows:

Cause: gasoline tank empty. **Remedy:** refill.

Cause: leaky tubing or connections. **Remedy:** replace tubing and tighten all pipe connections at the fuel pump and gasoline tank.

Cause: bent or kinked tubing. **Remedy:** replace tubing.

Cause: glass bowl loose. **Remedy:** tighten thumb nut, making certain that cork gasket lies flat in its seat and not broken.

Cause: dirty screen. **Remedy:** remove glass bowl and clean the screen. Make certain that cork gasket is properly seated when reassembling.

Cause: loose valve plug. **Remedy:** tighten valve plug securely, replacing valve plug gasket if necessary.

Cause: dirty or warped valves. **Remedy:** remove valve plugs and valves. Wash valves in gasoline. If damaged or warped, replace them. Examine valve seat to make certain there are no irregularities which prevent proper seating of valves. Place valve in valve chamber with the polished side downward. Make certain that valve lies flat on its seat and is not left standing on edge. Reassemble valve plug and spring, making certain that spring is around the lower stem of the valve plug properly. Use new gasket under valve plug if necessary.

Leakage of fuel at the diaphragm, check as follows:

Cause: loose cover screws. **Remedy:** tighten cover screws alternately and securely. Caution: Do not disassemble the pump body. Note: Sometimes there appears to be a leak at the diaphragm, whereas the leak actually exists at one of the pipe fittings and the fuel has run down pump to diaphragm flange, appearing to originate there.

Flooding of carburetor, check as follows:

Cause: carburetor needle valve not seating. **Remedy:** check carburetor for proper adjustment.

Important: Do not attempt to disassemble the fuel pump further than described above, because it is absolutely necessary to use a special fixture in reassembling the pump when once taken apart. When the above remedies do not correct the condition, replace with a new fuel pump sending the old fuel pump to your nearest United Motors Service branches or authorized AC Service Stations.

STROMBERG TYPE "D" DO

The features of the "D" series of c

1. The **down-draft carburetor** is si
flows down into the manifold, aided b
the suction in the engine, as in the u
mitted the use of carburetors of great
resultant increase in engine power. E
the carburetor, to give smoother all a

2. A new semi-automatic **choking device** f
down-draft carburetor. Fig. 5.

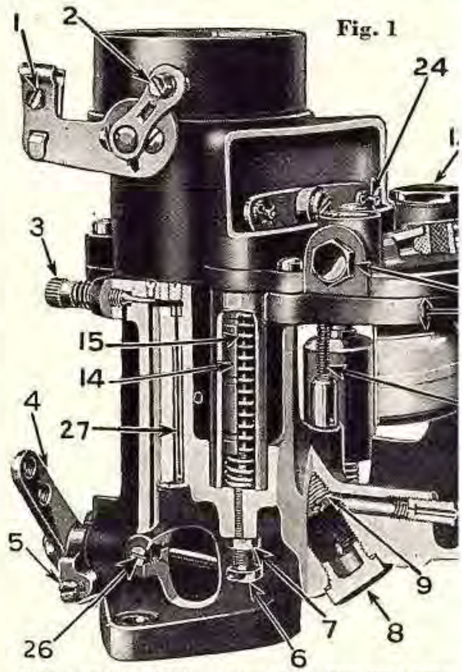
3. A new positive acting **accelerating devi**
charge immediately the throttle is moved, an
In the "D" down-draft type carburetor the a
of a vacuum piston **14**, Fig. 1, connected by a
The volume and force of the accelerating cha
automatically providing the proper charge fo

4. An **adjustment** to vary the quantity of

5. Idle and low speed jets below throttle, w

6. An **economizer** which permits the carbu
closed throttle positions of average driving, a
power of the engine is called for.

The economizer is operated as follows: At closed or
the throttle valve, therefore the vacuum piston **14**, Fig. 1
from the economizer valve **13**, Fig. 1, thus closing the e



Figs. 1 and 2. **Sectional view of the type "D" down-**

1. Choke control tube holder.
2. Choke lever wire clamp screw.
3. Idling needle valve.
4. Throttle lever.
5. Throttle stop set screw.
6. Vacuum piston adjustment screw.
7. Vacuum piston adjustment lock nut.
8. Main discharge plug.
9. Main discharge jet retainer plug.
10. Main metering jet.*
11. Gasoline connection.
12. Strainer plug.
13. Economizer poppet valve.
14. Vacuum piston.

**Important. When ordering venturi tubes, high speed b*
state type of carburetor and serial number.

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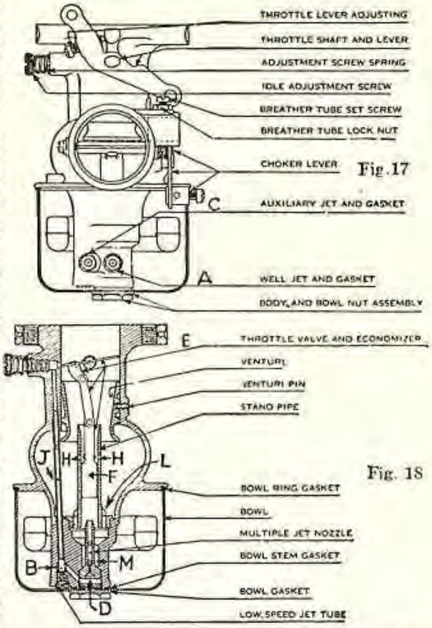


Fig. 17

Fig. 18

v speed tube is swedged (just above J). This slightly re-
s point, thus increases the velocity of the gas, insuring

tle butterfly valve is opened air rushes in through the
l in passing in and up through the venturi tube creates a
causes air to be drawn down through the four holes L
ir picking up gasoline from the main or accelerating well
the venturi tube where it is met by the main body of air
proper proportion for accelerating speeds.

A feeding the main or accelerating well M is unable to
the line of suction, therefore the level in the well M lowers,
ltiple jet nozzle.
rd through the four holes L surrounding the standpipe is
multiple jet nozzle creating an increased suction on the
is drawn direct from bowl chamber through multiple jet
pplies both gas and air at high speeds.

40 or 45 m.p.h. the economizer E covers the ports H as
h mixture resulting in greater speed and power.
at to machined surface of casting.

ɛR LEVERLESS VACUUM TANK

e **lever type of tank** discussed in the *Carburetor Encyclopedia* (pages 1303-1306) in that there are no levers with springs. The bends in the float stem cause the valves B and C to be opened and closed as the float reaches the bottom or top of its travel.

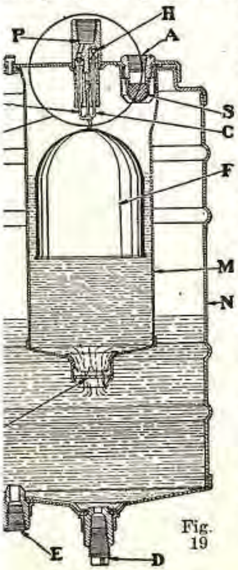


Fig. 19

When the float F is up the float stem lower bend (just above the top of the float) closes the vacuum valve B and opens the atmospheric valve C.

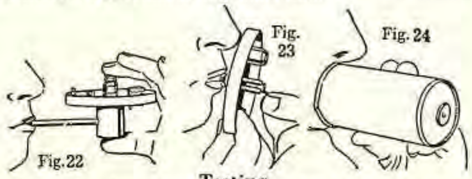
When the float F is down the float stem upper bend (at end of float stem) opens vacuum valve B and closes atmospheric valve C.

For example, when vacuum chamber M is full and the gasoline begins to flow into the outer chamber N, the float F starts to go down. It will thus be observed that the float stem lower bend no longer presses against the vacuum valve stem B to hold this valve closed. The manifold vacuum therefore must be great enough to hold this valve closed until the float reaches the bottom of its stroke. In the lever type a spring serves this purpose. The principle of operation otherwise is practically the same, therefore a study of pages 1303-1306 will make clear the operation.

Name of Parts of Stewart Model 493 Tank

Name of parts of the Stewart model 493 leverless type vacuum tank used on Chevrolet model, National AB (Figs. 19, 20): **A**, fuel inlet; **B**, vacuum valve stem **C**, atmospheric valve stem; **D**, drain; **E**, gasoline outlet to carburetor (gravity feed); **F**, float; **G**, flapper valve; **H**, air valve inlet; **K**, vent tube; **M**, inner or vacuum chamber; **N**, outer or reserve chamber; **P**, vacuum opening (connects with intake manifold); **S**, filter screen.

Stewart model 409 and 418 leverless type vacuum tank differs in the flapper **G** (Fig. 21). This type used on Essex, Erskine, Whippet and several other cars.



Testing

To test for leak in atmospheric valve C see Fig. 22; **to test for leak in vacuum valve B**, Fig. 23; **to test the flapper valve**, Fig. 24.

AC FUEL SUPPLY SYSTEM

Purpose: Pumps fuel from tank in rear of car through a combined gasoline strainer before forcing it into carburetor. **Can be operated** from push rods, tappets or eccentrics located on camshaft or other rotating parts giving a reciprocal motion of from $\frac{3}{16}''$ to $\frac{1}{4}''$ maximum.

As an example, the series "B," AC diaphragm type of fuel pump attached to the crankcase and operated from the camshaft is shown in Fig. 25. A reciprocal motion of about $\frac{1}{4}''$ maximum is imparted to lever **D**, by a small eccentric **H**, mounted on the camshaft **G**.

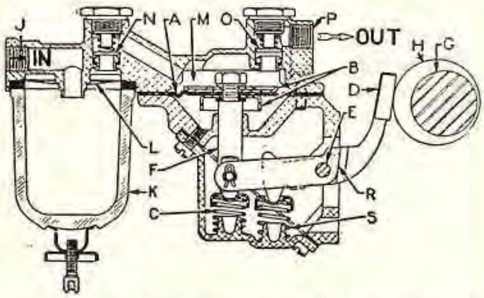


Fig. 25. **The AC fuel pump,** series "B" of the diaphragm type. Standard installation operating from engine camshaft with angular pump lever arm. Various other methods can be used for operating pump.

The diaphragm is composed of several layers of especially treated flexible cloth material, which is impervious to gasoline and benzol. This cloth material **A** is held between two unequal metal discs **B** and is pushed upward by a pump spring **C**. This diaphragm in its upward position almost fills the pump chamber **M** so that in its downward movement a very high vacuum is obtained, thus assuring high pumping capacity even at low speed.

The repeated $\frac{1}{4}''$ movement of the diaphragm is possible indefinitely without any injury, due to the extreme flexibility of this material. Further, the extreme movement of the diaphragm occurs only when the carburetor is empty. When the carburetor is full, this movement is greatly diminished, being directly proportional to the amount of gasoline used by the engine. This means that in practically all normal driving conditions this diaphragm is pulsating in a movement of a few thousandths of an inch.

This movement is controlled by the two-piece rocker arm **D**, split at **R**, because when the diaphragm is in the depressed position it carries part of the split rocker arm downward and forms a gap at line **R**, thus allowing the eccentric **G** to reciprocate part of rocker arm **D** without engaging the diaphragm on the suction stroke.

Operation: By revolving the shaft **G** the eccentric **H**

—over

INSTRUCTION No. 15

COOLING THE GASOLINE ENGINE: Cooling Methods; Water Circulating Pumps; Fans; Radiators; Water Thermostats; Water Temperature; Water Cooling Troubles; Overheating of Engine; Non-Freezing Solutions; Air-Cooling Methods; Heating a Car.

WATER COOLING

If no provision is made for **cooling the cylinder of a gasoline engine,** the intense heat of the explosions would heat it to a point that would cause the lubricating oil to burn and become useless. At the same time, the cylinder must not be kept too cool, for that would prevent development of full power; the cylinder must therefore be permitted to get as hot as is possible without burning the lubricating oil. About 170° Fahr. or below the boiling point, appears to give the best results.

The cylinder may be cooled either by water or air, and while the greater number of engines are water cooled, air cooling has been developed to a point where successful results are attained.

The water-cooling system consists of jackets around the part of the cylinder that is to be cooled, through which water may flow; a **radiator** for cooling the heated water; and some method of keeping the water in circulation, together with the necessary connections (see Fig. 4). **The cylinder water-jackets** are usually cast in one piece with the cylinder. When heated, the water passes to the radiator tank, thence through the radiator tubes, where the rush of air to which it is exposed absorbs the heat, cooling the water, which then passes back to the lower water connections on cylinders.

The radiator system is always fixed in the forward part of the car, to obtain the full benefit of the draught of air. The same water is used over and over again, so that it is only necessary to replace the loss caused by evaporation and leakage.

It is usual with **radiator systems to have a rotary fan** to assist in inducing a draught of cold air through the radiator tubes and in accelerating the cooling when the car is moving slowly, as in hill-climbing or slow running in traffic. The fan is driven from the engine shaft by a belt or gear and fixed back of the radiator. The alternative method, which avoids the use of a separate fan, is provided by fan-vaned arms in the fly wheel.

WATER—CIRCULATING METHODS

The two systems of circulation are the "thermo-syphon" system and the "force" system.

Thermo-Syphon Water Circulation System

The thermo-syphon system of water circulation is as follows: Upon becoming heated, the water rises to the top, entering the pipe and passing into the radiator at top where it is brought into contact with a large cooling surface, in the shape of the radiator. On being cooled and thereby becoming heavier, the water sinks again to the bottom of the cooling system, to enter the cylinders once more and to repeat its circulation. The cooling action is further increased by a belt-driven fan which draws air through the radiator spaces. The connections are the same as for the force system, except that there is no pump, and the connection from the water-jacket outlet to the top of the radiator slants upward. It is more necessary to have clear passages for the thermo-syphon system than for the force system, because the pump, in the latter, will force the water past an obstruction that would stop the flow of water that moves only because of its heat.

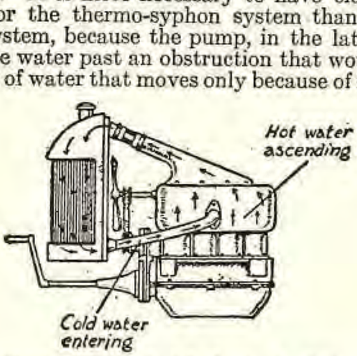


Fig. 1. Thermo-syphon principle of water circulation. See also page 155 for a typical example of a "thermo-syphon" system.

The height of the radiator with the thermo-syphon system must be higher and lower than the extreme top and bottom of the water jacket (see **Fig. 1** and also, refer to page 155).

The height of water with the thermo-syphon system should be kept at level above top inlet of radiator to insure proper circulation. Below this point circulation ceases and water boils.

Keep the radiator full: When the cooling water is kept in motion by thermo-syphon action, it is quite important that the radiator be kept reasonably full in order that there be a back resistance to aid in forcing the water forward. It is good engine care to add frequently a little cold water, instead of waiting for the engine to knock, especially in summer.

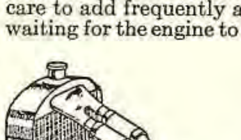


Fig. 2

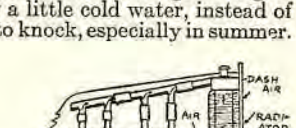


Fig. 3

Fig. 2. A thermo-syphon system in which independent pipes are taken from each pair of cylinders, the outlet pipes joining at the upper or tank part of the radiator. Cylinders in this instance are cast in pairs (obsolete). Where cylinders are cast in-block, one water inlet and one water outlet pipe will suffice, as in Fig. 1. See also, page 155.

Fig. 3. Simple thermo-syphon circulation without the use of a fan. The arms of the fly wheel are designed to act as fan blades; a separate fan is unnecessary, but the underpart of the engine must be carefully screened in (formerly used on Renault).

Force Water-Circulation System

In the force system, the engine drives a pump which keeps the water in constant circulation, as shown in Fig. 4. The pump forces the water from the bottom of the radiator to the inlet at the bottom of the water jacket, through which it flows to the outlet at the top, whence it goes to the top of the radiator, and flows through the radiator tubes to the bottom. As it passes through the radiator tubes it is cooled. After passing through in this manner, it is again drawn through the pump and forced again through the same path.

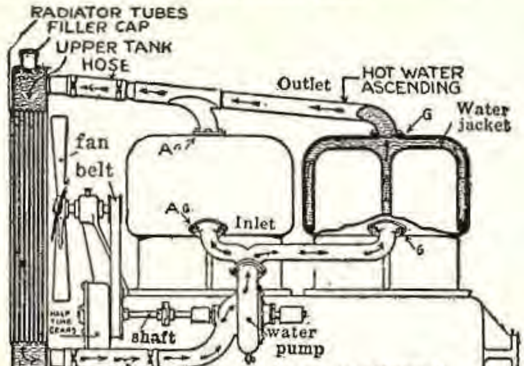


Fig. 4. This illustration shows how the pump shaft on the forced water-circulating system is usually driven, and also the fan. G are gasket connections which must be kept tight—usually made of copper asbestos-lined composition. The path of the water circulation is also shown.

Circulating Pumps

Practically **all water-circulating pumps are driven by a gear on the crank shaft or cam shaft,** so that motion is positive, and without slipping. All forced circulating systems must use a circulating pump.

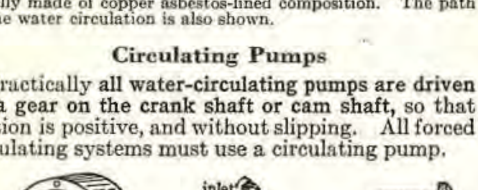


Fig. 5 Fig. 6 Fig. 7

Fig. 5. **The gear type of circulating pump** consists of two small gears with large teeth, the two being in mesh, and placed in a casing that fits as snugly as possible. The water enters at one side where the teeth separate and is carried around to the opposite side in the spaces between the teeth, where it escapes through an outlet.

Fig. 6. **The rotary, or vane type** pump consists of a ring-shaped casing, within which a disk revolves, the disk being "eccentric," or to one side of the center of the casing. Through a slot across the disk are two arms, their ends being pressed against the casing by a spring. As the disk revolves, the water is forced from the inlet to the outlet by the arms.

Fig. 7. **The centrifugal type of pump** acts on the principle of an air blower, and has blades projecting from a hub, which revolve at high speed inside of a casing. The water enters at the hub, and is thrown outward by the blades to the outlet in the casing. This is the type in general use.
See page 160 for the "piston" or "plunger" type.

There are four types of circulating pumps: the "gear" type, the "centrifugal" type, the "rotary" or "vane" type, and the "piston" or "plunger" type (Fig. 9, page 160).

Principle of circulating pumps: The principle is the same for water or oil. If the pump is elevated above the supply, the feed to the pump is by vacuum and the delivery by force; if submerged, or below the source of supply, the feed to pump is by gravity and the delivery by force.

Cooling Fans

In order to cool the water sufficiently, **a fan** is driven by a belt attached to a special bracket on the engine. This is shown in Fig. 4.

The fan draws a current of air through the passages in the radiator in addition to that driven through it by the forward motion of the car.

There are two types of fans in general use: the multiple blade (Fig. 9), and the two-blade (Fig. 10).

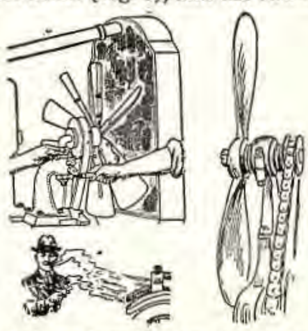


Fig. 8 (lower)
Fig. 9 (upper)
Fig. 10 (right)

Fig. 8 shows how the fan draws air in through the cores of the radiator to keep the water cooled. This demonstrates clearly the function of the fan, and shows how futile is its attempt to cool the radiator when a winter cover is placed over the radiator and is fully closed. There is no cooling action to the fan unless the front of the radiator is at least partially exposed. Often obstructions are placed in front of the radiator, as license tags, etc., which cut down the efficiency of the cooling system.

Fan adjustment: the belt can be tightened by raising the fan by an eccentric adjustment (Fig. 8A), or by bodily lifting the fan and its bearing and tightening a bolt holding it (Fig. 9).

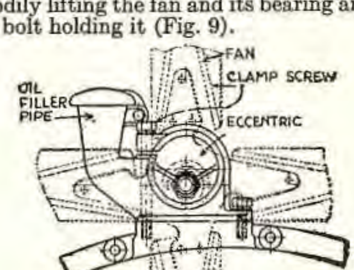


Fig. 8A

The belt should be kept tight. A slack fan belt often causes overheating. Ball bearings are usually provided and they should be kept well oiled. This is quite often overlooked.

RADIATORS

The purpose of a radiator is to keep the water, which circulates around the water jacket of the cylinders below the boiling point.

The early type of radiator (Fig. 11) consisted of a corrugated copper tank, with horizontal tubes running lengthwise of the tank. A tank was placed on each side of the body connected with the water jacket of the engine. A circulating pump was used to circulate the water. Modern constructions are shown farther on.

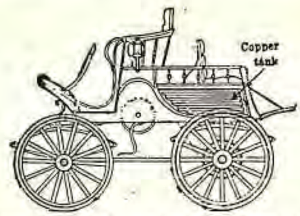


Fig. 11. One of the early methods employed for cooling the water.

The location of a modern radiator is usually in front of the engine, where it will come in contact with the air. The air passes between the tubes or fins on a tubular type of radiator and through the cells of a cellular type. A fan is usually placed directly behind the radiator, which is operated from a pulley on the crank shaft of the engine, for the purpose of drawing a large quantity of air through the radiator, thus increasing the cooling capacity.

Construction of a radiator: There is a reservoir or tank placed at the top and one at the bottom, as shown in Fig. 4. Between these two tanks, the tubes or cells are connected. A flexible hose pipe connection is made with the top and bottom tank from the engine, as shown. When the engine is running, the hot water passes to the top tank, thence downward through the radiator tubes (if a tubular type), or around the cells (if a cellular type), and is thus cooled. The cooled water then passes into the lower part of the engine from the lower tank of the radiator.

Radiators must be used with either the "forced-circulating" system, using a pump, or with the "thermo-syphon" system, which does not use a pump.

Types of radiators: There are two types in general use, the "tubular" and the "cellular," or "honey-comb."

The tubular type consists of vertical tubes placed between the upper and lower radiator tank. The **water passes** downward **through** all of the **tubes.** If one tube becomes clogged, then all of the water must pass through the other tubes. Each tube is a separate path through the radiator.

The cellular radiator consists of tubes or cells placed horizontally, through which the air passes and the **water flows** downward **around** these cells or tubes.

The honey-comb type of radiator was a term originally applied to a cellular type of radiator, due to its likeness to a honey-comb, but now that tubular type radiators can be constructed so as to have the appearance of a cellular radiator, the term could also be applied to the tubular type.

Tubular-Type Radiators

The tubular type of radiator used in 1900 and 1901 is shown in Fig. 13. The tubes were placed horizontally in heads (**H**). Crimped fins (**F**) were placed on the tubes. The radiator was suspended under the front of the car by studs (**S**). A pump circulated the water.

The vertical tubular type with "spiral" fins (**F**) (Fig. 14) was the next type introduced. These tubes were placed between an upper and lower tank (Fig. 4, page 146). This type is still in use, principally on trucks.

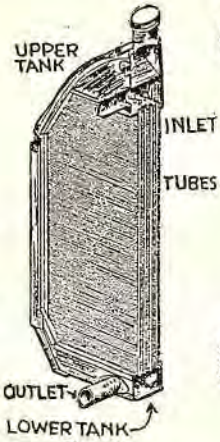


Fig. 12

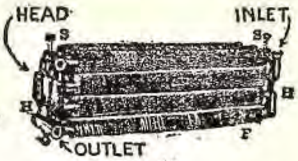


Fig. 13

Fig. 15

Fig. 14

The vertical tubular type with "flat" fins (Fig. 15) was the next type introduced, the idea being to have it resemble the cellular radiator which at that time was introduced on the Mercedes car. A tubular radiator made up with flat fins, is shown in Fig. 12.

Fig. 16

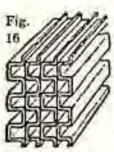


Fig. 17

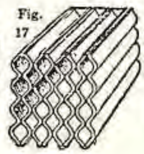
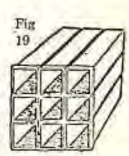


Fig. 18

Fig. 19



Variations of construction of the tubular type radiator are shown in Figs. 16, 17, and 18. Note that the appearance is similar to the cellular type, but the water flows through the tubes, whereas, with a cellular radiator, the water flows around the tubes.

Cellular-Type Radiators

The original cellular type was the Mercedes (Fig. 19). It consisted of four or five thousand ¼" square copper tubes 4" long, nested horizontally together, being separated from each other by wires arranged to run between the rows of tubes in both directions. The blocks so made were clamped together, and dipped in a bath of solder, both front and back, by which means a space $\frac{1}{32}$" thick was left on each side of every tube. The blocks (divided into sections similar to Fig. 20) were assembled with the top and bottom tank of the radiator, and water was forced to pass in between the tubes, the air being allowed to travel through the inside of the tubes. A very large radiating surface was thus obtained, and it would be hard to conceive of any arrangement offering a larger radiating capacity for any given size of radiator.

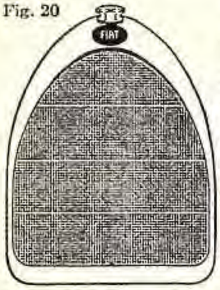
The cellular radiator is a very expensive type to construct. In this country, where large quantities are required, this construction was quickly modified to make the production cheaper.

Honeycomb Type of Radiator

The tubular type construction of radiator is often termed a "honeycomb" type. It is very much like a cellular honeycomb in appearance. See Fig. 18.

The Fiat true cellular type of radiator (Fig. 20) is similar to the Mercedes. It is formed in four divisions indicated by horizontal lines. Where these lines cross there are open horizontal passages through

Fig. 20



which the water may flow from one side to the other. Thus a section can be removed and repaired separately.

Some of the modifications employed are shown in Figs. 21 and 22. Note in Fig. 21 that the tubes are expanded at the ends, thus eliminating the wires.

The Mayo is constructed in a similar manner with the water passage to the sides of tubes. In the Fedders (Fig. 22) the hexagon tubes can be removed and replaced. The Harrison hexagon cellular is shown in Fig. 23. Between every other row of cells there is a water passage .08″ thick.

Figs. 24 and 25. Front and side view of a popular type of radiator, showing overflow pipe, upper and lower tank, and connections.

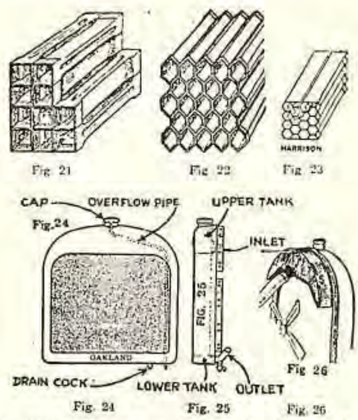


Fig. 26. Extension or syphon tank (S), used on many thermo-syphon systems to give greater body of water and to absorb steam and to maintain a constant level—a desirable feature on all radiators.

WATER TEMPERATURE

In general service it has been found that the water circulating around the water jackets has an average normal temperature of 170° F. in cars equipped with a water pump and about 200° F. in cars cooled by the thermo-syphon system. If the actual water temperature reaches 212° F., boiling occurs, with a consequent loss of water due to steam which passes off through the overflow pipe. Continued operation, when steaming, is liable to cause scored cylinders.

If the temperature of the water is low, the cold engine condenses a portion of the gasoline, which leaks past the piston rings, dilutes and thins the lubricating oil, with the result that the engine is not properly lubricated, and the raw, unvaporized gasoline produces carbon deposit in the cylinders.

Temperature Indicator

A device which is placed on the filler cap of the radiator (Fig. 27) serves to indicate the temperature of the air, or vapor, above the water and not the actual temperature of the water. This device is known as the "Boyce Moto-Meter." It is a very useful device for warning the driver when his **engine is overheating.** This device is placed on the radiator cap and the bulb at the end does not extend into the water. The fluid in the tube reaches different levels according to the temperature. These figures can be seen from the driver's seat.

By taking the temperature of the air over the water, the manufacturers claim that this instrument has greater utility, as follows:

First, because (up to the actual creation of steam) it always reads well below the danger point, and by a quick jump to "danger" (when steam occurs) it warns the driver to stop.

Second, on a thermo-syphon system, practically no jump would occur, since the water temperature is usually around the 200° F., and the change to 212° steam would be almost imperceptible to the driver.

Third, a broken water pump or stoppage of circulation would not show in time to prevent damage, were the bulb of the Moto-Meter to be submerged in the radiator water, as the radiator tank would remain cool while the steam passes out the overflow pipe. It is, however, directly in the flow of steam and immediately signals dangerous conditions.[1]

[1] **Another make of temperature indicator is the Radimeter.** It is installed on the dash and a tube leads to a bulb installed in the water jacket and indicates the actual temperature of the water.

Fig. 27. Boyce Moto-Meter, showing the lines which now appear on the dial of all Moto-Meters. The approximate temperature of the air space over the water in degrees Fah. is shown to the side.

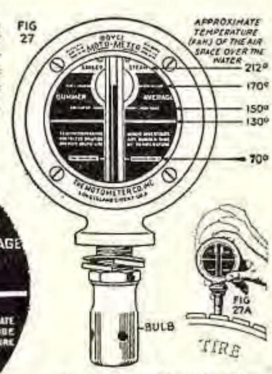


Fig. 27A. If fluid is driven from bulb into tube during shipment, tap it on tire.

The top line is danger; stop car and see if the overheating is due to lack of water, lubrication, too much gasoline being fed by carburetor, or loose fan belt.

The next lower line is an efficient temperature at which to operate an engine, especially of the thermo-syphon type during summer.

Note: "Summer average" represents a zone, not a line on the scale. It is quite impossible to give a definite line for all cars.

The next lower line for water-pump cars means the temperature at which most pump-equipped cars generally operate under summer conditions.

The next line is intended to show the bottom of the "summer average" zone, and a temperature above which alcohol nonfreeze is likely to evaporate in winter.

After the Moto-Meter is installed and the car is driven about ten miles, the engine's normal operating temperature, as registered on the dial should be carefully noted. This will usually be found to be at the bottom of the circle, or about 1/4″ below this point in **pump-equipped cars;** on **thermo-syphon cars,** about the middle of the circle. Unless unusual road conditions are met with, such as climbing hills, etc., **any rapid rise above this point calls for immediate action. Stop car and investigate the trouble as follows:**

First: See if radiator contains sufficient water.

Second: Examine the lubricating system, making sure the engine is receiving sufficient oil.

Third: Examine fan belt for breakage or slippage.

With plenty of water and oil and the fan in good condition, excessive heat is probably due to other causes. See p. 152, "Overheating of engine."

When the red fluid reaches the top of the circle of window on the dial, engine is dangerously overheated. Any water-cooled engine allowed to operate at this high temperature will sooner or later burn out its bearings or score its cylinders.

On cars operating without a water pump, employing the thermo-syphon system[1] **of cooling,** the water must reach a certain temperature before it will become agitated sufficiently to cause it to circulate (similar to a coffee percolator). Thus it will usually be found that on thermo-syphon cars the red column will be at **normal when about half-way up the window,** whereas on engines using a **water pump** the **normal** temperature will be **near the bottom of window.**

When using alcohol non-freeze solution, care must be used not to keep the radiator covered for too long a time, as alcohol causes boiling to occur at lower temperatures than the steam-point of water marked on the scale (see table, page 154).

Bear in mind, however, the engine should be heated as quickly as possible in order to prevent dilution of the lubricating oil, but not overheated.

Care should be taken in reading the instrument, when the car is being operated at high altitudes, for at an elevation of ten thousand feet above sea-level, steam occurs when the red column is 1/8" below the point marked "steam" on the dial (see page 116 for reason).

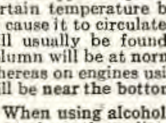


Fig. 28.

Extension or distance type of temperature indicator: This device (Fig. 28) will indicate the temperature of water circulating through the engine. The gauge is placed on the instrument panel of the car, and the bulb (E) is placed in the cylinder-head water jacket. This type is also used on motor boats, airplanes, etc., and can be used for engineering work where test of actual water temperature (or oil) in degrees is required. Instruments of this type are sometimes used to operate rheostats connnected with an *electric gauge* on the instrument panel.

Principle. The head of this instrument is of similar construction and operates on the same principle as a pressure oil gauge (see p. 162). The head, the copper tube (T), and bulb (E) are filled with treated alcohol under pressure. When the bulb (E) is subjected to changing temperatures, the alcohol expands or contracts, thus moving the minute column of alcohol forward or backward in the entire length of the tube, causing the head to operate like a pressure gauge.

Note. **The temperature often rises right after engine is shut off.** This condition is normal and is due to the heat that remains in the cylinder block after air and water circulation have stopped.

Temperature Regulation

There are four methods employed to heat a cold engine more rapidly than if these methods were not employed, as follows: **(1)** by the use of a **radiator shutter; (2)** by **restricting the water circulation** by means of a water thermostat (Fig. 30); **(3)** by **heating the carburetion mixture** (p. 106); **(4)** by **closing the hood ventilators** (p. 150).

Radiator Damper or Shutters

A radiator damper or shutter prevents circulation of air through the radiator core when the engine is cold, thereby permitting the engine to *quickly*[2] reach an efficient and economical operating temperature. Shutter Fig. 29 is **controlled by hand. A thermostatically controlled** shutter is shown on page 653.[3]

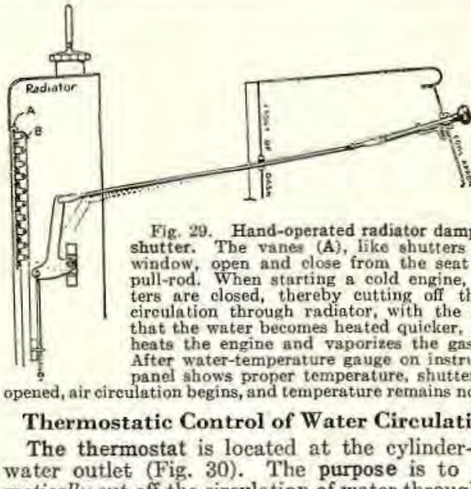


Fig. 29. **Hand-operated radiator damper or shutter.** The vanes **(A)**, like shutters on a window, open and close from the seat by a pull-rod. When starting a cold engine, shutters are closed, thereby cutting off the air circulation through radiator, with the result that the water becomes heated quicker, which heats the engine and vaporizes the gasoline. After water-temperature gauge on instrument panel shows proper temperature, shutters are opened, air circulation begins, and temperature remains normal.

Thermostatic Control of Water Circulation

The thermostat is located at the cylinder-head water outlet (Fig. 30). The **purpose** is to *automatically* cut off the circulation of water through the radiator when the water is *below* approximately 150° F.,[4] thereby permitting the water in the cylinder block and head to warm up *quicker,* and thus to make the engine more efficient in respect to power and gasoline consumption.

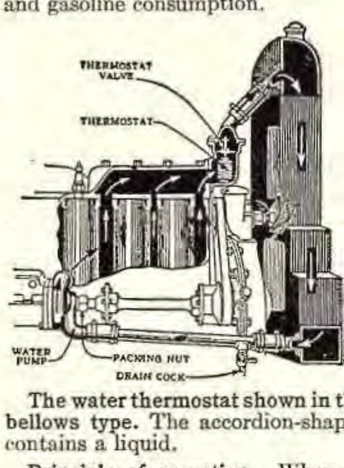


Fig. 30. View showing the thermostat valve open and normal water circulation through the radiator and cooling system. (Illustration is exaggerated in order to show the principle.)

The water thermostat shown in this example is the bellows type. The accordion-shaped metal bellows contains a liquid.

Principle of operation. When the water in the cylinder block is **cold,** or *below* approximately 150° F.,[4] the thermostat bellows is *contracted* and the thermostat valve is on its seat in a *closed* position, thereby cutting off the circulation of water to the radiator; thus the water in cylinder block water jackets and head warms up rapidly. When the water **warms up** and reaches a temperature *above* approximately 150° F.,[4] the liquid in the bellows is driven into a gas. The resulting pressure *expands* the thermostat bellows and the thermostat valve *starts to open,* allowing water to flow through the radiator. At a temperature of about 172°[4] the thermostat valve is *fully open.* A small hole in the thermostat valve provides an **air vent,** necessary when filling the cooling system with water while the valve is closed. It also permits very slow circulation when the valve is closed.

Care. Thermostats should be **removed** and **cleaned** whenever the cooling system is cleaned (see p. 739). The **vent hole in the valve** should be clear and free of obstruction. If thermostats become **inoperative,** they should be **replaced,** and not repaired. When **replacing,** the bellows end should be toward the engine.

Failure of the thermostat to close will be indicated by slow warming-up of the water and slow rise of the water temperature indicator.

[1] **The thermo-syphon** principle of water circulation is now **seldom used;** instead, a water pump, which forces the water through the cooling system, is in general use.

[2] **See pages 104, 462A, 462B, 166, why an engine should quickly reach normal operating temperature.**

[3] **Shutters on buses and trucks** are sometimes operated by a thermostat which in turn operates an air valve admitting compressed air to a small cylinder which operates the shutter.

[4] **The exact temperature** at which the different thermostats open and close varies slightly.

By-Pass Type of Water-Temperature Control

To provide water circulation during the warm-up period while the thermostat valve is closed, a **water by-pass** is sometimes provided. The Buick[1] thermostatically operated by-pass type of water temperature control is used as an example. The operation of this bellows-type thermostat and the by-pass valve is explained below.

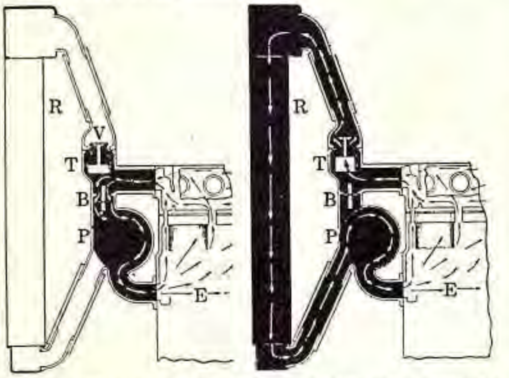


Fig. 31 (left). **When the coolant is below normal operating temperature,** it is blocked from circulation through the radiator (R) by the thermostat valve (V) as shown. The water pump (P) pressure forces the coolant through the spring-loaded by-pass valve (B) and allows coolant to *recirculate through the cylinder block and head.*

Fig 31A (right). **When the coolant has reached a temperature of 148° to 153° F.,** the thermostat valve (V) starts to open and the *circulation proceeds in the normal way* as shown. At approximately 170° the thermostat valve is fully open, relieving the water-pump pressure on the by-pass valve (B), which automatically closes.

Testing thermostat. Follow the same instructions as on page 739, except that the Buick thermostat valve should start to leave the seat at 148° to 153° F. and be fully open at a temperature not to exceed 175°.

A thermostat sticking closed, or a sticking by-pass valve either open or closed, will prevent the cooling sytsem from functioning and will cause overheating.

Bimetal-Type Water-Line Thermostat

An example of this type of thermostat is used on the Ford V-8 engine.[2] In order to reduce engine warm-up time and maintain more efficient operating temperatures, a thermostat, as shown in Fig. 32, is installed in each cylinder-head water-outlet connection held in position by the radiator hose.[3] It is designed to start opening at 145° F. and be fully open at 175° to 180° F.

The operating element in the Ford thermostat is a bimetal strip composed of two layers of co-operating metals of widely different expansion. The two different metals are permanently fused together. With temperature change, the tendency is for one to elongate faster than the other, so that a bending or deflection results. This bimetal in the form of a coil is anchored at one end, and the other end is attached to the butterfly valve. Thus, as the water temperature reaches 145° F., the butterfly gradually opens.

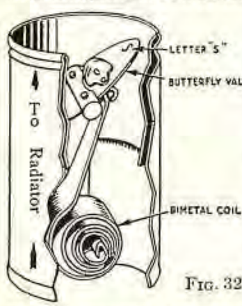


Fig. 32

When for any reason a thermostat becomes inoperative, the following should be checked: (1) Thermostats installed upside down. (2) Dirt and pieces of rubber hose getting imbedded on edge of butterfly, holding valve either open or closed. (3) Failure to expel all air from cooling system when filling radiator. (This is accomplished by running engine several minutes and then adding additional water to cooling system.) (4) With low-boiling-point anti-freeze solutions, it is important to watch the l'quid level in the radiator and to replace the evaporated solution.

Thermostats for Hot-Water Heaters, Adjustable, Etc.

High-reading thermostats. In areas where extreme cold weather is encountered, it may be necessary to instal a special high-reading thermostat in order to secure satisfactory results from a **hot-water heater.** Be sure to use an **anti-freeze** solution whose boiling-point is higher than the temperature at which it operates.

Thermostats can be obtained which are **adjustable,** that is, the temperature can be varied. Thermostats are commonly known as the **insert** type and the **hose-line** type.

Radiator Cover, Louver Openings, and Hood Ventilators

Radiator covers. Where radiator shutters are not provided, a cover over the cooling surface of the radiator during cold weather is advisable **if properly used.** The **purpose** is to prevent the fan from drawing cold air through radiator core, and thus to assist in heating engine more quickly. The cover should be left over the front of the radiator until the engine becomes warm, then removed. During extremely cold weather it may be advisable to remove only the upper half, because the hot water having just passed through the radiator on its way back to the engine is at its lowest temperature at the bottom of the radiator. The idea is to get the engine heated as quickly as possible to prevent dilution of the lubricating oil, but not to permit overheating, which is likely to occur if radiator is entirely covered for too long a period. When *volatile* anti-freeze solutions are used, care must be exercised in this respect. See pages 149, 153. A great many operators merely place a piece of *cardboard* over the lower front of the radiator.

Louver openings can be protected during cold weather from the inside, by covers made for the purpose, and thus assist in retaining warm air under the hood.

Hood ventilators on each side of the hood can be opened or closed by hand, according to the temperature. They can also be opened automatically by thermostats, controlled by the air temperature under the hood.

CARE OF THE WATER-COOLING SYSTEM[4]

Water

Water for the cooling system should be as nearly neutral as possible. Soft water is better than hard water,[5] for reasons stated on page 151. Rain water is usually soft and is desirable for cooling systems. Avoid water containing lime, alkali, or impurities. Where water is alkaline, acid, or saline, a rust preventive (inhibitor) can be added, as explained on page 151. Before adding however, the cooling system should be thoroughly cleaned (see pp. 151, 739). In localities where pure water is not easily obtained, it is well to strain it through muslin.

Water-Circulating Pump

Check the water pump for air or water leaks, end-play, worn or scored shaft, and worn bushings. The first condition can usually be remedied by tightening the packing nut (not too tight, however—see pp. 151, 735), that is, if water pump has a packing nut. The other conditions, if present, will necessitate the removal of water-pump assembly and an overhaul or replacement.

Fan

The fan requires no particular attention, except lubricating. Sometimes the belt gets loose and causes the fan to slip and does not turn as rapidly as it should, causing overheating of the engine. If this happens,

[1] **Compiled from** *Buick Shop Manual* (1937).

[2] **Compiled from** *Service Bulletin* of the Ford Motor Company.

[3] **On** 1937 cars and trucks they are installed in cylinder-head outlet opening.

[4] **See** p. 690 under "*Anti-Freeze and Cooling System*" for free instructive literature on *servicing the cooling system.*

[5] **To tell if water is hard or soft,** a simple test is to take a quantity in the hands and go through the motion of washing. If it is difficult to rub the hands together, the water is hard.

loosen the **nut which holds the eccentric arm of the fan,** raise the arm slightly, and retighten the nut. This will tighten the belt. Note that this nut frequently has a left-hand thread. Do not tighten too tight, as you are liable to crack the fan support. See also Figs. 8A., 9, and 36.

Where the fan, water pump and generator are driven by a conventional "V" type endless composition belt, the drive being off the front end of the crankshaft, the generator may be moved in or out to tighten or slacken the belt. **Too tight a fan belt** may pull the water pump impeller shaft out of alignment and causes excessive wear on the bearings and eventual leaks. *Follow car manufacturer's instructions for adjusting.* See p. 735 for adjusting, repacking, and lubrication of water pumps.

Cleaning and Care of the Cooling System

The cooling system should be flushed out in the spring and fall (the latter before adding antifreeze solution) to remove loose particles of rust, scale, and sediment, which, if allowed to remain, may **clog** the water passages of the radiator and prevent the heat of the engine being properly dissipated, resulting in **overheating.** Hard water (such as lime water) will cause a hard scale to form in the water passages, which impairs the efficiency of the cooling system in the same manner as does rust. Lime is present in nearly all water, more in some than in others.

The cleaning process should include the use of a good cleaning solution to loosen rust, scale, and grease by a chemical and solvent action before flushing (see p. 739). Use care in selecting cleaners, as some may contain acids that are too strong. *Follow the manufacturer's instructions.*

Where engines are equipped with **aluminum cylinder heads** attention is called to the fact that **caustic soda and alkaline solutions** react very readily on aluminum and aluminum alloys, and should **never be used.** DuPont No. 7 or "Eveready" radiator cleaners are recommended for flushing all kinds of engines, including those equipped with aluminum cylinder heads. There are other good cleaners.

Rust preventives can be obtained which are added to the water in the cooling system for the purpose of **preventing,** not removing, the accumulation of rust and scale in the radiator and cylinder block, and should be put into the cooling system of new cars and added when the cooling system has been flushed. When calling for rust preventive (**inhibitor**) at auto supply dealers, state if it is to be used in engines with aluminum cylinder heads.

Machinist's soluble cutting oils and emulsifying oils which have been properly prepared may be used to prevent rust. **Insoluble oils will deposit in the cooling system, thereby retarding heat radiation.** Approximately 3/4 to 1 pint to a 5–10 gallon cooling system and 1/2 to 3/4 pint for cooling systems of less capacity. Too much will have a tendency to penetrate through the connections.

The cooling system connections should be made leak tight, especially when adding anti-freeze solutions, in order to prevent leaks and loss of the anti-freeze solution. **Some of the places to check are:** (**1**) see that drain cocks are closed and tight; (**2**) tighten cylinder head nuts and cylinder block water jacket plate cap screws (on some engines). Engine should be warm; (**3**) tighten hose clamps (also on the hot water heater, if one is on the car). Swollen or disintegrated hose should be replaced, as the pump may build up sufficient pressure in forcing the solution through restricted hose to cause leaks in the cooling system, which will disappear when the restriction is removed; (**4**) draw up water pump packing nuts but not so tight that there is danger of binding the pump shaft. If the water pump is supposed to be lubricated with grease and the bearings or packing is in close contact with the hot water, apply *non-soluble waterproof pump grease* (*always follow the manufacturer's instructions*). Some lubricants become liquid when hot and may be taken into the cooling system, thereby coating and insulating the radiator and jackets, which retards dissipation of heat. High melting-point greases tend more to clog the radiator tubes. For these reasons, *do not over lubricate* (see also, p. 735); (**5**) tighten water-pump assembly; (**6**) tighten radiator hold-down bolts; (**7**) if radiator leaks or overheats, it is best to take it to a *radiator specialist,* who will determine if it is best to repair or replace the radiator core.

Overheating and consequent overflow through the radiator overflow pipe can be due to one or more of the causes as mentioned on page 152.

Cleaning a muddy radiator: If the air spaces of the radiator become clogged with mud, do not attempt to remove the mud with a screwdriver, wire, or other metal instrument. Instead, soften the mud with water. The best way is to wash the radiator by flushing a stream of water from a hose through it from the rear. **In doing this, take care not to let water get into the ignition distributor, magneto, or electrical system, which** is likely to be short-circuited in that way.

Hose Leaks

The rubber hose (H, Fig. 34) **and its connections** (C) are often a source of leaking.

Fig. 34. A good plan, especially where anti-freeze is being added, is to use a hose or gasket cement, obtainable at auto supply dealers, on the ends of the pipes before placing the hose on them. Shellac can be used but may necessitate renewal of hose when removed.

When the hose is old and worn it will become ragged-looking or swollen on the outside and may collapse and restrict circulation and shed its rotted lining, causing clogging of the radiator cores which is difficult to remove. The *reverse flushing method* (p. 739) may remove it, if not, the radiator will have to be disassembled. Hose should be replaced when it shows signs of deterioration. A copper coil type of **stiffener spring is now placed inside of hose on many cars.**

Cylinder Leaks

Cylinder leaks. A slight leakage of water from the jacket into the cylinder may be caused by a crack or sand hole in the casting, but more usually will be found to be simply a defect in the seating of the gasket. See legend under Fig. 66, page 733.

A crack in the cylinder, when on the inside, is difficult to locate. Its action may be of such a nature as to be only operative when the engine is at full working heat (due, of course, to the expansion). It is generally accompanied by misfiring and boiling, the former owing to leakage of water into the cylinder, and the latter owing to the hot gases (at a very high temperature) being forced into the water-jacket.

To test, fill the radiator entirely to top of cap, run the engine until it is hot, then stop engine and turn it over by hand against the compression in each cylinder. If there is a crack, bubbles will appear at the cap. Thus, by noting the compression of each cylinder, the defective one can be located.

Slight leaks inside of the cylinder have been remedied by rusting, if the hole is very small. See page 723.

When replacing a cylinder head it is good practice to install a new gasket. Do not remove a cylinder head while engine is hot; drain and allow engine to cool to avoid springing or warping head.

If the gasket is **copper-asbestos or steel-asbestos** some mechanics coat both sides with light cup grease or engine oil, others *immerse it in water* fifteen or twenty minutes prior to applying, in which case the grease or oil is not used. Other mechanics do not think it necessary to do either if the head and block are *clean.* The water immersion, however, is recommended, particularly if the head happens to be slightly warped, which condition shows black on gasket when head is first removed. Always look a gasket over carefully to see that it has not been damaged in any way. All cylinder head nuts should be drawn down evenly and tightened[1] in the order shown in Fig. 66, page 733, or *as recommended by the manufacturer*. Run engine for a time, and then **tighten again**. Operate engine for about 300–500 miles and do the **final tightening**.

Cast-iron cylinder head nuts are retightened while engine is **warm**. **Aluminum-alloy cylinder heads**, according to some car manufacturers' instructions, should be retightened when warm; others recommend to retighten while **cold**. Differences in design characteristics of engines *may* account for the difference of opinion; therefore, **follow car manufacturers' recommendations**. Failure to retighten after gasket has been compressed may result in a gasket leak. **Aluminum-alloy cylinder heads**, it is claimed, because of their *rapid heat dissipation*, **permit higher compression-ratios, increasing power and effecting economy in fuel consumption.**

Gaskets on water plates, on the side of some engines, should be tightened or renewed if there are leaks. This gasket material is usually Vellumoid, Seigelite or similar material. Gaskets on the backing plate of water pumps should always be replaced with new ones when removed.

Radiator Leaks

Leaks in the radiator are often hard to reach. They are detected by the steam arising or from the water that flows through the leak and down the outside of the radiator.

Testing: The usual method of determining a leaky radiator is by noticing water dripping from it and when the car owner complains of adding water too frequently. To detect all leaks and to locate them, the radiator should be submerged, see page 737.

Small leaks in radiators: There are several preparations which can be obtained of auto accessory dealers, which, the manufacturers claim, will stop small leaks temporarily until the radiator can be repaired; some claim to be able to stop small leaks permanently. Some of these preparations are **cements**, which are pasted externally on a leak and harden. Some others are in **liquid or powder form** which are placed internally in the radiator when the water is hot. The solution is supposed to pass out of the leak in the radiator and in so doing, is exposed to the air and oxidizes or hardens and thus closes the leak. It is also claimed that some of these preparations are particularly suited to correcting small leaks around the cylinder block side plates. Another method is by means of creating a slight vacuum in the radiator and applying with a brush around the leak, liquid solder, which is drawn through the opening making a seal. The cooling system is drained when making repair.

Quoting from the book mentioned in footnote 3, page 740, we find it states: "Soap shaved into a radiator will stop almost any leak temporarily. The repairman can effect this repair and tell the owner at the same time it will necessitate the radiator being boiled when it is brought for repair."

One manufacturer states that ordinary bran mixed with water will stop a slight leak. The writer has never tried this. Another manufacturer advises against the use of bran, meal, or patented preparations. **The best plan is to have the radiator soldered.** See index under "Radiator repairs."

Paint for radiator fins can be made from drop black ground in Japan and gold size, thinned with turpentine. See Index under "Painting radiator."

Water Temperature

Water boils at 212° F. at atmospheric pressure. Therefore an automobile cooling system is designed to maintain a water temperature less than 200° under average running conditions. This leaves quite a margin before the boiling-point.

If the water is kept **too cool**, the fuel mixture will not be properly vaporized, with results mentioned on page 104. If permitted to become **too hot**, the mixture will become too lean, with results as explained on page 106 and Addenda page 39 (footnote). The **best water temperature** to maintain varies with different engines.

When driving through mud and deep sand or up long hills in extremely warm weather, the water may steam. This condition should not be continued for any great length of time. If there is **persistent overheating** when the engine is working under ordinary conditions, find the cause of the trouble and remedy it; otherwise **damage will result** to the bearings and pistons.

When the radiator steams, let the engine **cool gradually.** When cooled to nearly operating temperature, start the engine and run at idling speed. Add cold water very slowly. This procedure will **avoid** the possibility of **cracking** the cylinder head or block and **warping** the valves. If water is **frozen,** see page 153.

Note: Permitting the engine to idle long enough for the valves to cool before turning the ignition "off" will materially lengthen the life of the valves when the engine is operated under sustained high speeds.

To determine if steaming is due to stoppage of circulation, feel the radiator. It should be slightly hotter at the top than at the bottom; but if clogged, there will be a pronounced difference in temperature. **The remedy then is to clean the circulation system.** See page 739.

OVERHEATING OF ENGINE; SOME OF THE CAUSES

1. **Insufficient water supply** in the cooling system.
2. **Radiator.** Core passages clogged; air passages clogged with dirt or insects.
3. **Radiator shutters** stuck.
4. **Cooling system.** Engine cylinder block or hose connections clogged; water thermostat faulty.
5. **Ignition.** Spark (ignition) retarded too far; timed too late; (see pages 304, 631, 291 explaining why); automatic advance stuck; ignition missing, which may be due to defective spark plugs, condensers, coils, interrupter points or high tension wire leaks. If engine is misfiring, it is necessary to open the throttle much wider, and this, with retarded or late spark timing, tends to cause overheating.
6. **Carbon** in the cylinder combustion chamber and on piston and valves. Take off cylinder head and remove. Do not scratch cylinder heads or pistons, as small projections may gather carbon, become incandescent, and cause pre-ignition and pinging. See also footnote, p. 763.
7. **Pistons, piston rings, piston pins and bearings** fitted too tight after reconditioning engine will cause overheating as will thick piston rings in shallow grooves.
8. **Driving in low gear.** The engine should not be raced when driving in low gear, and the spark should be well advanced, because the engine speed is comparatively high. The high speed of engine in low gear and slow forward motion, which does not provide sufficient air for cooling the water, overheats the engine. Do not use low, when high speed can be used without strain.
9. **Valves.** Timing incorrect. The exhaust valve may not open early enough to discharge all of the burned gas. Leaking valves.
10. **Carburetion.** Incorrect mixture, caused by improper proportions of air to gasoline, which in turn are sometimes caused by driving with carburetor choke (air valve) closed too far, automatic choke stuck, air cleaner badly clogged. See pages 117, 118, 462A, 462B.
11. **Insufficient or poor quality of oil.** Lack of oil will cause such friction between the pistons and the cylinder walls that the engine will overheat and the pistons may stick, likewise the bearings and other moving parts. Poor oil, due to its probable admixture of compounds not derived from crude petroleum, fails to provide the oil film to separate friction surfaces and to transmit heat (see page 166). Use *oil recommended by the manufacturer*—it costs less in the long run.

[1] **Torque-indicating wrenches** should be used for tightening, to obtain **proper and uniform pressure**—see pages 733, 691. Charts which accompany torque wrenches indicate that it is general practice to give *less* pressure in tightening aluminum-alloy cylinder-head nuts than on cast-iron heads. **Follow manufacturers' recommendations** and tighten "*cold*" or "*warm*," and in the *order*, and exactly the *pressure* specified by the manufacturers.

12. **Racing the engine.** Close the throttle when the clutch is disengaged, and so save gasoline and prevent overheating.

13. **Clogged muffler.** Too rich a mixture or too much oil will deposit soot in the muffler and by preventing the escape of the exhaust, will cause overheating. Clean the muffler by disassembling it.

14. **Water frozen—steams.** Water usually freezes at bottom of radiator first, thereby stopping the circulation. It then begins to steam excessively. It would appear that the steam or heat would thaw it out and start the circulation again, but such is not the case. When the water freezes, do not run the engine to try and start circulation, as the fan draws in cold air and only assists in keeping it frozen. The best plan, if possible, is to get it into the nearest garage and turn warm water on the bottom of the radiator, having first *carefully* removed the radiator cap and opened the radiator drain cocks. If too far from a garage, it is *sometimes possible to thaw out the radiator* by entirely covering same so that the fan will not draw in cold air, and run engine at idling speed.[2] When cold water is added, follow instructions, page 152.

14a. **When the engine overheats and steams; to tell if it is frozen or due to something else, see page 152.**

15. **Fan not working properly.** A broken or a loose and slipping belt will not rotate the fan fast enough to draw a cooling current of air through the radiator. This will tend to cause overheating, particularly at high speeds or when in low gear. Tighten or replace the belt. If the fan blades are bent to an improper angle, do not bend them in order to draw more air, as this may throw fan out of balance unless extreme care is used. The safest method is to replace the fan.

16. **Poor water circulation** may be due to low water, clogged condition, sticking water thermostat, faulty water pump, etc. Leaks may lower the level. The clogged condition may be due to rust corrosion or a loose flap of rotted lining inside of the hose, impeding the flow of water.

16a. **Water losses from cooling system may be due to:** improper seating of radiator cap, air leaks into system, cylinder-head gasket leak when under power, overheating. Overheating may cause the water to boil and pass out overflow pipe; and this may be due to a weak thermostat, retarded spark, improper valve-timing, dirty air-cleaner, clogged radiator, or some of the other causes mentioned under "Overheating."

17. **Broken pump shaft.** It is difficult to tell whether or not a circulating pump is working. Remove the radiator cap and see if water is circulating while running the engine. The pin through the pump shaft and impeller may be sheared off, yet the pump shaft would continue to revolve. Examine pump for broken or cracked blades and air leaks.

18. **Brakes dragging.** This would call for an increase of power from the engine. Examine the brakes with rear wheels jacked up.

19. **Bearings.** If the engine is new or just overhauled, the bearings may be too tight. Put in plenty of oil and run until loosened up.

20. **Radiator clogged with mud or dirt,** or an obstruction in front of the radiator, thus preventing passage of air.

Q.: How is the engine on an automobile fire truck cooled when the engine is running continuously for long periods with the car standing, which is often the case at a fire?

Ans.: There is a cooling line from the discharge side of the main pump directly into the water manifold. This is a ⅜" line, and is controlled by a gate valve which enables the operator to keep the engine at any desired temperature. An overflow on the radiator allows this cooling water, which amounts to 8 to 10 gallons per minute, to pass off.

ANTI-FREEZE SOLUTIONS FOR COOLING SYSTEM

In winter, a water-cooled engine must be carefully guarded against freezing, for if the water freezes in any part of the system it will cause the breakage of piping or radiator, or crack a water jacket. When the engine is running, the water is kept warm; therefore the danger is not as great, particularly if the cooling system is equipped with a radiator shutter or cover or a water thermostat, or both. It is advisable, however, to take no chances, as freezing can occur even with the engine running.

One method to prevent the water from freezing during cold weather is to drain the water out of all parts of the system,[3] drain cocks being provided for the purpose at the lowest point of the system, usually at the bottom of the radiator.

If drain cocks are also provided at the lower edge of the water jackets of the engine cylinders, they should also be opened. Engine should be warm when draining; and, after draining, run it for a minute or so to make sure all the water has been removed.

The best method to prevent the water from freezing is to use an anti-freeze. Commercial materials generally available for preparing anti-freeze solutions are: denatured alcohol (188, 200 proof), methanol (synthetic wood or methyl alcohol), glycerine, and ethylene glycol (Prestone).

Other anti-freeze solutions. Salt solutions, such as calcium or magnesium chloride, sodium silicate, etc., and other solutions such as honey, glucose, and sugar solutions, oils,[1] and kerosene are not satisfactory for use in automotive cooling systems.

Alcohols

Alcohols are extensively used, and those in general use for preparing anti-freeze solutions are denatured alcohol and methanol. **Denatured alcohol** is an ethyl alcohol to which has been added a denaturant to make it unfit as a beverage. **Methanol** is generally obtained from the destructive distillation of wood, or made synthetically. Methanol is poisonous when taken internally.

Many alcohols are now sold in different concentrations and under various trade names: and, owing to this fact particularly, the proportions to use and instructions for its use, usually on the container, should be carefully followed. The higher concentrations require less material for protection.

The various alcohol anti-freeze materials available in most localities are **not injurious** to the cooling system, and many of them contain special corrosion inhibitors, an added advantage.

Alcohol solutions are volatile and evaporation losses will occur, the greatest loss being when it is permitted to boil. **Boiling is usually caused by:** hard driving on warm days; high opening water thermostats, as explained on page 739; using a mixture more highly concentrated than is necessary to assure protection; sudden stops after hard driving, at which time the thermal expansion of the solution may cause it to pass out of the overflow pipe. Long-continued idling will also cause an increase of temperature.

Alcohol solutions accidentally spilled on the car finish should be washed off immediately with plenty of clean, cold water to prevent damage.

[1] Oil is sometimes used in heavy-duty tractors; but a cooling system designed to use oil, instead of water, requires, in general, a more rapid rate of circulation on account of the relatively low heat capacity, and larger or less obstructed passages on account of the relatively high viscosity of most oils. See also p. 155 "Kerosene for cooling."

[2] Be sure there is sufficient water in the cooling system to avoid damaging engine. [3] Providing of course engine will not be run.

Loss of solution through leaks, boiling, or evaporation of the alcohol will **weaken** the solution.

In order that the solution may be kept at the proper strength it will be necessary occasionally to add alcohol until the desired **hydrometer reading** of the specific gravity of the solution is obtained. Automobile accessory houses sell a **specially made hydrometer for this purpose,** and it is a good idea to obtain one rather than guess (see page 1041).

When testing, it should be tested at the temperature for which the hydrometer is calibrated, and the correct hydrometer for the solution should be employed in testing.[1]

If a hydrometer is not available, replace losses with alcohol, or in accordance with instructions given by the manufacturer.

To prevent loss of solution from thermal expansion when the engine warms up, regardless of what anti-freeze mixture is used, the radiator should not be filled to the top but should be below the level of the overflow pipe.[2]

Check solution level after engine has been warmed up to normal operating temperature but with engine not running. Do not add water if the solution can be seen.

The following table gives the proportions of water and denatured alcohol (188 proof) for cooling systems of various capacities, and the approximate temperature to which mixtures may be subjected without freezing. The approximate specific gravity and boiling-points are also given.

Total Capacity of Cooling System	10° F ABOVE ZERO		0° F ZERO		10° F BELOW ZERO		20° F BELOW ZERO	
	Pints Water	Pints Alcohol	Pints Water	Pints Alcohol	Pints Water	Pints Alcohol	Pints Water	Pints Alcohol
16 pints (2 gallons)	11	5	10	6	9	7	8	8
24 pints (3 gallons)	17	7	15	9	14	10	12	12
32 pints (4 gallons)	23	9	20	12	18	14	16	16
40 pints (5 gallons)	29	11	26	14	23	17	20	20
48 pints (6 gallons)	35	13	31	17	28	20	24	24
Percent of Alcohol and Water	73%	27%	65%	35%	58%	42%	50%	50%
Specific Gravity of Mixture	0.9691		0.9592		0.9486		0.9345	
Boiling Point of Solution	188°		185°		183°		181°	

The specific gravity figures above are obtained when the solution is thoroughly mixed and at a temperature of 60° F. An ordinary glass dairy thermometer can be used to test the temperature; see page 1041 for hydrometers (F. means Fahrenheit).

The boiling point figures are approximate. Also bear in mind that when a car is operated in high altitudes, for example at ten thousand feet above sea-level, the solution will boil at a lower temperature (water at sea-level boils at 212° F. and at 10,000 feet altitude, at 193° F.; see page 116).

Heat is very desirable and necessary for the efficient operation of the engine, and an engine should be **heated up as quickly** as possible to prevent dilution of the lubricating oil; but don't overheat.

It has sometimes occurred that car operators have permitted their engine to run with radiator covered until a considerable portion of the alcohol boiled away. When the engine cooled down, the solution froze, owing to the decrease in amount of alcohol remaining.

Glycerine and Water Solution

Glycerine raises the boiling point of the solution and does not boil away on warm days, neither does it evaporate, and the engine can be run at a higher temperature, and so long as none is lost by leakage, the addition of water is all that is necessary, as the glycerine itself will not evaporate. If there are **leaks,** replace both the glycerine and water.

Although glycerine does not freeze solid, solutions containing extra large percentages of glycerine may have a tendency to become thick at low temperatures, especially if not **thoroughly** mixed before putting into the cooling system.

The following table gives the proportions, by volume, of glycerine and water to mix for various freezing points, and also approximate boiling points of the solution.

Glycerine	Water	Freezing Point	Boiling Point
0%	100%	32° F. above	212°
30%	70%	12° F. above	217°
40%	60%	2° F. below	221°
45%	55%	8° F. below	223°
50%	50%	15° F. below	225°
55%	45%	20° F. below	227°

Glycerine and water should be thoroughly mixed in a separate vessel and stirred before putting it into the cooling system.

Example: Suppose a solution was to be mixed for a 5-gallon capacity radiator (40 pints), with a freezing point of 2° below zero. The table gives 40 per cent glycerine and 60 per cent water; therefore 40 per cent of 40 pints (.40×40) = 16 pints of glycerine, and (40−16) = 24 pints of water.

It has been said that glycerine will injure the rubber water hose. Experiments show that this is not altogether true. Glycerine tends to reduce swollen rubber to normal size; hence, tightening of the hose clamps is usually necessary to insure against leakage at these points.

It is a good plan to put on new water hose before filling the radiator and to use a good gasket cement or shellac on the inside of the hose connections to prevent seeping at the joints. All water-hose connections, pump packings, cylinder-head and other gaskets should be tightened at the time of filling and then be inspected again a day or so after.

The glycerine referred to above is the 95 per cent chemically pure (c.p.) 1.26 specific gravity or 30° Baumé (drug store grade). It must be **mixed thoroughly** before putting it into the radiator.

Radiator glycerine anti-freeze, made under the approved formula of the Glycerine Producers Association, termed "G.P.A. radiator glycerine," contains a rust inhibitor and is ready-mixed so that it can be introduced directly into the radiator. The proportions differ from the glycerine tables shown on this page.

Ethylene Glycol

Ethylene glycol (Eveready Prestone) has a higher boiling-point than water and will not evaporate at engine-operating temperatures. The material sold in the United States for anti-freeze purposes is chemically treated to reduce the normal rusting and corrosion action of water. Before using, it is advisable to flush and clean the cooling system and to tighten all hose connections and cylinder-head gaskets to prevent leakage.

The following table gives the amount of ethylene glycol required (in gallons) for various capacity cooling systems to protect freezing to the temperature points shown below. (If car is equipped with a hot-water heater add 1/4 gallon.)

Eveready Prestone Required in Gallons

Cooling System Capacity In Gallons	½	¾	1	1¼	1½	1¾	2	2¼	2½	2¾	3
2¼	14°	0°	−21°	−50°							
2½	16°	4°	−12°	−34°	−62°						
2¾	18°	8°	− 6°	−23°	−47°						
3	19°	10°	0°	−15°	−34°	−57°					
3¼	21°	13°	3°	− 9°	−25°	−45°					
3½		15°	6°	− 5°	−18°	−34°	−54°				
3¾		16°	8°	0°	−12°	−26°	−43°				
4		17°	10°	2°	− 8°	−19°	−34°	−52°			
4¼		18°	12°	5°	− 4°	−14°	−27°	−42°			
4½		19°	14°	7°	0°	−10°	−21°	−34°	−50°		
4¾		20°	15°	9°	2°	− 7°	−16°	−28°	−42°		
5			16°	10°	4°	− 3°	−12°	−22°	−34°	−48°	
5¼			17°	12°	6°	0°	− 9°	−17°	−28°	−41°	
5½			18°	13°	8°	2°	− 6°	−14°	−23°	−34°	−47°
5¾			19°	14°	9°	4°	− 3°	−10°	−19°	−29°	−40°
6			19°	15°	10°	5°	0°	− 8°	−15°	−24°	−34°
6¼			20°	16°	12°	7°	1°	− 5°	−12°	−20°	−29°
6½			21°	17°	13°	8°	3°	− 3°	− 9°	−16°	−25°
7				18°	15°	10°	6°	1°	− 5°	−11°	−18°

Percentages of Eveready Prestone in solution with water: 20 per cent protects to +16°; 25 per cent to +10°; 30 per cent to +4°; 33 per cent to 0°; 40 per cent to −12°; 50 per cent to −34°; 60 per cent to −62° maximum protection.

[1] Hydrometers can be obtained of E. Edelmann & Co., 2332 Logan Blvd., Chicago, or of auto accessory houses.

[2] **Some manufacturers give instructions to fill until water level is visible through the filler neck and then to stop.** Owing, however, to the arrangement of overflow pipe, baffle plates, etc., being different on some cars, it is advisable to *follow the manufacturer's instructions.* Some cars have a pressure-operated vent valve fitted to the radiator filler cap. **Where hot-water heaters are used,** be sure to open the vent valve on the top of the heater, with engine running, in order to remove the air. See p. 690 under "*Anti-Freeze and Cooling System*" for free instructive literature on *servicing the cooling system.*

Before Adding Anti-Freeze

Before adding anti-freeze, the cooling system should be **flushed** thoroughly, as explained on page 739. This is also a good time to put on **new hose** connecting radiator to engine and water pump. The **cooling system connections and water pump should be made leak tight** in order to avoid the **loss** of anti-freeze. See page 151, giving some of the places to check. If there are **leaks** or signs of leakage in the **radiator core,** have them soldered. See that **fan belt** is properly adjusted and replace if necessary. Check **water pump** (see pp. 151 and 735). Checking as above is usually done when engine is at operating temperature.

Condenser

With this patented condensing device it is possible to restore vapor to liquid form when using alcohol and water solution as an anti-freeze cooling medium. A condenser of simple construction is attached to the frame and is connected by a tube to the overflow pipe which runs from the upper tank of the radiator.

Alcohol vapor driven out of the solution by heat, as well as any water vapor, **is restored to liquid form** in the condenser. When the radiator gets cold, the vacuum produced by the contraction of its contents automatically causes the surplus liquid in the condenser to return under atmospheric pressure to the radiator. The filler cap on radiator should be kept air tight. Before filling cooling system with non-freeze solution, drain condenser.

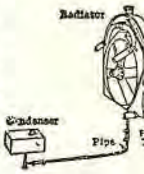


Fig. 37

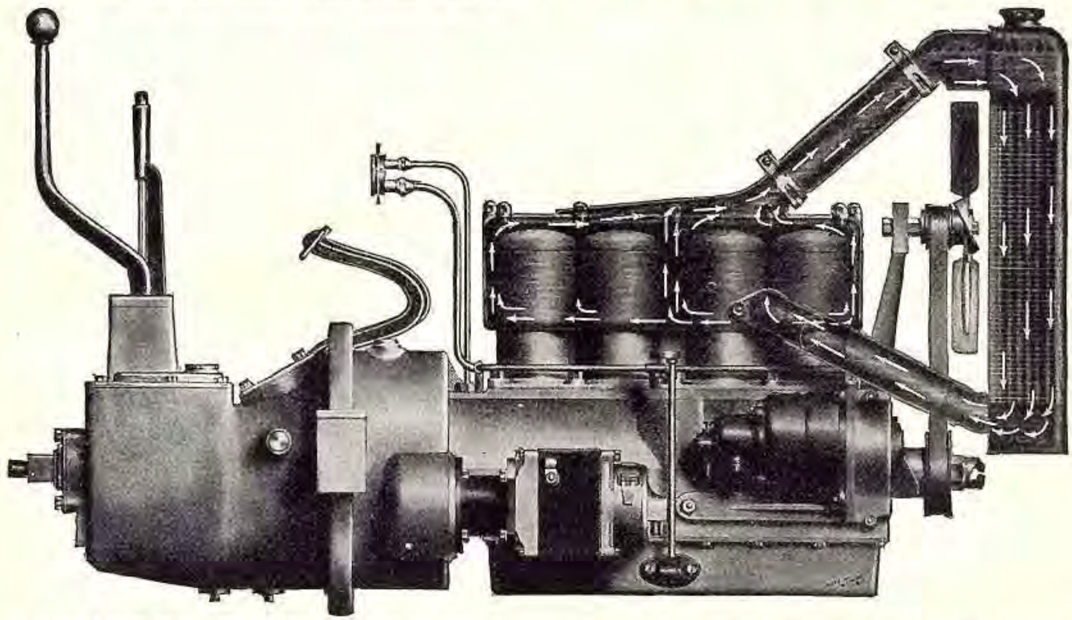
Kerosene for Cooling

Kerosene (also oil, see footnote, p. 153) is sometimes used in extremely cold climates on heavy-duty engines equipped with water-circulating pumps. It could not be used with the thermo-syphon system.

Objection to kerosene is the odor of heated kerosene. When heated, kerosene evaporates and is liable to cause a fire if near a flame; on warm days in winter there is a tendency for the engine to heat on account of difference in the coefficient of heat of kerosene and water or alcohol; kerosene rots radiator tubing and will also deposit a greasy mist over the car. Gas is also liable to form and cause expansion and bulging of the radiator. The boiling-point of kerosene is much higher than alcohol. See page 1050.

EXAMPLE OF A THERMO-SYPHON WATER-CIRCULATING SYSTEM

Although thermo-syphon water circulation is now seldom used, the principle is shown below in order that the reader can make comparison with the "forced water-circulation" system referred to on page 146, Fig. 4.



Internal view of a thermo-syphon principle of water circulation system. Principle: When the water is heated it rises, and passes from the top of the water jacket at the top of cylinders, through the upper rubber hose connection, to upper tank of radiator, through radiator cores, whence it is **cooled** by air drawn through the radiator openings by the fan. The cooled water then passes to the lower radiator tank, up through lower hose connection, to lower part of cylinder water jackets.

The word **"thermo"** pertains to heat and the word **"syphon"** refers to drawing off a liquid from a higher to a lower level.

AIR COOLING

The object of cooling is to remove the excess heat from the cylinders. This is accomplished by the air direct, without the use of water.

Air-cooled engines usually have small-bore cylinders.

The different methods of air cooling are summed up as follows:

(1) By having a large radiating surface by means of cast or copper flanges or gills, inserted pins, or tubes.

(2) By using extra large exhaust valves, so as to cool the combustion space between power strokes.

(3) By large radiating surfaces in multiple-cylinder engine.

(4) By the use of auxiliary exhaust ports, combined with surface radiation.

(5) By forced draught of air circulating through an air jacket around the cylinder.

A cylinder with radiating flanges is shown in Fig. 38. When in motion, the current of air blowing against the flanges drives the heat away. This principle is used extensively on motorcycle engines.

The "copper-cooled" cylinders are fitted with copper flanges (copper radiates heat quicker) and a draught of air is circulated around cylinders.

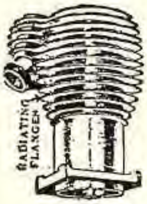


Fig. 38

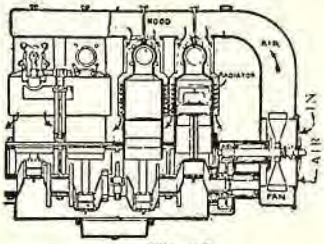


Fig. 39

A forced draught air-cooling system is shown in Fig. 39, formerly used years ago on a prominent make of car. With this system the circulation of air was forced through jackets placed around each cylinder, open at the bottom and top, being connected to a pipe from a centrifugal air blower or fan. The forced air passed the radiator flanges, and out at the bottom.

The Franklin air-cooled engine is a very successful engine for automobile pleasure cars employing the air-cooled method. The six cylinders are 3¼" bore and 4" stroke, giving a formula horsepower of 25.3.

By referring to the illustration (Fig. 40), the path of the air is shown, first through the hood, thence over and down through the air jackets. The air is then deflected downwards and out through the fly-wheel blades.

Vertical steel fins are made integral with the individual cylinder casting, by having the iron poured around the strips of steel. Very light aluminum jackets guide the air draught downward from the heads of the cylinders.

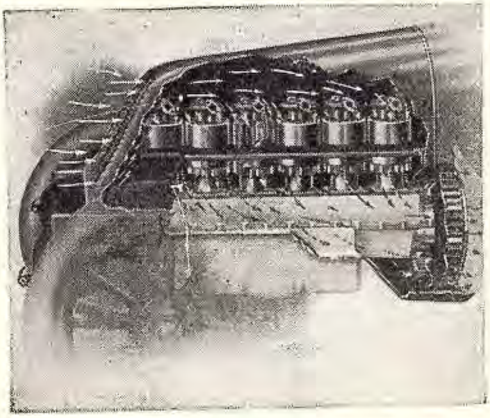


Fig. 40. Direct air cooling of the Franklin. The fly wheel is the only moving part of the cooling system. This is termed a **"draught system."** The later Series 10 car uses a **"blast system"**; the air being drawn by a fan placed in front.

Note the vanes in the fly wheel, which create a suction equal to 2,200 cubic feet every 60 seconds; a continuous flow of air literally wiping the heat away. It is stated that the heat on a Franklin engine is about 350° Fahr. (see Fig. 12, page 107, for Franklin exhaust-heated inlet manifold). This heat is shut off after the engine is warmed up.

The Franklin at one time employed **auxiliary exhaust valves** to assist in dispelling the heat of explosion from the cylinder as rapidly as possible. This method, however, has been discontinued.

Another popular make of air-cooled car is the Holmes.

HEATING A CAR

There are three methods of heating a car as explained below:

(1) hot water; (2) exhaust gas; (3) hot air.

Fig. 41. Hot-water method of heating a car.

The hot-water method is shown in Fig. 41. This method can be used only where there is a forced or pump-circulation system. Connections are made with the circulating system at the top of the rear cylinder. The water circulates through the heater, whence it returns to the bottom of the radiator.

The heater is made of regular water pipe, and the housing of aluminum or light cast iron. The floor is cut away, allowing the surface of the heater to be flush with the floor. The top plate, made of aluminum, is then placed over the heater box.

The exhaust method for heating is to utilize the exhaust gases instead of water. In this instance the pipes would be connected with the exhaust pipe instead of with the water pipe. Only one side, the inlet, would be connected and an outlet is provided for the emission of the gas.

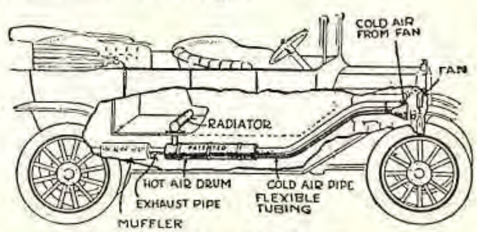


Fig. 42. Hot-air method of heating a car.

The hot-air method is shown in Fig. 42. This example illustrates the Brickly (patented) method. The air is taken from the fan through a funnel opening, and a flexible metal hose drives it through a metal jacket 24 to 30 inches long, which covers the "piping hot" exhaust pipe, and warms it thoroughly. It then drives it through a 1½-inch opening in the floor of the car, into a tubular register, along the back edge of the front seat, sending a continuous stream of heated air into the car. (Exhaust gases are not used.)

See also page 1056 for later information on heating a car