# GAS-ENGINE DETAILS

INTERNATIONAL
TEXTBOOK COMPANY
SCRANTON, PA.

# Gas-Engine Details

By

I.C.S. STAFF

GAS-ENGINE DETAILS
GAS-ENGINE LUBRICATION
CARBURETERS

356

Published by
INTERNATIONAL TEXTBOOK COMPANY
SCRANTON, PA.

Printed in U. S. A.

Gift Publisher
Sept. 7, 1923

International Textbook Press
Scranton, Pa.

71463

# CONTENTS

NOTE.—This book is made up of separate parts, or sections, as indicated by their titles, and the page numbers of each usually begin with 1. In this list of contents the titles of the parts are given in the order in which they appear in the book, and under each title is a full synopsis of the subjects treated.

## GAS-ENGINE DETAILS

## GAS-ENGINE LUBRICATION

## CARBURETERS

# GAS-ENGINE DETAILS

Serial 1859 Edition 1

## PARTS OF GAS ENGINES

## FEATURES OF CONSTRUCTION

### FRAMES

**1. Requirements of the Frame.**—The main structure of an engine, on which the various other parts are mounted, is called the **frame** or **base.** It must be rigid and substantial so as to withstand the shocks resulting from successive explosions in the cylinder, and from vibration due to the reciprocating and rotating parts. The frame should be so constructed that the working parts of the engine can easily be reached for inspection, cleaning, and repairs.

**2. Standard Types of Frames.**—The principles involved in the design of gas-engine frames have standardized the construction to a large extent, the type depending somewhat on the size of the engine. A common type of frame for engines of small and medium powers is shown in Fig. 1. The sides *a* of the frame are low, as shown, thus giving easy access to the interior of the cylinder and the reciprocating parts. The overhung cylinder required with this frame is attached by means of the stud bolts *b*. The main bearing *c* is divided at an angle, usually 45°, so that the wear due to the weight and the thrust from the explosions in the cylinder comes on the face of the bearing instead of on the joint.

**3.** In the larger types of engines, especially where very steady running is required, the frame is frequently constructed as shown in Fig. 2. In this design the sides *a* form a straight and rigid connection between the cylinder and the main bearings *b*. The cylinder shell, or jacket, *c* and the frame are cast in one piece so that the parts cannot get out of alinement. The cylinder is supported throughout its length by the frame and consequently the vibration, sometimes experienced with large engines with overhung cylinders, is avoided.

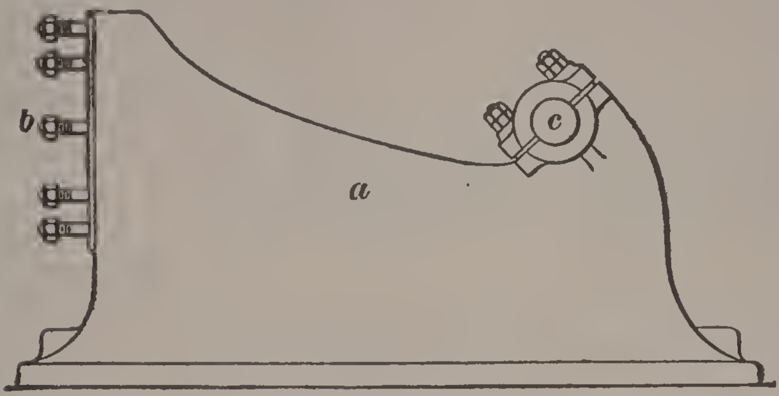


Fig. 1

**4.** A section through the frame of a vertical stationary engine is shown in Fig. 3. The frame is made up of two parts, the upper base *a* and the lower base *b*, and forms a crank-case of the enclosed type in which surplus oil from the bearings is collected. The dotted outline *c* shows the position of the cylinder when mounted in place on the frame. The main bearings *d*, which carry the crank-shaft, are mounted in the lower base and are adjusted vertically by means of wedges *e*, which may be

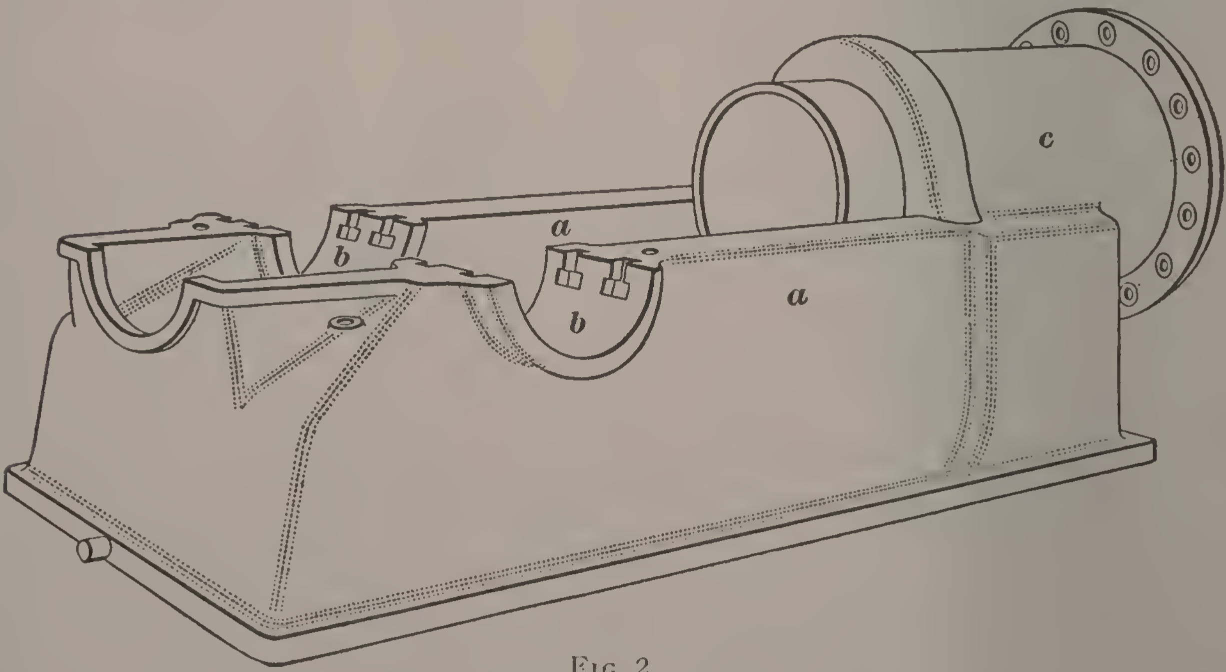


Fig. 2

moved horizontally by turning the threaded rods *f*. The upper base is connected to the lower base by bolts *g* and heavy rods *h* which take the stress due to the explosions. Openings *i* are provided on both sides of the crank-case opposite each crank to permit the inspection and adjustment of the working parts. The frame is strengthened and stiffened by webs *j* cast at intervals.

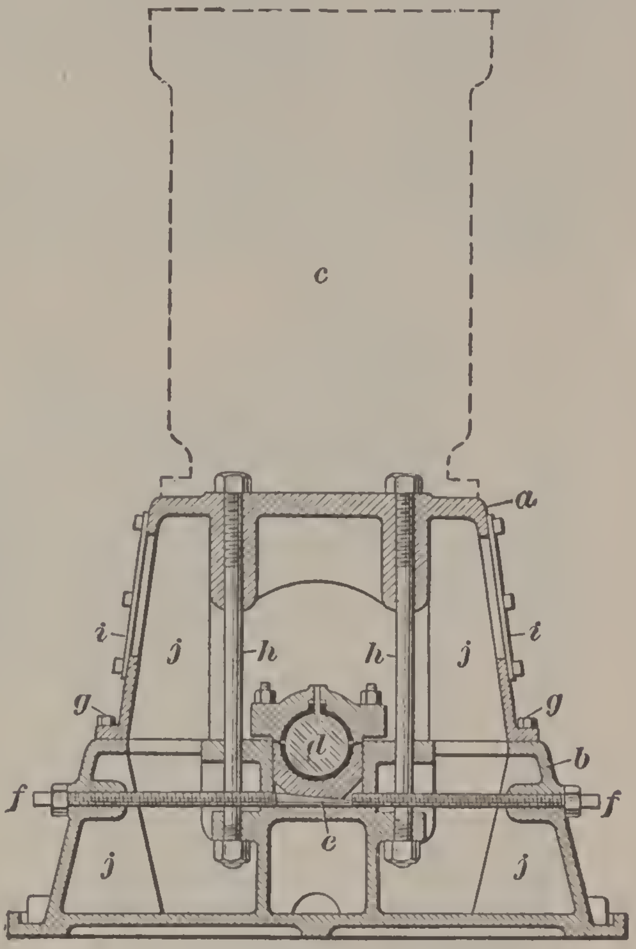


FIG. 3

---

## CYLINDERS

**5. Cylinder, Head, and Jacket in One Piece.** A sectional view of a cylinder of a vertical, four-cylinder, tractor engine of the four-cycle type, having the cylinder *a*, head *b*, and water-jacket *c* cast in one piece, is shown in Fig. 4. The object of this construction is to avoid packing joints between the cylinder and head and between the cylinder and water-jacket. One-piece cylinder castings can be made very satisfactorily for small or medium-sized engines but it is not usually considered good practice to use such castings for engines of large size.

**6.** Cylinders of horizontal stationary engines of the four-cycle type are usually cast with water passages cored in the sides and head, as shown in Fig. 5. A cover *a* carrying the igniter plug *b* is bolted to the head, and a cover ring *c* is bolted to the crank end of the water-jacket. The inlet valve is located at *d* and the exhaust valve at *e*. The ring *c* provides a convenient means of cleaning the water-jacket of any dirt or sediment that may accumulate from the use of dirty or impure water. Since the water pressure in the water-jacket is small, ordinary packing is used to keep the joint tight.

An outside view of this cylinder is shown in Fig. 6. The opening *a* is for the igniter; that on top, at *d,* is for the inlet valve, and a corresponding one at *e,* at the bottom, is for the exhaust valve. The gas-inlet pipe is connected to the opening shown at *f* and the exhaust pipe at *g*; chambers are cored from these openings to the valves. At *h* is an oil hole, and at *i* is the outlet for the cooling water as it leaves the water-jacket. On each side of the cylinder there is a bracket like the one shown at *j,* by means of which the cylinder is bolted to the frame or engine bed.

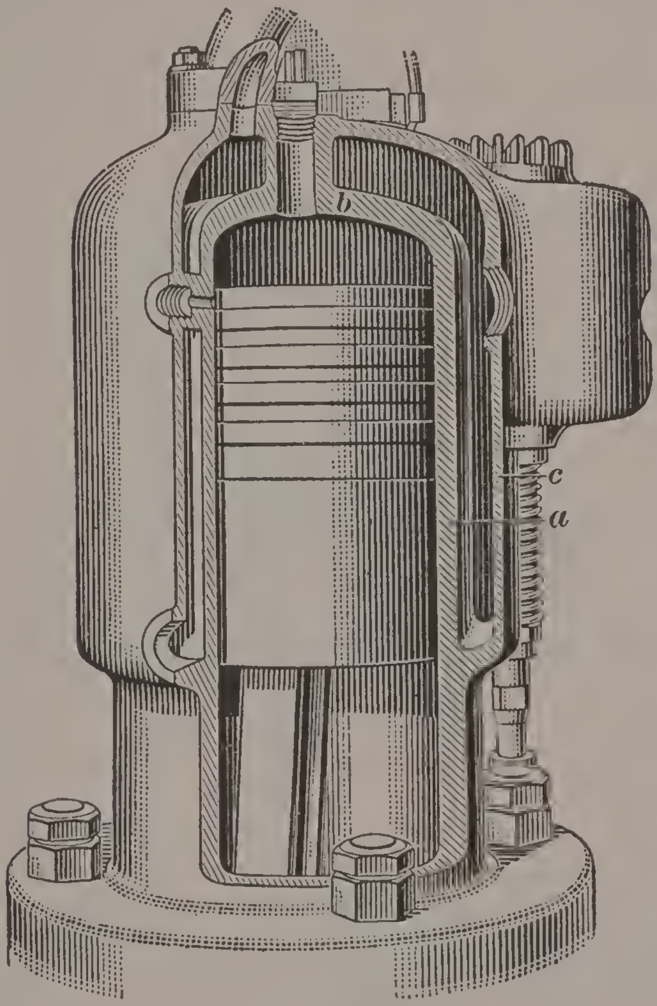


FIG. 4

**7.** There are disadvantages as well as advantages in having the cylinder, head, and water-jacket cast in one piece. Some of the disadvantages of this construction are the difficulty or impossibility of determining the thickness of metal in the cylinder walls or water-jacket and the difficulty of inspecting the closed end of the cylinder when machining, or when it is suspected that there is an accumulation of carbon in the combustion chamber. Casting the head and cylinder in one piece also makes it difficult to counterbore the cylinder and secure a good finished surface. A section *a* of a part of the piston is shown in Fig. 7; at *b,* a sectional view of part of the cylinder is given, showing the counterbore *c,* or the portion of the cylinder bored to a slightly greater diameter than that in which the piston fits, so that, as the surface of the cylinder wears away, it will not leave a shoulder or raised ring for the piston to strike. Experience has shown, however, that counterboring a gas-engine cylinder is sometimes likely to do more harm than good, especially if the counterbore extends, as it usually does, to the middle of the outer piston ring, as shown at *d*. In such a case, the outer ring may do very little toward preventing the gas from leaking around the piston.

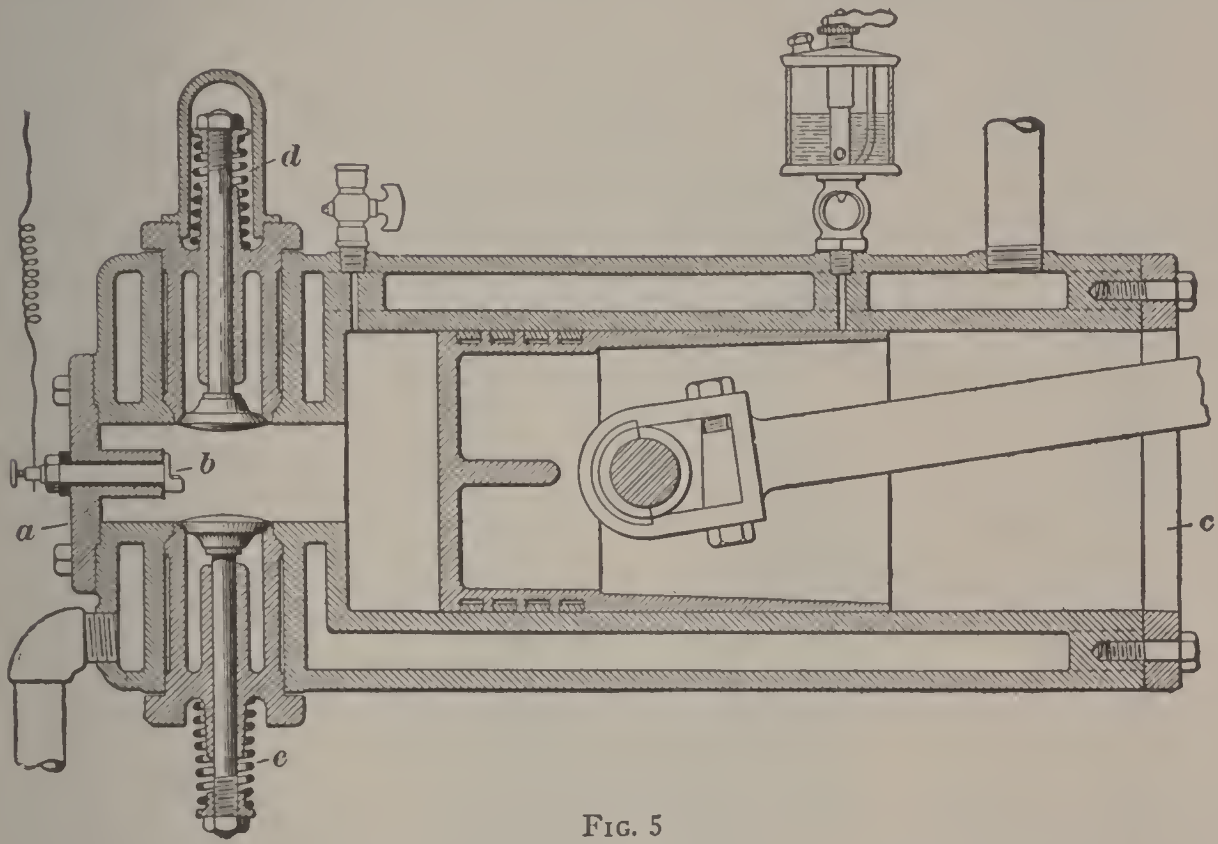


Fig. 5

**8. Cylinder With Separate Head.**—When the cylinder is provided with a separate removable water-jacketed head, as shown in Fig. 8, the head end of the cylinder and the water-jacketed head contain passages, as shown at *a*, through which the cooling water circulates. The shape of these openings in the cylinder is shown more clearly in the enlarged view of the top

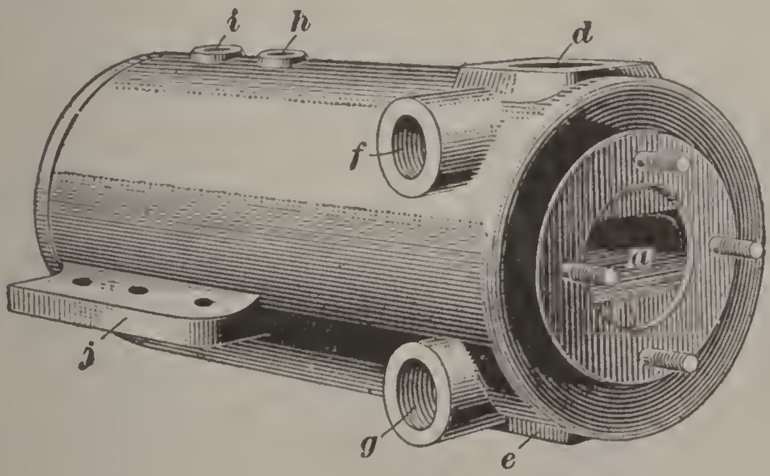


Fig. 6

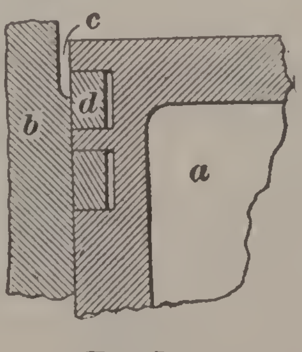


Fig. 7

of the cylinder with the head removed in Fig. 9, the water passages being shown at *a*. The openings in the head and in the head end of the cylinder must match when they are put together, and any gasket placed between them must have holes

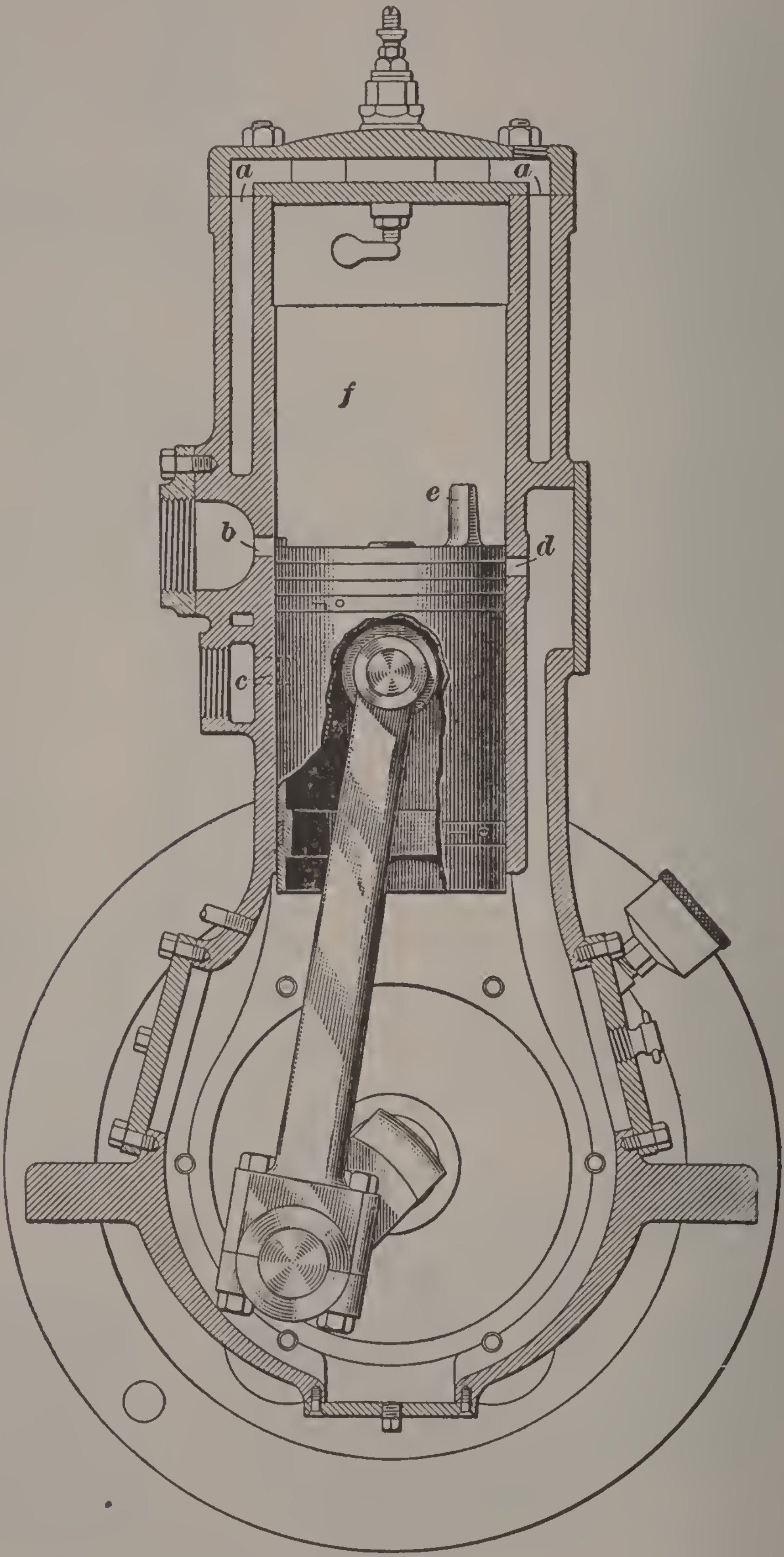


Fig. 8

cut to match these openings. The bolt holes must be so located that the joint may be made tight. Occasionally, the openings are made round, so that a part or all of them may readily be tapped and plugged. Since these passages should be as large as possible, the thickness of the metal on the inside forming the cylinder wall and that on the outside is sometimes made as little, in the case of small engines, as ¼ or ⅜ inch. The strips, shown at *b*, are so narrow that it is only with difficulty that the joint is made tight at these points under the high pressures developed in the gas-engine cylinder. Cylinder heads for small engines are sometimes made so thin that they will spring between the studs shown at *c*, allowing the gasket, or packing, to be blown out by the pressure; this is due to faulty design.

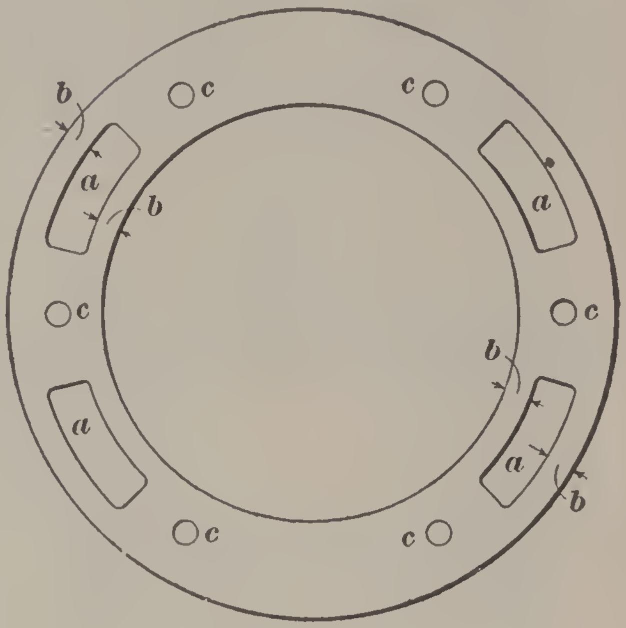
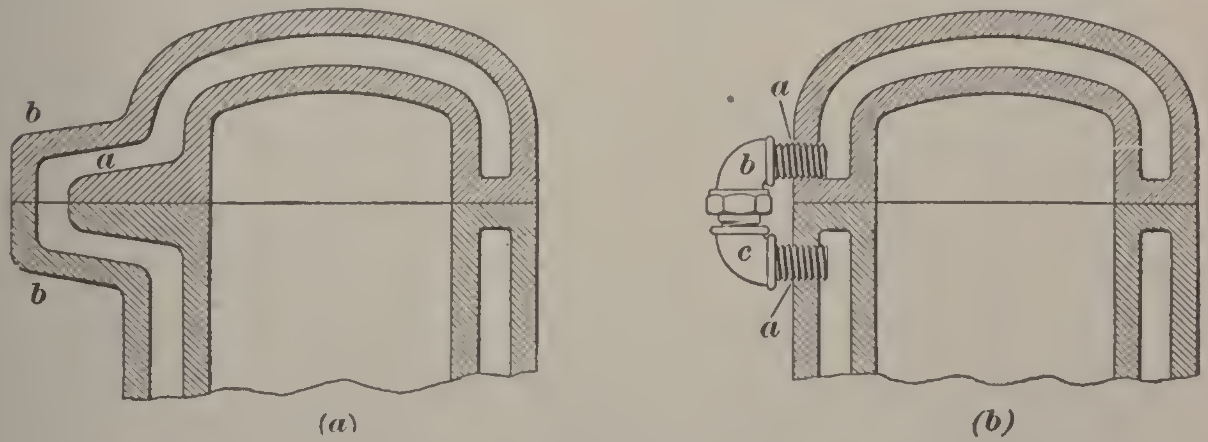


FIG. 9

**9.** The head and cylinder are sometimes put together with a ground joint—that is, no packing or gasket is used between them—but such a joint is difficult to keep in good condition where the head must be removed for inspection or repairs. The difficulty of bringing the surfaces to such a condition that they will not leak is so great that very often a gasket must be used after the head has been removed a few times. Some



(*a*) (*b*)

FIG. 10

manufacturers omit the cored openings for communication between the water-jacket and the head, using an outside connection instead, either cast on as shown in Fig. 10 (*a*) or connected by means of pipe connections as shown in (*b*). In (*a*), the water passage *a* is cored in the lugs *b* in the cylinder and head. In (*b*), the connection is made by means of two short nipples *a,* a union elbow *b,* and a common elbow *c*.

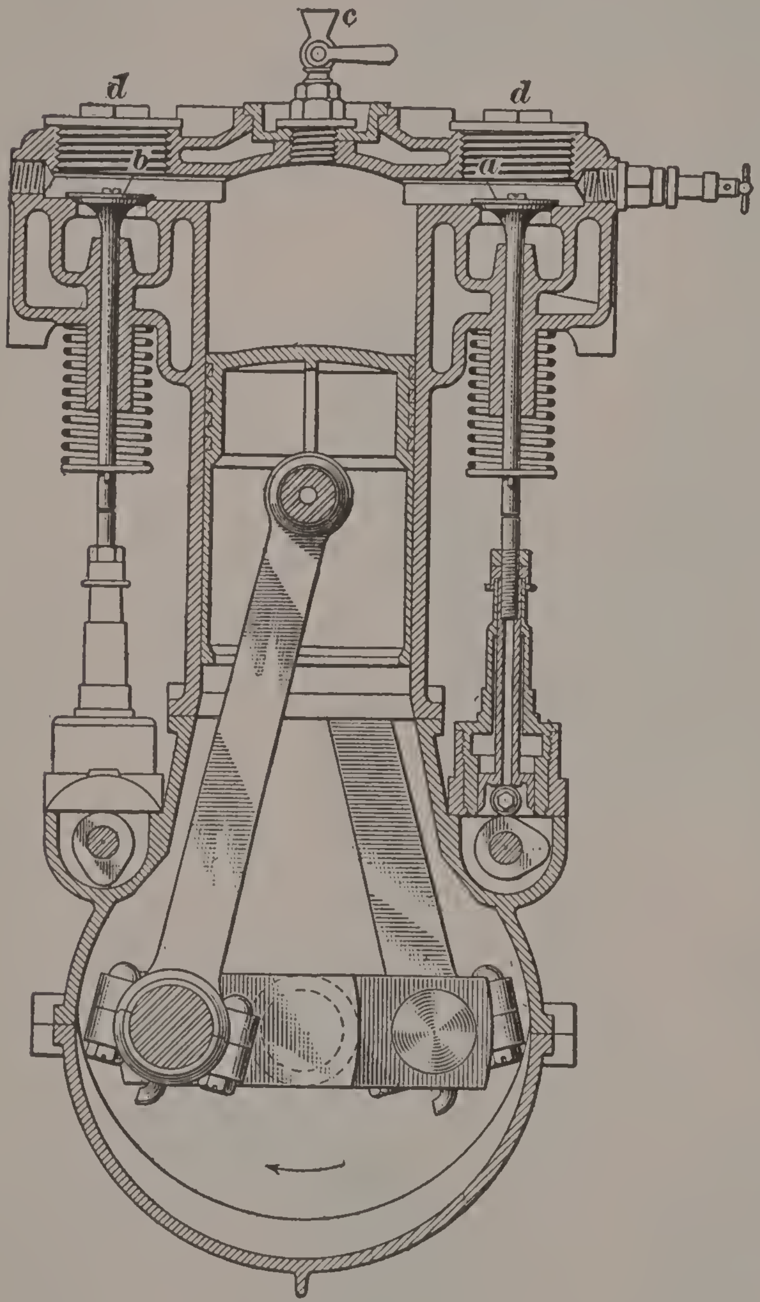


Fig. 11

**10. Cylinders of Automobile Engines.** — The form of an automobile-engine cylinder depends on the location and arrangement of the inlet and exhaust valves. The cylinders are sometimes made as shown in Fig. 11, in which case they are known as the **T**-*head type.* The inlet valve *a* and the exhaust valve *b* are located on opposite sides of the cylinder, giving it, roughly, the appearance of the letter **T**. In the cylinder head is the priming cock *c,* used for admitting gasoline when starting the engine. The screwed plugs *d* over the inlet and exhaust valves make them accessible for repairs. Sometimes the inlet and exhaust valves are placed together on the same side of the cylinder and are operated by the same cam-shaft. The cylinders are then said to be of the

**I**-*head type.* A construction is sometimes used in which the inlet and exhaust valves are placed in the cylinder head, the valves being operated by push rods and rocker-arms. This is known as the **I**-*head,* or *valve-in-head, type.*

**11. Cylinder for Large Double-Acting Engine.** Gas engines for power-plant work are often built in large sizes. Many of these large engines are *double-acting;* that is, work is done on both sides of the piston. The cylinder of a double-acting engine is somewhat different from the cylinder of a *single-acting* engine, in which work is done on one side of the piston only. The cylinder for a large double-acting engine is shown in section in Fig. 12. The cylinder barrel *a,* in which the piston works, is surrounded by a water-jacket that is cast split; that is, a part of the jacket wall at the center is omitted and the opening is then closed by means of a band *b* drawn tight by bolts. This construction is sometimes used on large gas-engine cylinders as it simplifies the casting, prevents excessive casting stresses, and, under working conditions, relieves temperature stresses resulting from unequal expansion in the

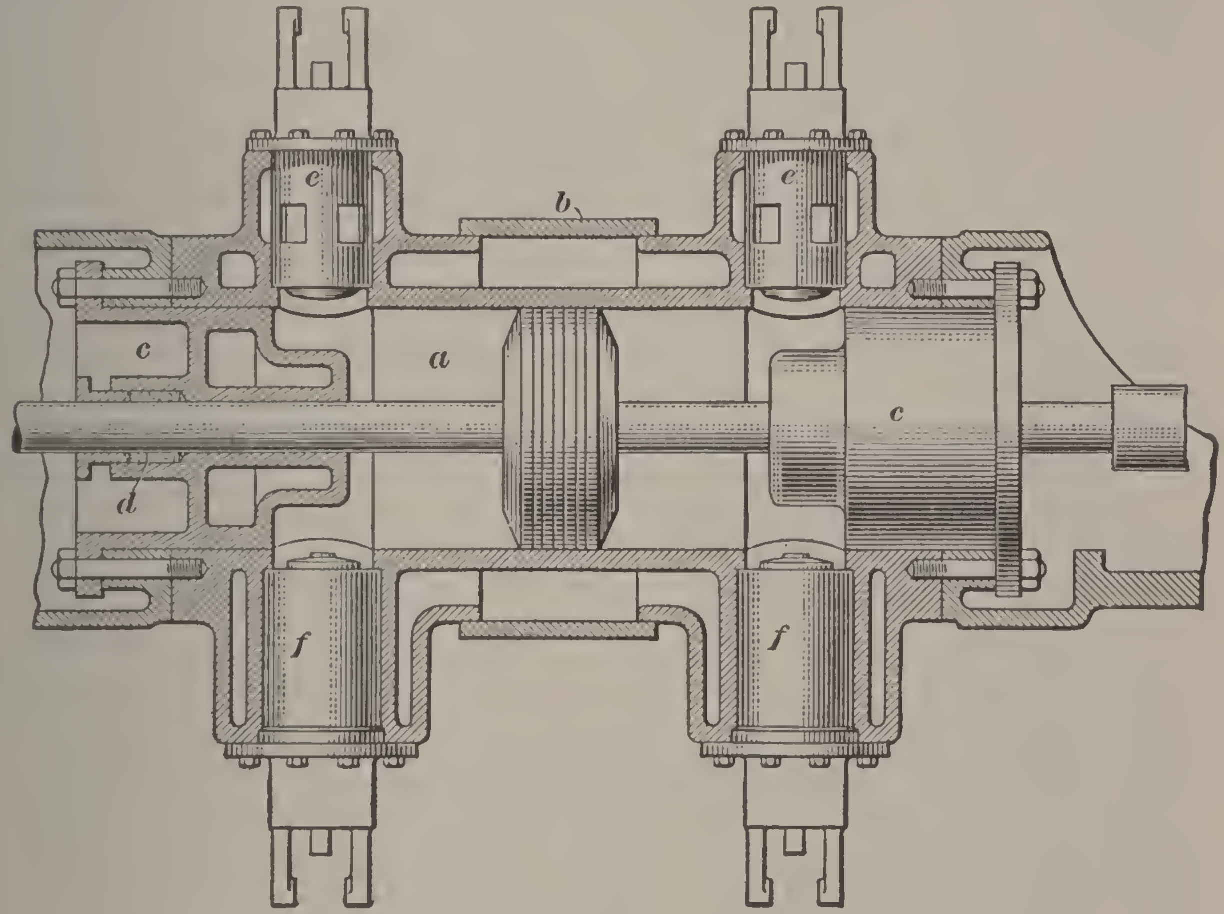


Fig. 12

jacket wall and the cylinder barrel. The ends of the cylinder are closed by water-cooled heads *c*, one of which is shown in section. The leakage of gas around the piston rod is prevented by the use of metallic packing, shown at *d*. The inlet-valve cages *e* are located at the top of the cylinder and the exhaust-valve cages *f* are placed at the bottom, as shown.

**12. Water-Jackets.**—In order to prevent the high temperature inside the cylinder from overheating and damaging the piston and cylinder, it is necessary to keep them cool by circulating water around the cylinder, or by some equivalent means. Hence, the water-jacket that surrounds the cylinder is one of the important features of the internal-combustion engine. From a scientific point of view, a stream of water circulating around a cylinder in which a flame is burning is very wasteful, but for general use nothing better has yet been found. For small engines, however, it is found possible under certain conditions to substitute a strong current of air that strikes directly on the outer surface of the cylinder.

**13.** Great care must be taken to select lubricating oils that will stand as high temperatures as those reached in the cylinder walls. Difficulty would be found in employing higher temperatures, for the reason that the fresh charges would be likely to ignite from contact with the hot cylinder walls. When such inflammable fuel as gasoline is used under high compression, it is necessary, in order to avoid premature explosion, to keep the walls of the combustion chamber, the piston head, and the valves reasonably cool.

**14. Air-Cooled Cylinders.**—The internal construction of an air-cooled cylinder is the same as that of a water-cooled cylinder; also, the arrangement of the valves and other mechanism is similar. The external surface of an air-cooled cylinder, however, is extended, or increased, by various means, usually by the use of thin heat-radiating flanges, or ribs, cast on the cylinder walls or fitted to them. These ribs, or flanges, serve to conduct the heat from the cylinder walls, the heat being absorbed and carried away by the air that comes in contact with the flanges. In some of the earlier air-cooled engines, the cylinders were provided with pins, or studs, radiating from the outer surface of the casting. These studs, which were screwed into the cylinder walls were sometimes threaded from end to end in order to provide a greater heat-radiating surface.

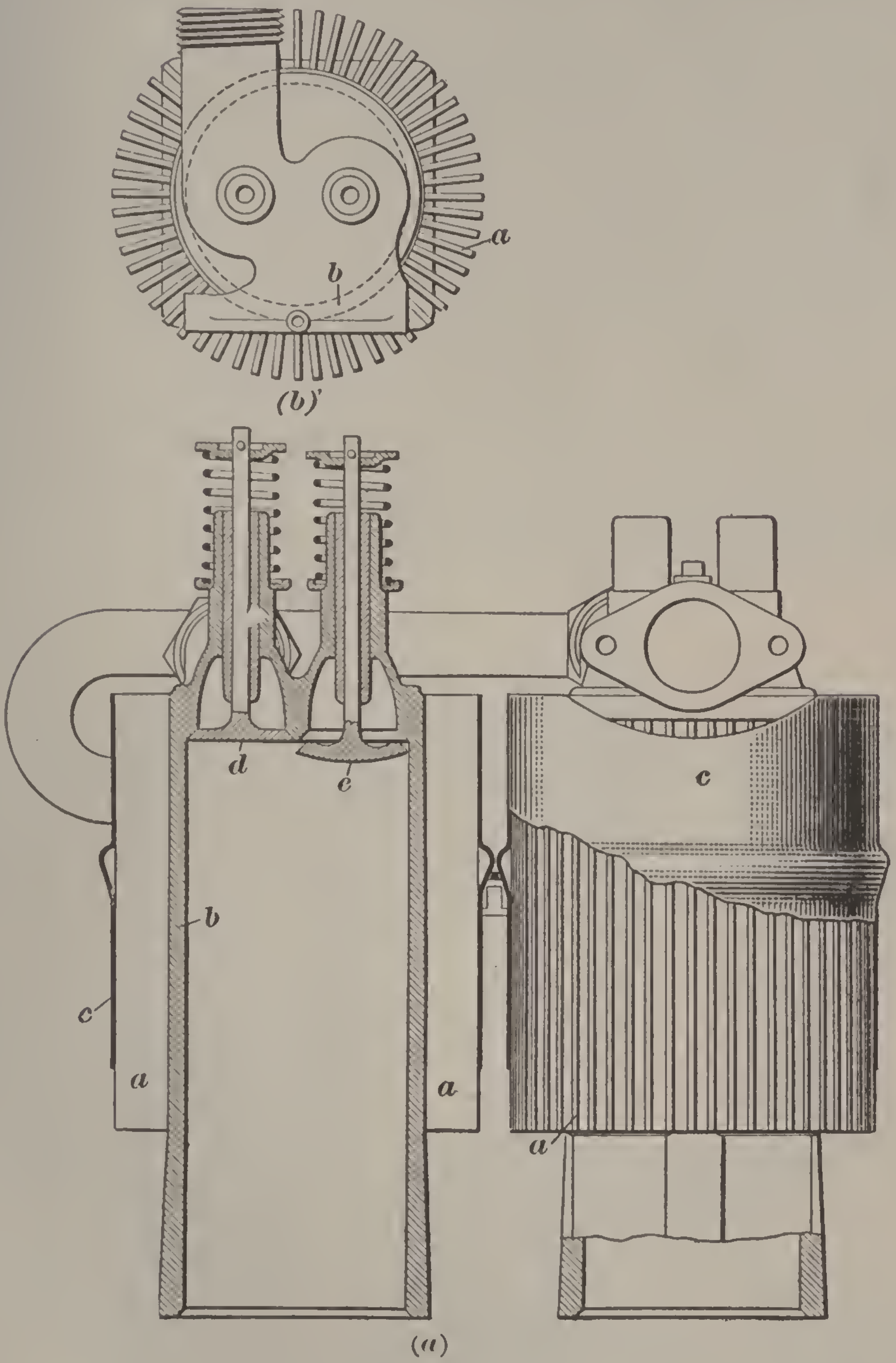
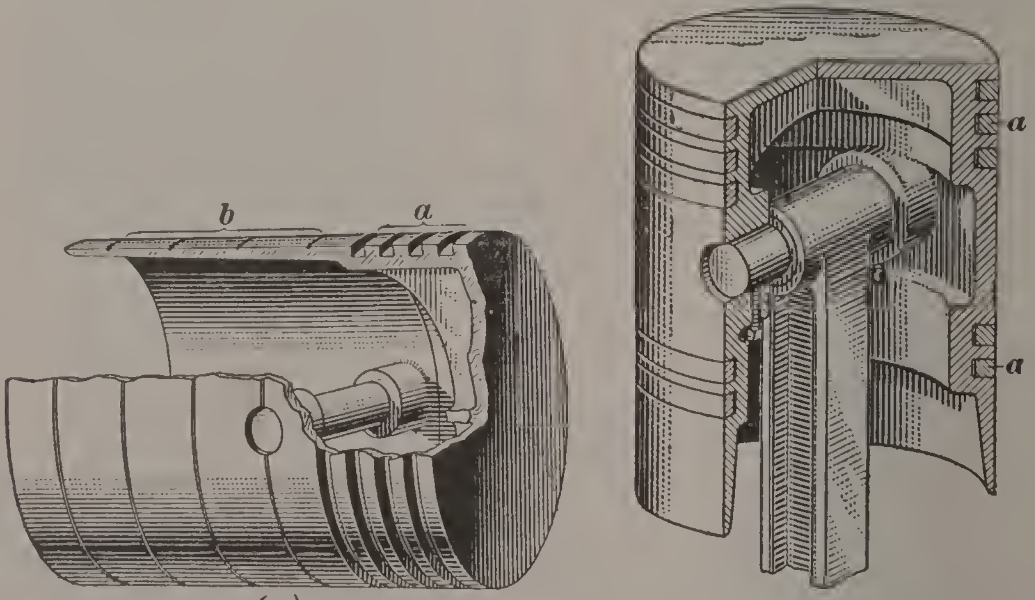


Fig. 13

**15.** A good example of the air-cooled cylinder is shown in Fig. 13. The construction is of the valve-in-head type. Two cylinders are illustrated, a sectional view of one and an external view of the other being shown in (*a*) and a top view of one of these cylinders in (*b*). Like parts are lettered the same in each view. A large heat-radiating surface is obtained by the use of vertical steel flanges *a* that are cast on the wall *b* of the cylinder. The flanges are spaced about $\frac{1}{4}$ inch apart around the entire outer circumference of the cylinder and project radially outwards a distance of about 1 inch. The average length of these flanges is 8 inches. A cylindrical air jacket *c* surrounds each cylinder and, with the cylinder wall, it forms an air-tight passage through which the cooling air is drawn. The air is thus brought into close contact with the flanges, which conduct the heat from the cylinder walls. The inlet valve *d* and the exhaust valve *e* are located in the cylinder head as shown and are operated by push rods and rocker-arms. The valve seats are cast in the cylinder head; that is, no valve cages are used.

## PISTONS

**16. Trunk Type of Piston.**—Single-acting gas engines are provided with hollow cylindrical pistons closed at one end and open at the other to receive one end of the connecting-rod, as shown in Fig. 14 (*a*) and (*b*). Such pistons are of what is known as the **trunk type.** This form of construction eliminates the crosshead and guides and thus makes possible a more compact engine. In order to make the engine as short as possible, the piston pin is usually set close to the head, or closed,

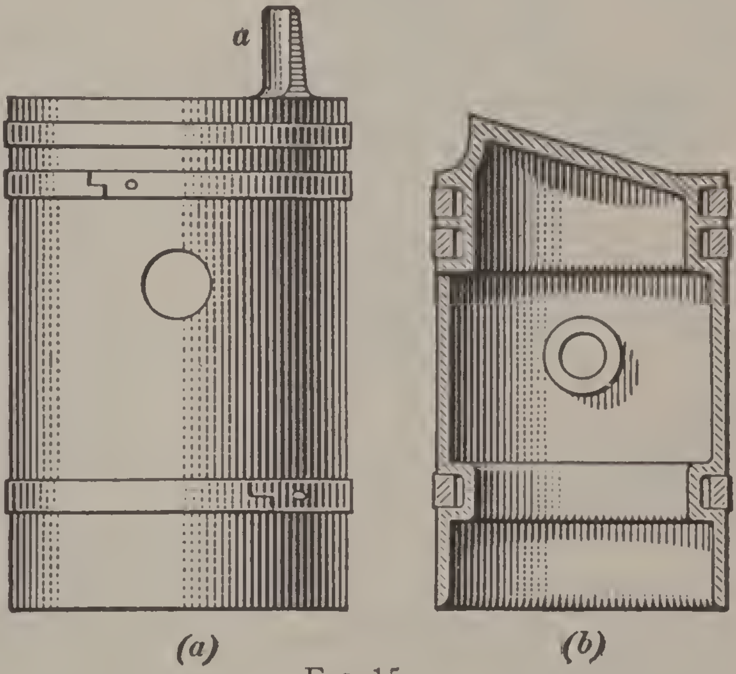


(*a*) (*b*)

FIG. 14

end of the piston, leaving just room enough for the piston rings beyond the piston pin. Near the head end of the piston there are three or more grooves $a$ in which are placed *piston rings,* which serve to make a gas-tight joint between the piston and the wall of the cylinder. The smaller grooves $b$, Fig. 14 ($a$), retain and distribute the lubricating oil to all parts of the cylinder wall, and thus aid in keeping the gases from blowing past the piston. Some pistons have one or two piston rings on the crank end of the piston, as shown in ($b$).

**17.** In two-cycle engines, the shape of the top of the piston is very important, particularly if the transfer port is located in the side of the cylinder. The part of the piston that projects upwards, as shown at $a$, Fig. 15 ($a$), and that deflects the incoming charge so that it clears the cylinder of the burned gases, is called a *deflector,* or *baffle.* Instead of using such a projection, the piston is in some cases so shaped as to deflect the charge in the same manner; such a piston is shown in ($b$).



(a) (b)

FIG. 15

The piston of a two-cycle engine is made about 25 per cent. longer than the stroke, because otherwise the exhaust port would not remain completely covered during the compression stroke and the gas in the crank-case would escape to the atmosphere. In three-port, two-cycle engines, a piston ring is placed at the lower end of the piston, as shown, to prevent the fresh charge in the crank-case from escaping past the piston and out of the inlet port.

**18.** The piston must be made appreciably smaller in diameter than the cylinder in which it works on account of the expansion of the metal due to the high working temperature.

As the back, or closed, end of the piston is in contact with the burning fuel and becomes the hottest, it is customary to allow for greater expansion at this end. An allowance of .002 inch for each inch of cylinder diameter may be made over that portion in which the grooves are turned for the rings. For example, an engine having a cylinder 6 inches in diameter would have the piston made $6 \times .002 = .012$ inch smaller, or $6 - .012 = 5.988$ inches in diameter at the back end. The remainder of the piston is of slightly larger diameter and may be made .001 inch smaller per inch of diameter than the cylinder. Thus, for a 6-inch cylinder the front portion of the piston would be $6 \times .001 = .006$ inch smaller, or 5.994 inches in diameter.

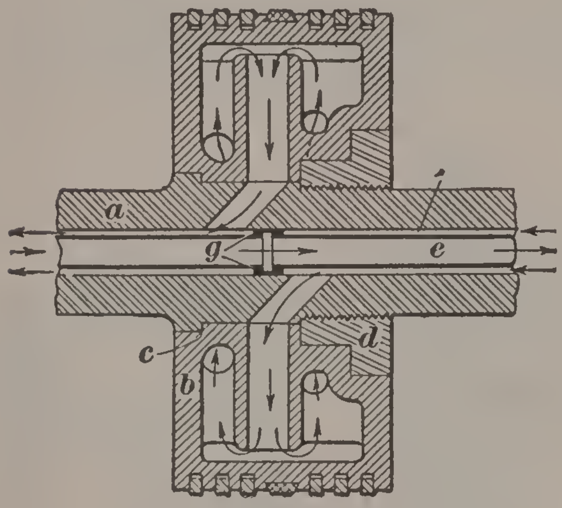


FIG. 16

**19. Piston for Double-Acting Engine.**—The construction of the piston for a double-acting engine is entirely different from that of the trunk type used on a single-acting engine. A double-acting engine always has a piston rod to which the piston is attached. The large size in which these engines are built makes it necessary to cool the piston and piston rod by circulating water through them. As this type of piston is necessarily heavy, it is customary to prolong the piston rod through the rear cylinder head, the prolongation being called a *tail-rod*.

**20.** A water-cooled piston for a double-acting engine is shown in section in Fig. 16. The hollow piston rod *a* is slightly enlarged to receive the piston *b*, which is held in place by the shoulder *c* and the nut *d*. A tube *e* passes through the hollow in the piston rod, forming an annular space *f* around the outside of the tube. The thimble *g* closes the annular space but does not close the inside of the tube. The water passes from one end of the piston rod, through the tube, direct to the other end of the rod, returning through the annular space and circulating through the piston as indicated by the arrows. The water is supplied to and taken from the piston rod through pipes connected by swinging joints or trombone, or slip, joints.

**21. Piston Rings.**—A piston ring is made with an opening or split, and is of such width and thickness that it can be sprung open enough to slip over the end of the piston and snap into the groove. Such a ring is sometimes called a *snap ring.* It is practically the only type of piston ring used in gas engines, as it seems to answer the requirements better than any other style. The width of the ring should be uniform; it should be free in the groove in the piston and should be in contact with the cylinder for its entire circumference. In order to furnish a sufficient packing action to the piston, the rings are usually made about 1.03 times the diameter of the cylinder in which they are to be used. Each ring is then cut through and a sufficient length of metal is removed to allow the ring to enter the cylinder easily. After piston rings have been in use for a long time they frequently lose their elasticity. Such rings can sometimes be improved by removing and hammering them on the inside with the round peen of a light hammer, but the most satisfactory remedy is to replace them with new rings. Piston rings should be made of close-grained gray cast iron of uniform quality.

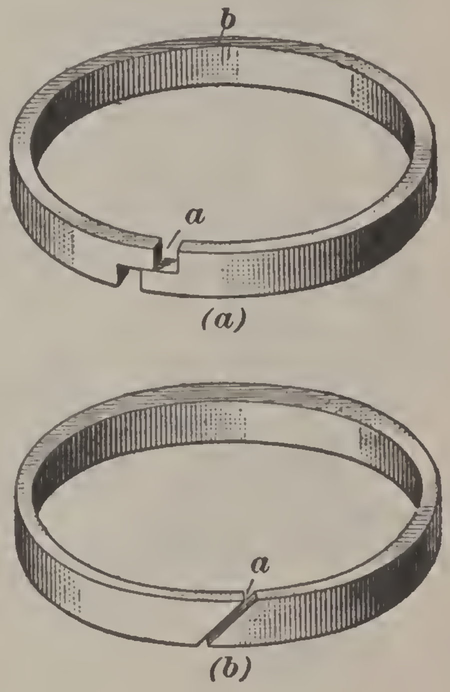


FIG. 17

**22.** Two forms of piston rings that are commonly used are shown in Fig. 17. The one shown in (*a*) is of uniform cross-section, with the ends lapped at the parting as shown at *a*. There should be more spring in the ends of the ring than at the back *b*; consequently, the ring is frequently made eccentric, as shown in (*b*). The diagonal parting shown at *a* in (*b*) is not likely to cut or scratch the cylinder, as no portion of its parting line is parallel with the motion of the piston. The parting shown at *a* in view (*a*) is very effective but is more difficult to make than the diagonal parting.

---

### CROSSHEADS

**23.** In the single-acting gas engine the trunk type of piston serves as a crosshead, but in the double-acting engine, where the piston is attached to a piston rod, a separate crosshead must be used. The crosshead shown in Fig. 18 represents a type that is often used on double-acting gas engines. The crosshead body *a* is a steel casting and is threaded to receive the piston rod *b*. The crosshead is split and clamped on the rod by means of through bolts *c*. The crosshead pin *d* is straight and is held in the crosshead by means of heavy clamping bolts *e*. The crosshead shoes *f* are also steel castings and have a swivel connection to the body of the crosshead which always gives a full bearing of the shoes on the guides. The shoes are adjusted for wear by means of eccentric bolts *g*, which are securely clamped after adjustment.

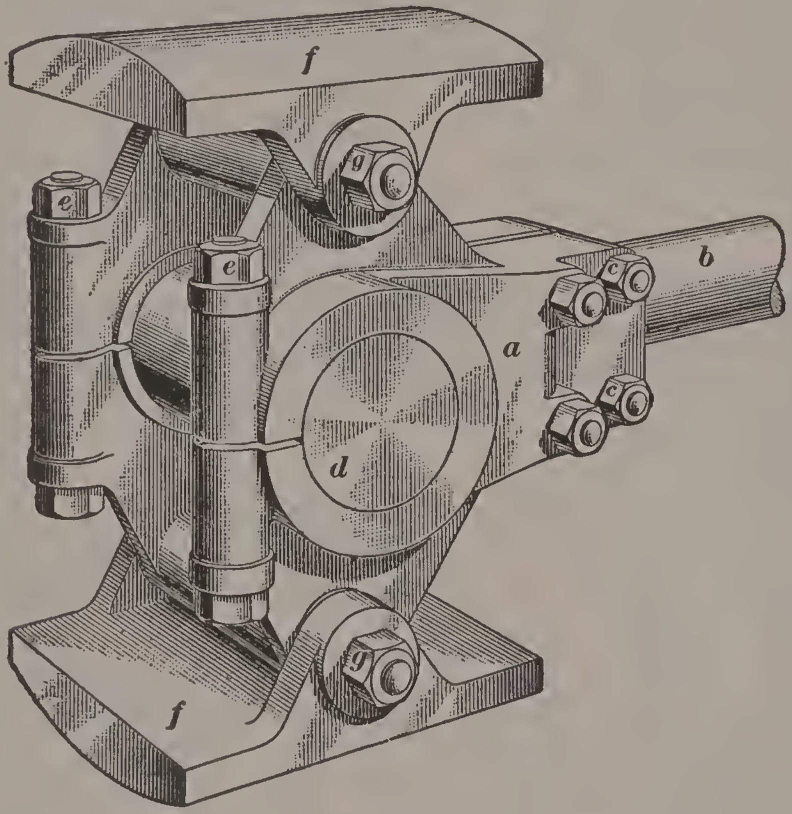


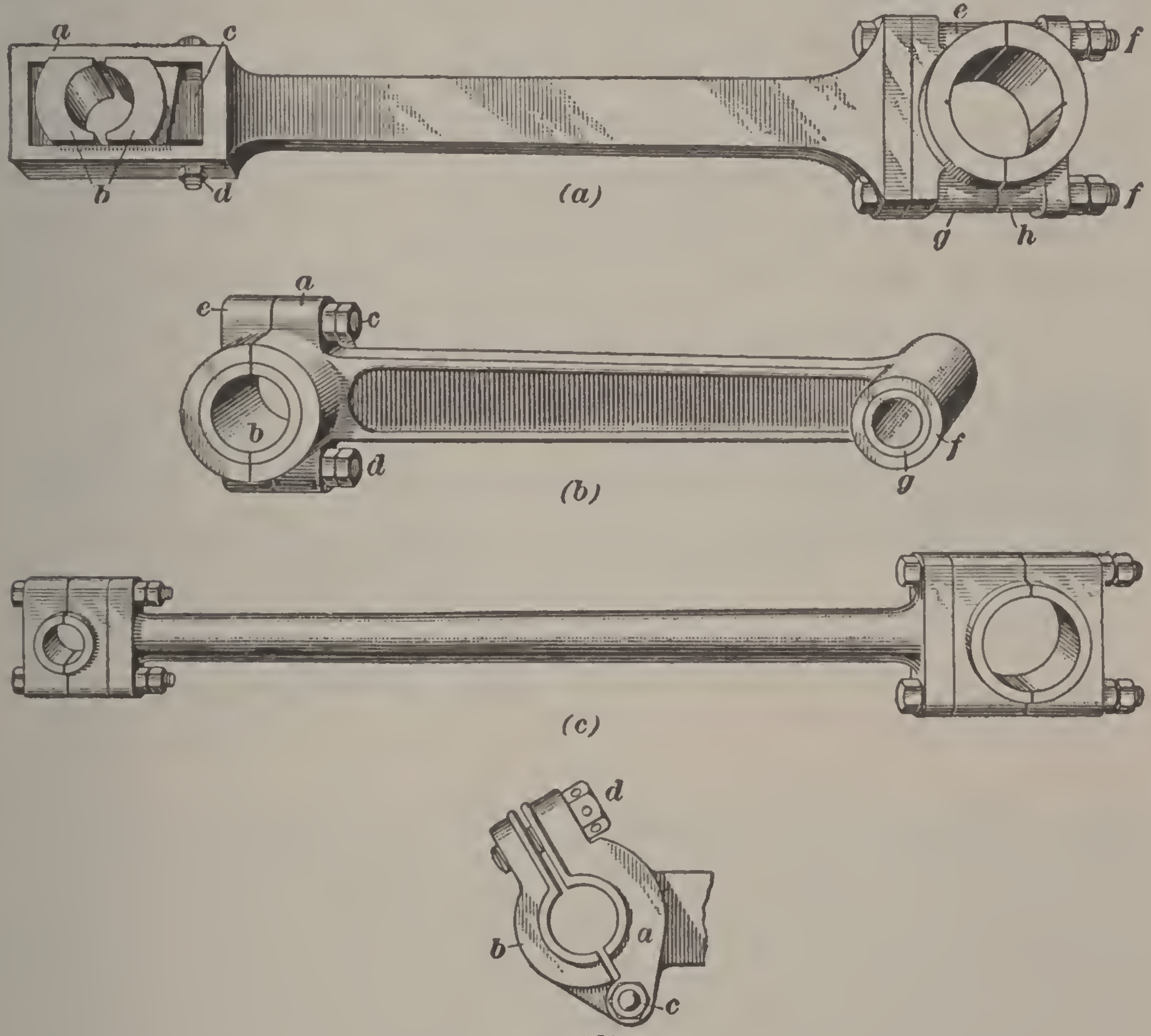
Fig. 18

---

### CONNECTING-RODS

**24. Length of Connecting-Rod.**—The length of the connecting-rod of a horizontal gas engine working on the four-cycle principle is usually about 2½ times the length of the stroke, or, in other words, about 5 times the length of the crank radius. Vertical engines and large double-acting engines usually have shorter connecting-rods so as to make the engine more compact. The longer rod causes less wear of the moving parts, because in its various positions it does not make such large angles with the center line of the engine.

**25. Connecting-Rods for Single-Acting Engines.** Many types of connecting-rods are used on gas engines; three of the more common forms for single-acting engines are shown in Fig. 19. The one shown in (*a*) is rectangular in cross-section. The smaller end *a* is composed of a box containing the brasses *b* that form the piston-pin bearing, and the adjusting wedge *c* through which the wear of the brasses is taken up. The wedge is adjusted by means of the screw *d,* which is locked by a nut when the proper adjustment has been secured. This form of connecting-rod end is known as a *box end*. The large,



(a)

(b)

(c)

(d)

FIG. 19

or crankpin, end, or foot, *e* is attached to the body of the rod by bolts *f*, which also pass through and hold the brasses *g* and *h*. The outer ends of the bolts are provided with locknuts to prevent the nuts from turning while in service. This form of connecting-rod end is known as the *marine type*.

**26.** The connecting-rod shown in Fig. 19 (*b*) is of the **I**-shaped section, the large end *a* being split at right angles to the rod through the center of the bearing and having a brass lining *b*. The two parts of the bearing are held together by the bolts *c* and *d*, which pass through the cap *e*. The bolts are provided with locknuts to prevent the nuts from loosening. The smaller end *f* is made solid, bored out, and a brass bushing pressed into place, as shown at *g*. The connecting-rod shown in (*c*) is of circular cross-section. Both ends are of the marine type. A hinged end sometimes used on connecting-rods for automobile engines is shown in (*d*). The end *a* and cap *b* are hinged at *c*, and a screw *d* is provided to hold the parts together. When the piston end of a connecting-rod is made solid and bored out, it is frequently provided with a bronze bushing. In some engines, the piston pin and the bushing are made of case-hardened steel, and both pin and bushing are ground to fit.

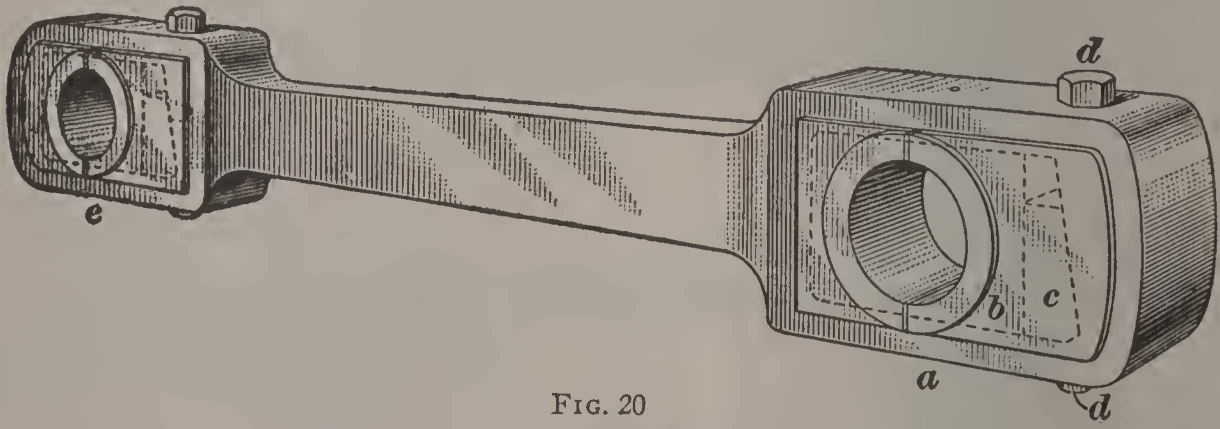


FIG. 20

**27. Connecting-Rod for Double-Acting Engine.** In single-acting engines the connecting-rod always takes the force of the explosion in compression, or in the form of a push. In double-acting engines, however, the force of the explosion is taken alternately in compression and tension. For this reason it is usually customary to make the crankpin end of the connecting-rod solid as well as the crosshead end. A connecting-rod of this kind, designed for a double-acting engine, is shown in Fig. 20. The crankpin end *a* is machined from the solid steel forging and is fitted with babbitted boxes *b* which may be adjusted for wear by means of the wedge *c* and the bolts *d*. The crosshead end *e* is also machined from the solid forging and fitted with bronze boxes with wedge take-up as shown. The body of the rod is rectangular in cross-section.

---

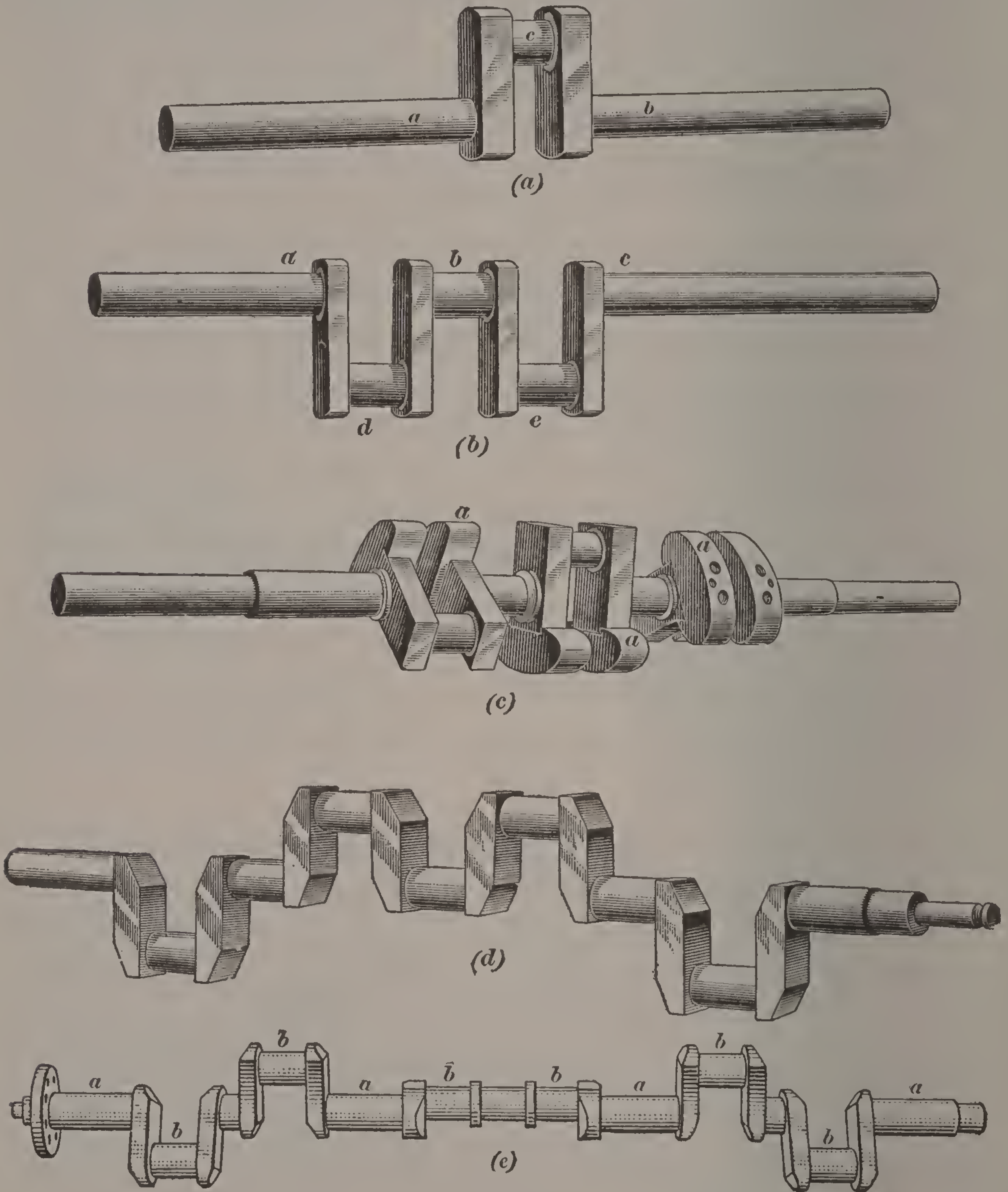
### CRANK-SHAFTS

**28. Types of Crank-Shafts.**—Crank-shafts for gas engines are made of steel; those for automobile engine use are made of special alloy steels, to obtain lightness and strength. They must be strong enough to resist the twisting and bending action to which they are subjected, and the bearing portion must withstand the wear due to continuous rotation at high speed. The type of crank used on single-cylinder gas engines is known as the *center crank,* and has two arms with a crankpin between them. Such a crank is shown in Fig. 21 (*a*). The bearings *a* and *b* of the shaft are close to the crank-arms, and the crankpin *c* connects the arms. The two ends of the shaft must be in line with each other, and the crankpin must be parallel with the shaft.

**29.** The type of crank-shaft generally used for two-cylinder four-cycle engines when the cylinders are placed side by side is shown in Fig. 21 (*b*). The shaft rests in bearings at *a, b,* and *c* and the crankpins *d* and *e* are in line with each other so that the shaft receives an impulse at every revolution. To obtain this result with two-cylinder horizontally opposed engines the cranks would be placed 180° apart, or opposite each other. This latter arrangement is also adopted for two-cylinder, two-cycle engines.

**30.** The cranks of three-cylinder engines, which are usually of the vertical type, are set at an angle of 120° with each other, as shown in Fig. 21 (*c*). This arrangement gives an even turning effect and tends to make a smooth running engine. The shaft is supported by four bearings and the weight of the reciprocating parts is usually balanced by counterweights *a* attached to the cranks opposite to the crankpins as shown.

**31.** A crank-shaft for a four-cylinder vertical engine is shown in Fig. 21 (*d*) in which the shaft receives two impulses during each revolution. The two outer crankpins are in line and the two inner crankpins are in line, so that the two pair of crankpins are 180° apart. Since there are always two pistons on the up stroke while the other two are on the down stroke, the reciprocating parts tend to balance each other and no



(*a*)

(*b*)

(*c*)

(*d*)

(*e*)

FIG. 21

counterweights are required. The crank-shaft shown is supported by five bearings, but often the second and fourth bearings are omitted, leaving three bearings to support the shaft, and in some cases only two bearings are used. The arrangement of the cranks, however, is the same in any case.

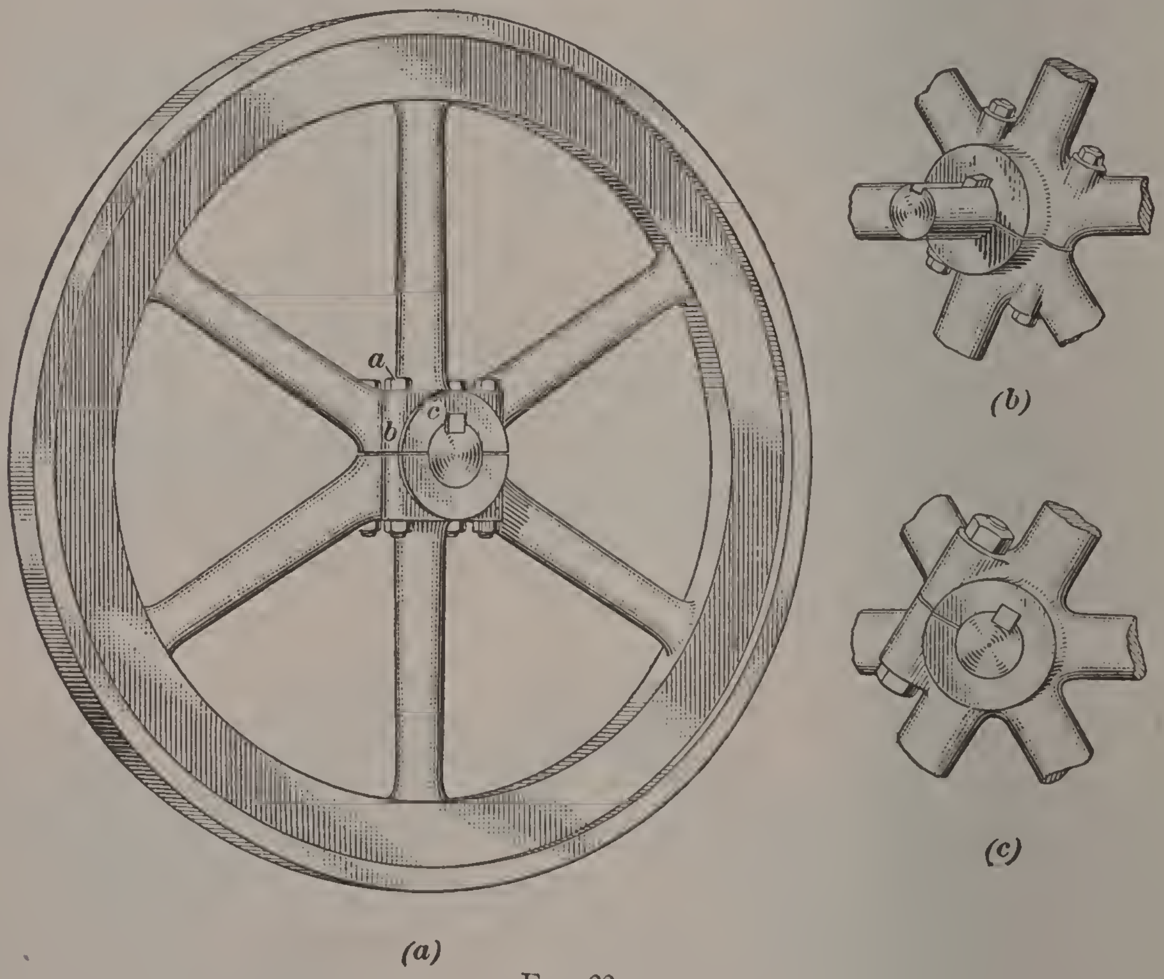
**32.** Crank-shafts for six-cylinder engines are supported by three, four, or seven bearings. The crank-shaft shown in Fig. 21 (*c*) is carried on four bearings. The journals that run in the bearings are shown at *a* and the crankpins at *b*. The cranks are arranged in pairs, one and six forming a pair, two and five forming a pair, and three and four forming a pair. The crankpins of each pair of cranks are in line and the pistons connected to them move in unison; the three pairs of cranks are 120° apart.

Crank-shafts for eight- and twelve-cylinder automobile engines are practically the same as the crank-shafts for four- and six-cylinder engines, respectively, with the exception that the crankpins are so proportioned that each can accommodate two cylinders instead of one. This is made possible by the **V**-arrangement of the cylinders by which half the cylinders stand at an angle to the other half.

## FLYWHEELS

**33. Object of Flywheel.**—A heavy flywheel is necessary for most gas engines, and especially for those of the single-acting four-cycle type, in which the piston receives only one power impulse in each four strokes. In one of these four strokes compression takes place, and the flywheel must store up sufficient energy to do the work of compressing the charge. The weight of the flywheel depends largely on the number of cylinders and the use for which the engine is intended. An engine designed to drive a dynamo for lighting purposes must run with very little variation of speed, and the flywheel must therefore be heavier than a flywheel on an engine intended for ordinary shop use or for pumping. Even with a heavy flywheel a single-cylinder engine can not be made to run without some slight variation of speed. Consequently, when even running is necessary, engines are built with two or more cylinders, so that the energy of the impulse is divided. If the engine is to run slowly, the flywheel must be correspondingly heavier; the higher the speed and the larger the number of cylinders, the smaller and lighter may be the flywheel.

**34. Construction of Flywheels.**—The aim in designing flywheels is to place the weight as far as possible in the rim and to make the hub and arms as light as is consistent with strength and safety. In practice, however, this aim cannot always be carried out, as the difference in body of metal between the rim and the arms may cause severe stresses to be set up when the wheel is cast. To relieve these stresses the hub is often divided into two parts as shown in Fig. 22 (*a*). The wheel is clamped to the shaft by four strong bolts *a* which pass through the hub *b*, and the wheel is further secured by a key *c*. This construction is usually adopted for medium and heavy flywheels, but very large heavy flywheels are sometimes cast in



(b)

(c)

(a)

Fig. 22

halves and afterwards fastened together at the rim and hub. In some cases two bolts are used through a split hub as shown in (*b*) and sometimes the hub is split only on one side and one bolt is used as shown in (*c*). When shrinkage stresses, due to casting, are not excessive, as in small flywheels, the hub is cast solid and a tapered key is used to fasten the flywheel to the crank-shaft.

---

## VALVES

**35. Inlet and Exhaust Valves.**—The inlet and exhaust valves used in gas engines are of the mushroom type and are known as poppet valves. A *poppet valve* consists of a disk with a stem at right angles to the plane of the disk. Poppet valves are used for the admission of the charge and the control of the exhaust. The valves open in the direction of the axis of the

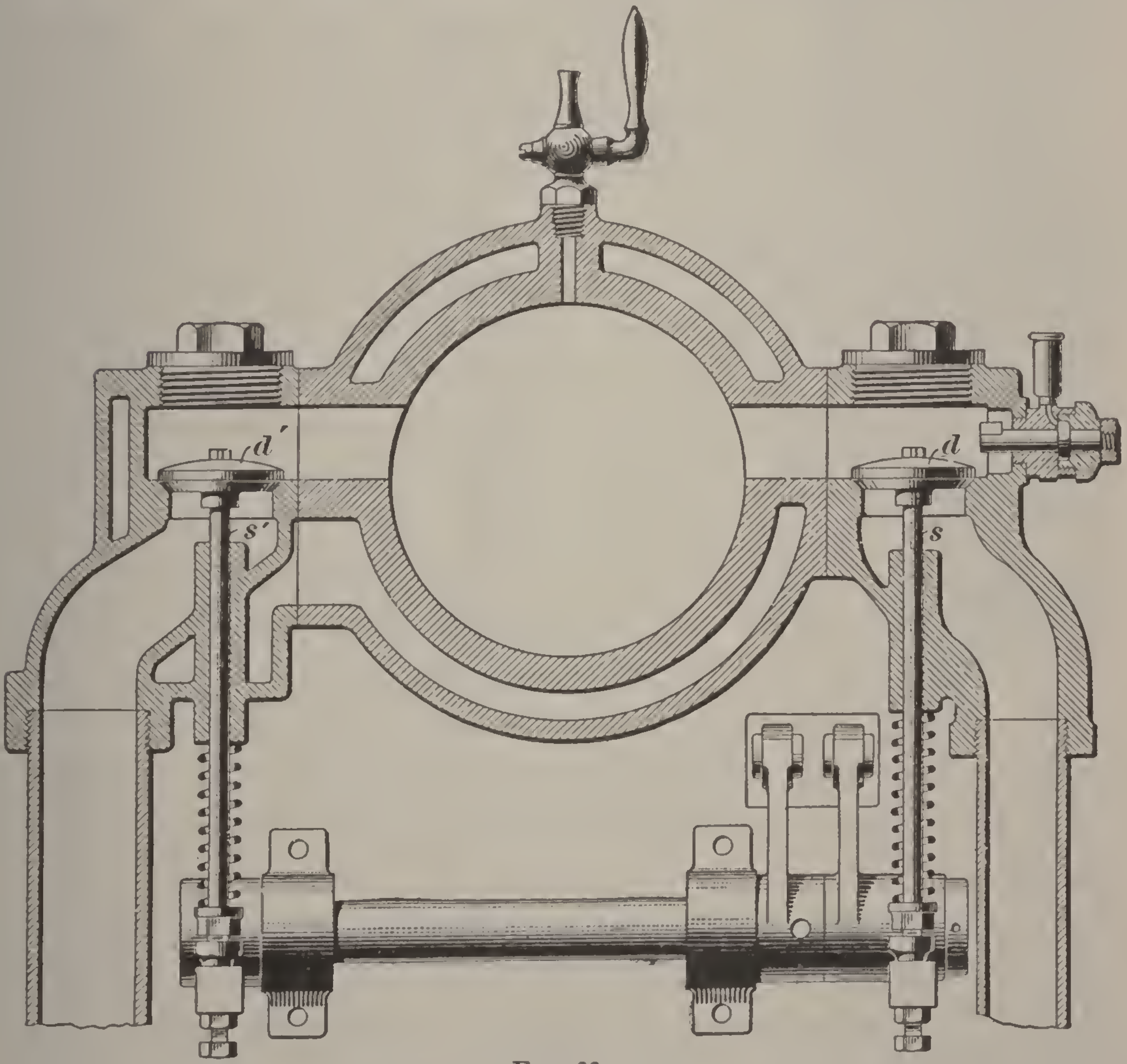


FIG. 23

stems, and are held to their seats by springs. As they open inwards, they have no tendency to leave their seats during the explosion, the pressure in the cylinder helping to keep them on their seats. The valve seats and valve-stem guides may be located in removable heads or in the cylinder casting. An example of the application of poppet valves to the cylinder of a horizontal stationary gas engine is shown in Fig. 23. The valve disk *d* and the stem *s* admit the charge and the disk *d′* and stem *s′* control the exhaust.

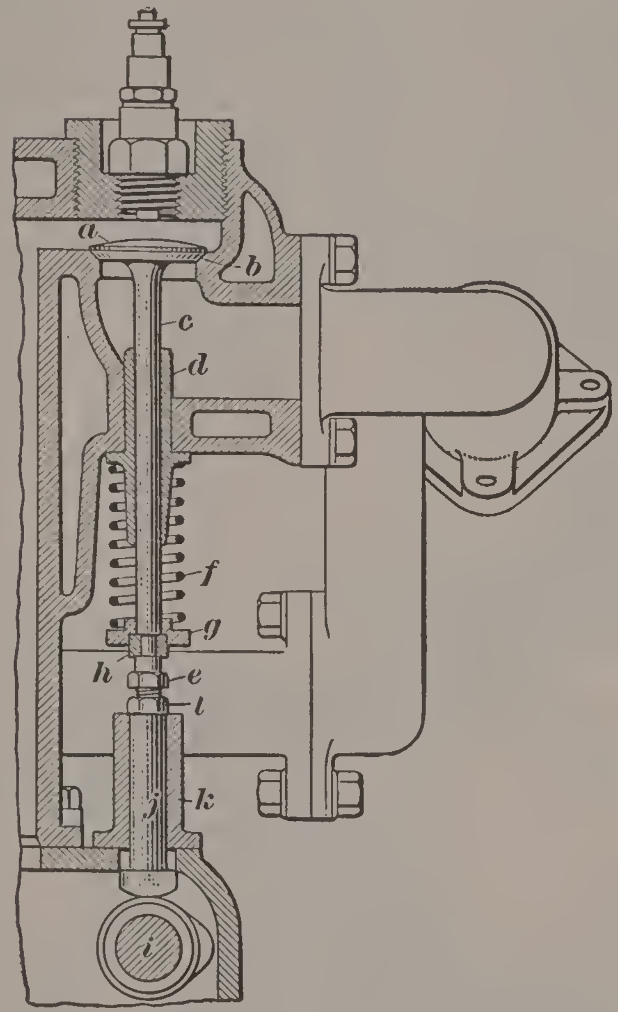


Fig. 24

**36.** The valve seats are usually made of cast iron. Nickel steel and tungsten steel are quite commonly used for valves when the head and stem are made in one piece; nickel steel is also used extensively for the heads of built-up valves having the stems made of machinery steel. It is claimed that valves made of nickel steel will neither warp nor scale from excessive heat; in addition, valves made of tungsten steel seem to be free from pitting. Cast-iron exhaust valves having steel stems are sometimes used, and also soft-steel valves faced with cast iron welded to the head.

The valve seats are occasionally flat, though more frequently they are beveled to an angle of 45°. The bevel-seat type of valve is kept tight more easily than the flat-seat type, and for this reason it is generally used.

**37.** A valve that is opened by mechanical force applied by rigid parts is called a *mechanical valve,* or, less commonly, a *mechanically operated valve.* An exhaust valve of the poppet type must always be mechanically operated, because it must be lifted against the pressure in the cylinder at the time the exhaust is to begin. The inlet valve, however, can be so constructed as to be opened by the pumping action of the piston during the suction stroke. When thus opened it is known as an *automatic inlet valve*.

**38.** A mechanically operated inlet valve for a vertical engine is shown in place on its seat in Fig. 24. The disk *a* rests on the beveled seat *b* and the stem *c* extends downwards through the guide *d* to the *adjusting screw e*, which is not a part of the valve stem, however. The valve spring *f* is held in compression between the guide *d* and the cap *g*, which is held in place by a collar *h* with a radial slot that fits in a groove around the stem *c*. As the cam *i* turns so that its lobe is directly under the *valve lifter j*, the valve is raised against the compression of its spring and an opening is formed between the edge of the valve and the seat. The valve lifter *j* by suitable means is prevented from turning in the *valve-lifter guide k*, and can be adjusted by screwing the adjusting screw *e* up or down. A locknut *l* prevents the adjusting screw from turning out of adjustment. In the center of the top of the valve disk is a slot to receive the end of the tool used when grinding the valve. Frequently the spring cap is held in place by means of a key that passes through a hole in the valve stem, instead of by a slotted collar.

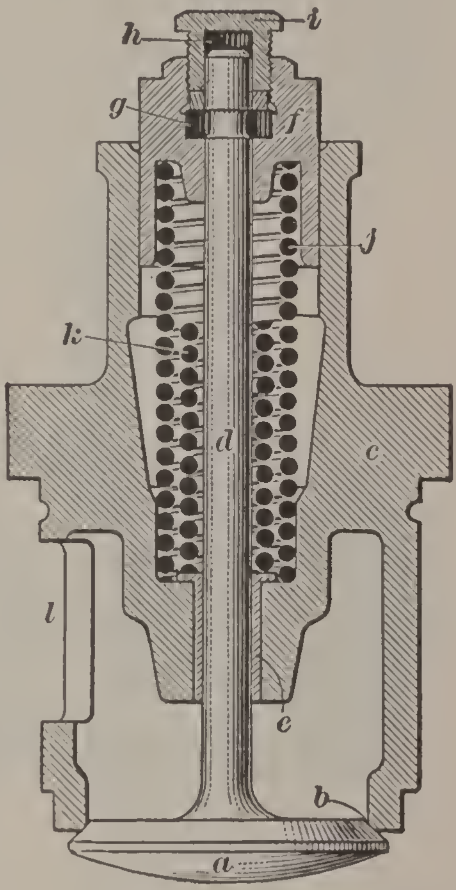


Fig. 25

**39.** A mechanically operated inlet valve and cage for a vertical stationary engine is shown in Fig. 25. The valve *a* is shown in place on its seat *b* which is carried by the cage *c*. The valve stem *d* is guided at one end by the bushing *e*, which is fitted in the cage, and at the other end by the guide piston *f* which is a working fit in the upper part of the cage. In order to fasten the valve stem to the guide piston, the valve stem is grooved near the top end, as shown, to receive a split ring *g*, which, when in place, fits into a recess in the piston. A liner *h* is clamped tightly between the top end of the valve stem and the inside of the socket nut *i* so that the pressure on the top of the socket nut from the valve lever, which is not shown, is transmitted directly to the inlet valve. The outer spring *j* is the valve spring proper which returns the valve to its seat, and the inner spring *k* serves as a buffer to cushion and arrest the motion of the valve in case of back fires. The charge is taken into the cylinder, when the valve is open, through the port *l* in the side of the valve cage.

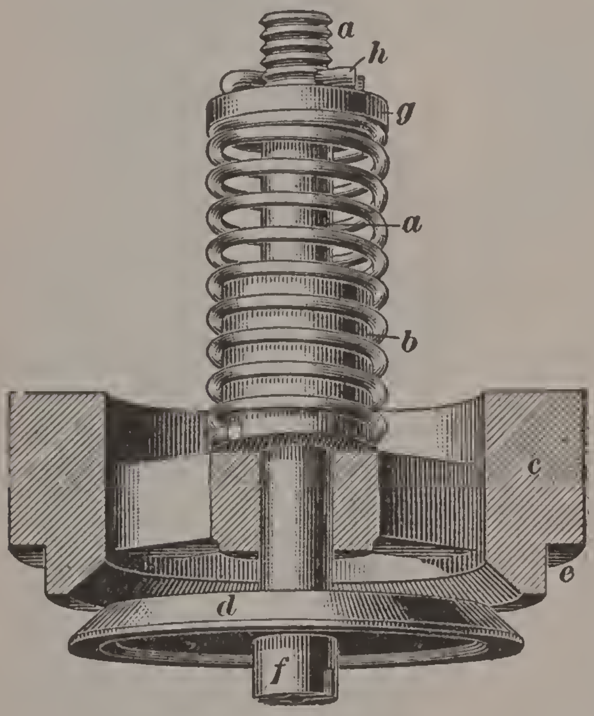


FIG. 26

**40.** The principle of operation of an automatic inlet valve is shown in Fig. 26. The valve stem *a* works in a guide *b*, which is connected by a three-armed spider to the shoulder cage *c*, against whose base the valve head *d* seats. A gas-tight fit between the valve *d* and its seat is secured by grinding. The shoulder *e* is carefully machined, and fitted against an internal shoulder in the cylinder head, the joint being practically gas-tight. In the center of the valve head is a slotted boss *f*, to receive a screwdriver for turning the valve for grinding. A thin nut *g*, backed by a cotter pin *h*, retains the spring. As it takes a little time to unscrew this nut, a washer is sometimes used in its place and is retained by a thin flattened key slipped through a narrow slot in the valve stem. The key is so formed that by compressing the spring slightly it is readily slipped out, but cannot otherwise escape.

## VALVE MECHANISM

**41. Valve Springs.**—Springs for valves are usually made from steel spring wire or from soft cast-steel wire, the former being wound cold and not requiring any heat treatment; when the soft wire is used, the spring is hardened and tempered after it is formed. Springs made from spring wire have the disadvantage of becoming set if subjected to hard usage, and hardened and tempered springs are liable to break if not tempered just right.

*Helical springs,* or springs wound in the form of a screw thread, are used more often than any other. Occasionally, the springs on inlet and exhaust valves are made up in the shape of a cone. Such springs are called *cone-shaped springs.*

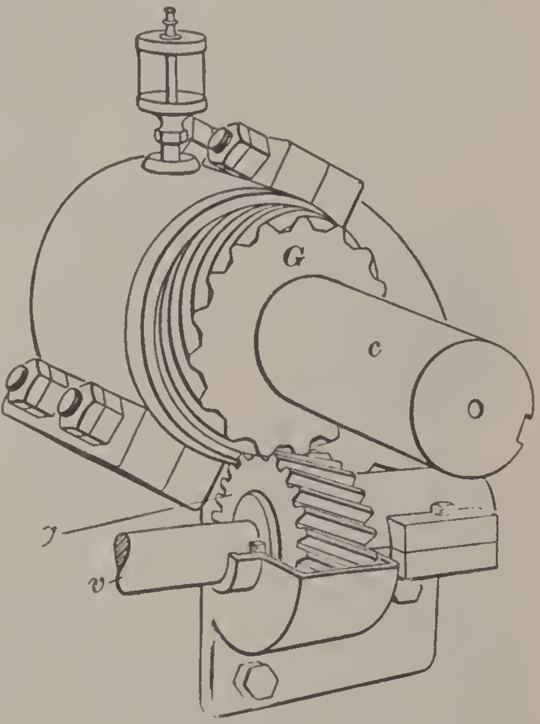


Fig. 27

**42.** When the inlet and exhaust valves are interchangeable, and hence are mechanically operated, the tension of the springs is unimportant as long as it is sufficient to seat the valves. The amount of tension on the springs of automatically opened inlet valves is, on the other hand, an important matter. To get the greatest amount of power from an engine having an automatically operated inlet valve, the spring must be carefully adjusted to insure the required opening of the valve when in operation. In adjusting the tension of the inlet-valve spring, it is necessary to be careful that nothing is accidentally dropped into the cylinder and to make sure that the nut or pin holding the inlet-valve spring does not become loose, especially if the valve is of the inverted type.

**43. Cam-Shafts.**—On horizontal stationary gas engines the *cam-shaft,* sometimes called the *side shaft, lay shaft,* or *two-to-one shaft,* is usually at right angles to the crank-shaft and is driven from it by means of spiral gears as shown in Fig. 27. The crank-shaft *c* carries a spiral gear *G*, which is essentially a short screw having a large number of threads. This gear meshes with the spiral gear *g* on the cam-shaft *v*. The number of teeth on this gear is double the number on the gear *G*, so that the shaft *c* makes two revolutions to one of the shaft *v* that it drives. From the cam-shaft, the valves themselves are operated by cams. If the cam-shaft is driven by spur gears, as is commonly the case in vertical stationary, automobile, aviation, marine, and tractor engines, the cam-shaft is parallel with the crank-shaft. In automobile engines the cam-shaft is sometimes driven by means of a silent chain.

**44. Operation of Valves.**—In order to lift the valves at the proper time and to keep them open for the correct period, cams are generally used on gas engines, except in the largest sizes of stationary engines, where eccentrics are sometimes used. Cams vary considerably in shape, or profile, the outline depending somewhat on the type of *contact-piece,* or *cam-follower,* which is the part of the valve-operating mechanism that is in contact with the cam. An inlet-valve cam designed to be used with a roller follower is shown in Fig. 28 (*a*), and the corresponding exhaust-valve cam is shown in (*b*). Another common form of cam, also used with a roller follower, is shown in (*c*). The cam shown in (*d*) has rising and falling shoulders *a* and *b* of convex form, giving a gradual opening and closing. This form of cam is used with a flat contact-piece, or follower. The cams may be secured to the cam-shaft by keys, taper pins, or screws, or by combinations of these, but in many cases the cams are forged on the cam-shaft.

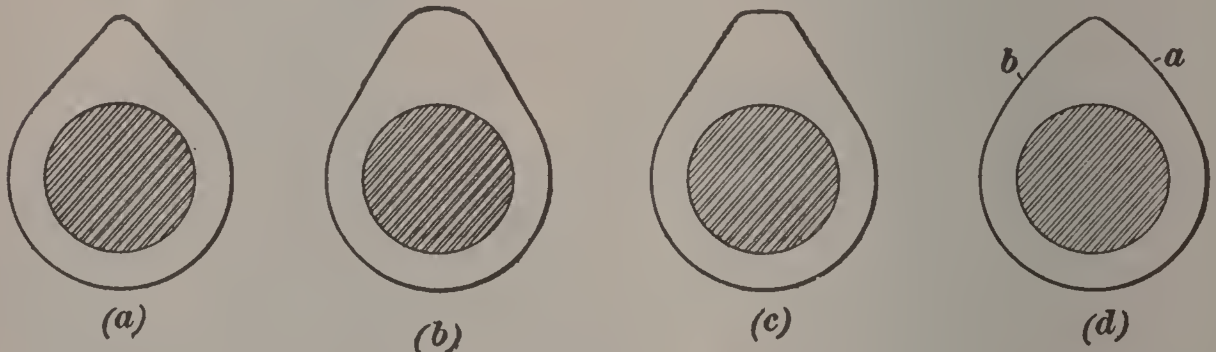


FIG. 28

**45.** The use of cams for operating the valves of a stationary gas engine is illustrated in Fig. 29, which is a section of the engine through the cylinder and valve mechanism. To the side, or cam, shaft *a,* which is driven from the main shaft by means of a pair of spiral gears, are keyed the cams *f* and *b* for operating the valves. The cam *b* operates the exhaust valve *c* by means of the valve lever, or rocker-arm, *d,* which is supported by a bearing at *e*. The cam *f* opens the inlet valve *g* by means of the rocker-arm *h,* which is pivoted in a bearing *i,* and the adjustable push rod *j.* The cam-follower, or roller, *k* is held in a yoke which is free to move about the pivot *l.* A roller cam-follower *m* is also used on the rocker-arm for operating the exhaust valve.

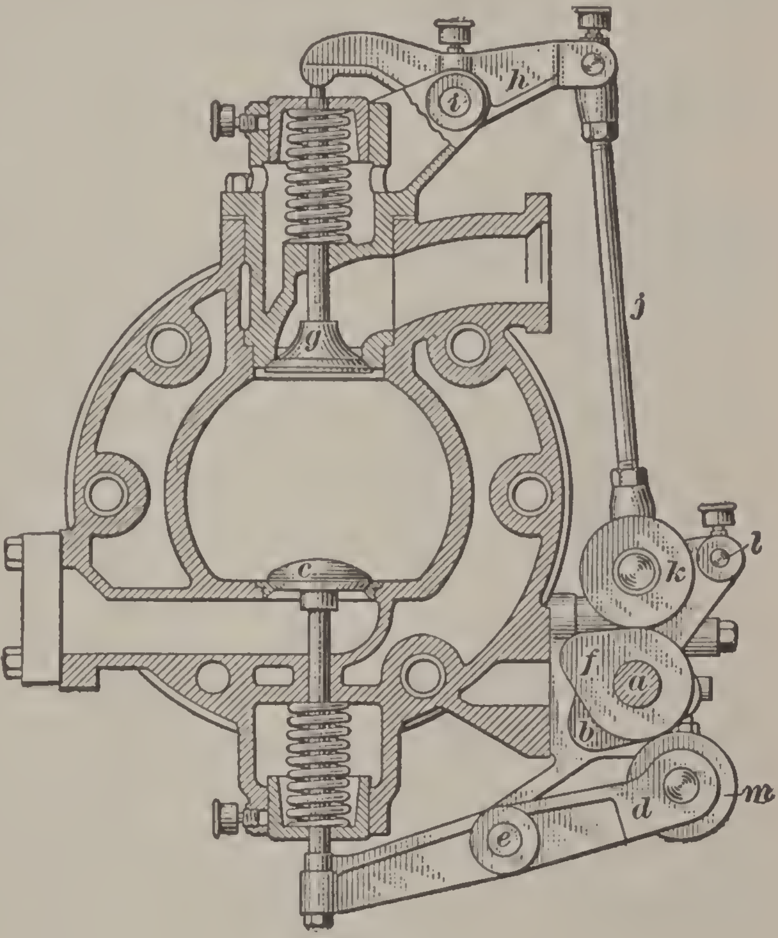


Fig. 29

**46.** The valves of large stationary engines are usually operated by eccentrics instead of cams. The eccentrics are keyed to the side shaft in the same way as cams and, as a general rule, give more quiet operation, without shocks. Eccentrics are more costly than cams but they have a larger wearing surface and give a smoother action to the valves which makes them more desirable for large engines. Both the inlet and the exhaust valves are usually operated by means of a rocker and wiper-cam arrangement which is driven by pull rods attached to a common eccentric.

## MISCELLANEOUS ENGINE FITTINGS

**47. Priming Cups.**—A cock by means of which an engine may be primed by pouring fuel into the combustion chamber, and which may also be used to relieve the compression, is shown in Fig. 30. It consists of a circular plug *a* carefully ground to fit the tapering, or conical, socket in which this plug is turned by means of the handle *b*. The cup *c* is sufficiently large to hold the required amount of gasoline for the priming charge when the engine is to be started. The plug *a* is held in place by a phosphor-bronze spring *d* placed between two washers *e* and *f*, and a pin *g* serves to hold the whole together. The tension of the spring *d* is sufficient to hold the plug firmly in position and to take up wear, thus preventing loss of compression by leakage. The spring also serves to keep the plug tight under heavy vibration. In using this plug, the gasoline for priming is poured into the cup *c* and the cock *a* is turned so as to permit the gasoline to flow into the cylinder either before the engine is started or during the suction stroke.

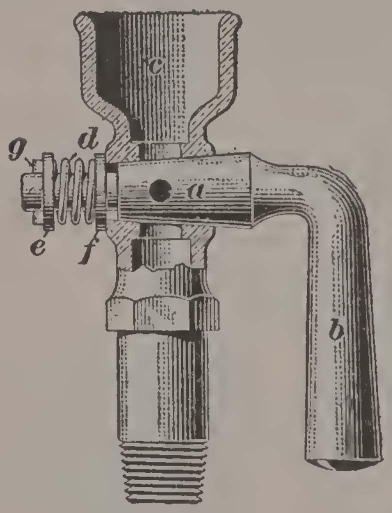


Fig. 30

Priming cups are also used for introducing kerosene or any other similar substance into the cylinders for the purpose of keeping down carbon deposits.

**48. Joints.**—In order to prevent leakage at the joints of a gas engine, a packing, or *gasket*, is usually placed between the two parts forming the joint. The materials used in making joints are usually copper, lead, asbestos, brown paper, wire gauze, etc., or combinations of these materials, the copper asbestos combination being most used. Gaskets containing rubber should never be used around a gasoline engine or in gasoline-supply piping, because rubber is more or less soluble in gasoline. In the water-supply and water-discharge piping, rubber gaskets or packing are frequently used, but it is much better to use ground-joint unions, that is, unions in which the joint is made by metal surfaces ground together. This form of joint is also used in gasoline piping, where gaskets of any description are dangerous. A gasket material composed largely of brass-wire gauze and asbestos is much used for joints that are subjected to high temperatures. When properly fitted and provided with graphite facing, such a gasket will, with care, last a long time. Combined copper and asbestos ring gaskets are also well adapted for use in recessed places, under inverted inlet valves, screw plugs, valve bonnets, etc. This form of gasket consists of compressible, elastic packing encased in soft-rolled copper, which makes a lasting joint under high pressures and temperatures.

**49. Fastenings.—Bolts** should be used for fastening the different parts of the gas engine together whenever a strong joint is desired, unless the construction of the part is such that this cannot well be done. The reason for this is that it is much easier to split and remove a rusted nut from a bolt than to drill out the rusted end of a capscrew that has been twisted off when trying to remove it from the part into which it was screwed.

**Capscrews** and **tap bolts** have a thread on one end and a hexagonal head on the other. They are sometimes used where it is difficult or impossible to use a bolt and a nut. Where two parts are to be fastened by a capscrew, a hole is drilled through one and a smaller hole drilled and tapped into the other. The parts are put together, and the capscrew passed through the larger hole and screwed into the tapped part.

**Setscrews** are used for fastening collars or couplings to shafts, or for fastening other temporary connections. The heads are often square, but are sometimes of other shapes. The points may be conical, flat, ball-shaped, or cup-shaped, so that when screwed into place they prevent the parts from slipping. The shaft should have a small depression where the setscrew strikes it, so that the setscrew will hold better without causing a burr to be formed on the shaft. The heads of all projecting screws in revolving machinery should be covered by a guard, so as to prevent the possibility of accidents to any person through catching the clothing on such projections while the machinery is in motion.

**Stud bolts** are rods of wrought iron or steel with threads cut on both ends; one end is screwed permanently into some part of the engine to hold in place another part—such as, for example, a brace, a cylinder head, or a valve cage—by means of a nut screwed on the other end of the stud bolt. As the parts into which these stud bolts fit are frequently made of cast iron, they sometimes rust solid; but constant removal of the loose parts tends to destroy the threads on the free ends of the stud bolts and hence to produce trouble from leakage. They should be used in preference to capscrews wherever possible.

**Spring cotters,** or **split pins,** are necessary on bolt or stud nuts to prevent them from jarring loose and from working off entirely. They should be used wherever loose bolts or nuts are liable to prove harmful.

**50. Collars.**—In order to prevent or limit endwise motion of revolving or reciprocating parts collars are generally used. They are either solid or split. Solid collars may be held in position by setscrews, taper pins, or other means, or they may be used loosely on shafts to keep other parts at a distance. Split collars are made in halves and are held together by pins or screws. While they are not so strong as the solid pattern, they are frequently very convenient and often used in gas-engine practice. The split collar has the advantage over the solid form in that it can be put into place anywhere in a space equal to twice its width, while the solid form must be slipped over the end of the part on which it is to be fastened.

# GAS-ENGINE LUBRICATION

Serial 1860 Edition 1

## PURPOSE AND NATURE OF LUBRICANTS

### FRICTION AND LUBRICATION

**1.** No matter how smooth a metallic surface may seem to the sight or to the touch, it is in reality covered with very minute projections, so that the surface consists of ridges and hollows. These may readily be seen under a microscope. Thus, when two clean metallic surfaces are placed together, and motion is given to one or both of them, so as to cause one to slide or roll on the other, the little ridges engage one another, or interlock, so that there is a resistance to the motion. This resistance is called **friction.** The amount of friction depends on the pressure with which the two surfaces are held together, the materials of which the surfaces consist, and the condition of the surfaces. The movement of one surface over the other causes some of the small ridges to be broken off or torn loose from each surface. This tearing away or abrading of the metal is called **wear.**

**2. Lubrication** consists in introducing some substance, either liquid or solid, between two rubbing surfaces, to reduce the friction and the wear that would otherwise occur. The substance used, which may be oil, grease, graphite, or combinations of these materials, is known as the **lubricant.** When it is put between the two surfaces, it spreads out and forms a thin layer, or film, that fills up the very small hollows in the surfaces and so prevents the metals from touching each other except at the points of the highest ridges. As a consequence, fewer ridges can interlock, and so less effort is needed to move one surface over the other; in other words, the friction is decreased. As fewer ridges are broken off or torn loose, the wear is correspondingly lessened.

## LUBRICANTS

### OILS

**3.** The lubricants most extensively used are oils, although they are often adulterated with other substances to produce or increase certain properties, such as viscosity, fluidity, weight, etc. The **viscosity** of an oil is a measure of the ease with which it flows. A very viscous oil, or one that has high viscosity, flows very sluggishly; on the other hand, if the viscosity is very low, so that the oil flows rapidly and freely, the oil is said to be fluid, or to possess fluidity. The oils that are used as lubricants may be obtained from animal, vegetable, or mineral sources.

**4.** The animal oils that are most commonly used for lubricating purposes are tallow, lard oil, neat's-foot and sperm oil. These are commonly called fat, or fixed, oils because they do not volatilize when heated to moderate temperatures. As they are of animal origin, they are liable to become rancid, in which condition they are unfit for use; otherwise, they are excellent lubricants, but they are usually too expensive for general use.

**5.** There are two oils that are of mineral origin, namely, *shale oil* which is obtained from certain shales, and *mineral oil,* which is obtained from oil wells. Shale oil is not of much value as a lubricant and it will therefore not be considered further. Mineral oil as it comes from the wells is called *crude oil.* When it is heated, vapors are given off, which, when condensed, form various lighter oils that are called *distillates.* Among the distillates thus obtained are various lubricating oils. The heating of crude oil to a temperature but slightly above that of the atmosphere drives off vapors that form gasoline when they are condensed. A somewhat higher temperature drives off vapor that forms kerosene, and so on. Each increase in temperature drives off a different oil from those that have preceded and each oil is less fluid than the one that was obtained before it. After kerosene, a number of oils that are used for lubricating purposes are obtained. When the lighter elements have been driven off, the residue is drawn off, and is passed through a strainer to free it from grit and earthy matters. It is afterwards cooled and the wax removed. Heavy bodied oils, including steam-engine cylinder oil, are made largely from this residual product. Many cylinder oils for use in internal-combustion engines consist of combinations or blends, of distillate with the heavier residual stocks in varying proportions. Some lubricating oils are comparatively thin whereas others are quite thick. All lubricating oils increase in fluidity when their temperature is raised; that is they lose their body, or decrease in viscosity.

**6.** The thickness, or body, of an oil, commonly called its viscosity, is an important property in lubricating. The lower the viscosity—that is the thinner the oil—so long as other conditions are satisfied, the better the oil for lubricating purposes. Some oils become so thin at high temperatures that they lose most of their lubricating properties. Mineral oils, when heated, lose their viscosity much more rapidly than animal or vegetable oils, but vegetable and animal oils burn more easily.

Mineral oils give off inflammable vapors when heated. The amount of these vapors is at first not sufficient to ignite, but at a certain temperature enough is given off to ignite with a flash, though the flame dies out almost immediately. The temperature at which the flash appears is called the *flash point*. Vapor is given off in sufficient amount to maintain a flame constantly when the temperature is raised somewhat above the flash point. This temperature is called the *burning point*. An oil is said to have a high fire-test or a low fire-test according as the burning point is high or low. The higher the viscosity of an oil, the higher is its fire-test. The fire-test of lubricating oil should, therefore, be as low as is consistent with safety under service conditions. When the flash point of an oil is 300° F. or higher, there is little danger of fire when handling it under ordinary circumstances. Oils that flash at a temperature much below 300° F. give off, at atmospheric temperature, inflammable vapors that increase the fire risk if the oil is stored where there is not free ventilation. The loss by evaporation is also greater from an oil of low fire-test than from one having a high fire-test. Lubricating oils do not, as a rule, flash at a temperature below 300° F., and they therefore do not offer very great danger of fire.

**7. Cylinder Oil.**—There are three essential properties that a good gas-engine cylinder oil must possess.

1. It must have as high a fire-test as practicable; that is, the temperature at which it gives off inflammable vapor should be as high as is consistent with the desired body. In the best gas-engine cylinder oils, this temperature will be about 450° F., which gives a satisfactory factor of safety, inasmuch as the temperature of the cylinder walls of internal combustion engines rarely rises above 250° F.

2. It must be of the best quality; that is, it should leave as little residue as possible when the oil is vaporized by heat. Any cylinder oil will leave some carbon deposit, which gradually accumulates on the inner walls of the combustion chamber and on the piston head and valves, but it is desirable that this accumulation should be prevented as far as practicable. If it becomes thick, especially if the compression is high or if the form of the combustion chamber is such that sharp corners are exposed to the heat of the flame, particles of the unburned carbon clinging to the walls or elsewhere may become heated to such a degree as to ignite the charge before compression is complete.

3. The third requirement of a good gas-engine cylinder oil is that it shall have the proper body. If the oil is too heavy, it will not work past the piston rings in sufficient quantity, while if it is too light, the high temperature of the cylinder will reduce its viscosity and make it too thin to be used satisfactorily as a lubricant.

**8.** It is often advisable to use oil of different characteristics in an automobile engine than is necessary in a stationary engine, because of the greater rapidity of the explosions in the automobile engine and the consequently higher internal temperature. As it is hard to get at the combustion chamber to scrape the carbon deposit from it, it is well to use an oil that leaves as little deposit as possible. For air-cooled cylinders, only the heaviest oil obtainable and with the highest possible fire-test should be used, and the oil tank should be placed near enough to the cylinder or exhaust pipe to insure that the oil will feed readily in cold weather.

**9. Grade of Oil.**—For water-cooled engines of the high-speed type, such as are used in automobile and aeroplane service, the grade of cylinder oil known as *medium* is appropriate for summer use. In weather cold enough to cause this oil to stiffen, the next lighter grade, or *light,* may be employed. In cold weather, if the *light* oil does not feed freely, it is best to use a special oil suitable for use at low temperatures, though it is possible to thin the regular oil with kerosene or gasoline, to make it flow, and to increase correspondingly the feed of the oil cup or mechanical lubricator. It is best in every case to purchase oil that is known to be reliable. Besides, most manufacturers of automobiles recommend certain oils for use in their engines. These oils may always be used with confidence in any engine of about the same character as that for which they are put up.

**10.** Should it be found impossible to obtain oil that is known to be suitable, the samples available may be tested for viscosity by putting a few drops of each on an inclined sheet of clean metal or glass, and noting the relative rapidity of their downward flow. The one that flows most rapidly has the least or lowest viscosity, and the one that flows most slowly has the greatest or highest viscosity. The oils may be tested roughly for flashing point and for the carbon residue they leave by putting a little on a sheet of iron or tin plate, and heating gradually over a flame, care being taken to move the plate over the flame so that all parts of it are evenly heated. The oils will become less viscous and will run on the plate, and for this reason two samples compared at the same time should not be placed too close together. They will gradually vaporize, leaving only a brownish and somewhat thick residue, which should be as small in amount as possible. A good, heavy oil will vaporize almost completely, but will retain considerable body even at temperatures where an oil of low fire-test would be entirely burned away. Oils, either heavy or light, that leave any considerable amount of black, tarry residue should be avoided.

**11.** Although, strictly speaking, cylinder oil needs to be used only for cylinder lubrication, the same oil is generally used for all bearings of the motor. This is particularly true of automobile engines, where the oil supply is carried in the crank-case and used for the lubrication of the bearings as well as the cylinders. Cylinder oil is an excellent lubricant for bearings subjected to hard service, as those of the crankpins and crank-shaft, but, when possible, better service can be obtained by supplying each bearing with an oil that is particularly suited to its working conditions.

## GREASES

**12.** There are cases in which the use of oil as a lubricant is either inconvenient or impossible, and under such circumstances grease is commonly used. Grease is generally made by adding a soap to lubricating oil, thus thickening it. The thickness of grease varies from the consistency of a thick liquid to that of a hard soap. The harder grease contains more soap than the soft grease. The lubricating properties of a grease are not usually available for the reduction of friction in a bearing until the temperature of the bearing has become sufficiently high to melt the soap and thus liberate the oil contained in the grease. The soap adds little, if anything, to the lubricating properties of the grease.

Mineral oil is commonly used in grease, the soap used for thickening it being either a tallow soap or a mineral soap. The tallow soap is made of tallow or other suitable fat which is commonly saponified by the addition of potash, and it is therefore sometimes called a potash-tallow soap. Some of the vegetable oils, such as olive, rape-seed, and cotton-seed oils, may be saponified by such alkalies as lime, soda, and potash. In mineral greases, a mineral soap such as aluminum soap is used.

**13.** Since a grease must melt before the lubricant is available, a grease that melts at a temperature sufficiently low to keep the bearing from being damaged must be chosen. Grease melts at temperatures varying from about 75° F. to 150° or 200° F. The melting temperature depends both on the amount of soap in the grease and on the kind of soap. The flash point and the fire point of a grease are usually the same as those of the oil contained in it.

Both grease and oil are frequently used in places where the temperature around the bearing is very high or very low. When the temperature of the surrounding air is high, a grease suitable for use in the bearing must have a melting point only slightly above that of the air, in order that the bearing will not become too hot before the grease melts. Furthermore, if oil, by itself, is employed, neither it nor the oil used in the grease should flash at a temperature less than 100° above the air temperature. If the bearing is exposed to very low temperatures, a grease of such consistency that it will not become hard at the temperature of the air must be used.

Solid materials such as graphite and soapstone are sometimes added to grease to harden it. Graphite also adds valuable lubricating qualities to the grease or oil with which it is mixed, providing the graphite is not used in such quantities as to make a mud and clog the bearing. Graphite smooths the surfaces of the bearing by filling up the hollows and thus reduces both friction and wear.

**14. Automobile Greases.**—The greases used in automobile work are made in different consistencies to suit different climatic conditions and service. As a general rule, each brand of grease is made in three consistencies, often known as *hard, medium,* and *light grease,* although some makers manufacture five consistencies and give each an identification number. A distinction is usually made between *cup greases,* which are intended to be used in compression grease cups, and *transmission greases,* which are often called *non-fluid oils.* Transmission greases are very soft and fluid and, as implied by their name, are intended to be used in automobile transmissions and rear-axle housings to furnish a suitable lubricant for their gears and bearings; they are entirely too fluid to be used in grease cups.

The viscosity of many cup greases is greatly affected by the temperature to which they are subjected, the greases becoming more fluid as the temperature rises and less fluid as it becomes lower. With such greases, a hard grade should be employed in summer, a medium grade in the spring and fall of the year, and a light grade in winter, in order that the grease may be fed freely from the grease cups. Some cup greases are affected but little by temperature changes, and then the same grade may be used all the year around.

The use of grease in transmissions and rear axles is not as common now as formerly, many automobile manufacturers recommending the use of a heavy, steam-engine cylinder oil instead. Ordinary, cheap, steam-engine cylinder oil is of little value as a lubricant for transmissions and rear axles; best results are usually obtained from a cylinder oil suitable for superheated steam and having a fire-test of about 600° F.

**15.** Some transmission greases are of a fibrous nature and cling to the gears with great tenacity; better results are usually obtained from such greases than from greases that are so fluid that they will drip at once from the gears. Greases that are so heavy that the gears simply cut a path through them are of no value in transmissions, etc.; by mixing them with gas-engine cylinder oil, however, their consistency can often be reduced so that they will give satisfactory service. A transmission grease that is too light to cling to the gear-teeth can be thickened by mixing it very thoroughly with a sufficient quantity of heavy cup grease. As a general rule, however, it will be more satisfactory to use a transmission grease of the right consistency than to attempt to obtain it by mixing as just described.

## LUBRICATING SYSTEMS AND DEVICES

### LUBRICATING FILM

**16.** The lubricant that is introduced between two bearing surfaces should form a film sufficiently thick to keep the surfaces separated. The pressure between the bearing surfaces tends to break the lubricating film down and to squeeze the lubricant out. The lubricant should therefore have a sufficient viscosity to maintain itself in the bearing. If a shaft carrying a weight revolves in a bearing, it tends to roll up on one side of the bearing so that the point of greatest pressure is a little to one side of the bottom of the bearing and the point of least pressure is diametrically opposite the point of greatest pressure. The lubricant tends to squeeze out at the point of greatest pressure, therefore it should be introduced at the point of least pressure, so that the revolving shaft will continuously carry a fresh supply of oil to the part of greatest pressure. If an oil has too little viscosity, the film of oil will break down and allow the metallic surfaces to come together. The bearing will then heat and it may be damaged. On the other hand, an oil may be too thick to enter the space between the surfaces of the bearing. The proper oil will, however, be carried into the bearing by the movement of the shaft so that the two surfaces are separated by a film of oil. There are four general systems of supplying oil to bearings. They are the *gravity system,* the *splash system,* the *force-feed system,* and the *combination system.*

### GRAVITY SYSTEM

**17.** In the **gravity system** of lubrication, the oil supply is contained in a cup or tank placed above the bearing. Sometimes the cup supplies oil for only one bearing and in other cases for a number of bearings. One of the simplest forms of gravity system is shown in Fig. 1. It consists of a cup *a* fitted with a central tube *b* and a removable cover *c*. The oil contained in the cup is led into the central tube by capillary attraction, a few strands of lamp wick, shown at *d*, carrying the oil over. The advantage of this oiling device is its simplicity; the disadvantages are its unreliability and its lack of adjustment of the oil feed. The latter can be adjusted to some degree by changing the number of strands of lamp wick; as the flow of oil is not in plain sight, however, there is always some doubt about the action of the lubricator.

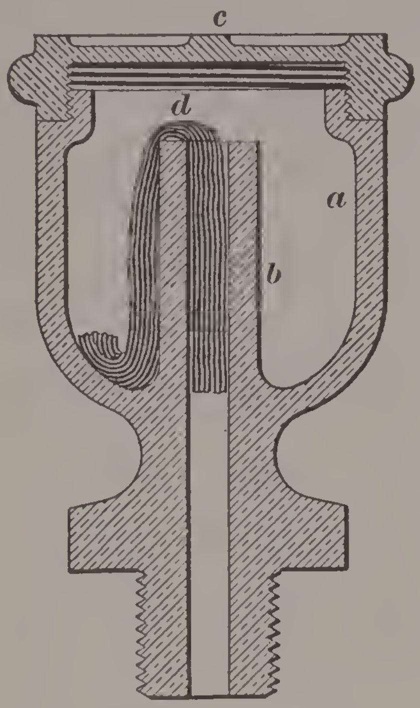


Fig. 1

**18.** The *sight-feed lubricator,* shown in Fig. 2, permits the regulation of the oil supply and the observation of the rate of flow. The glass cup *a* contains the oil, which flows out through the small hole at the lower end of the tube *b*. The amount of oil flowing to the bearing is controlled by a needle valve inside of the tube *b*. The needle valve is adjusted by the screw *c* which is set and locked in any desired position by the locknut *d*. The rate of feeding the oil to the bearing is visible in the sight-feed glass *e*. The cup may be filled through the hole in the top, which is then closed by the cover *f*.

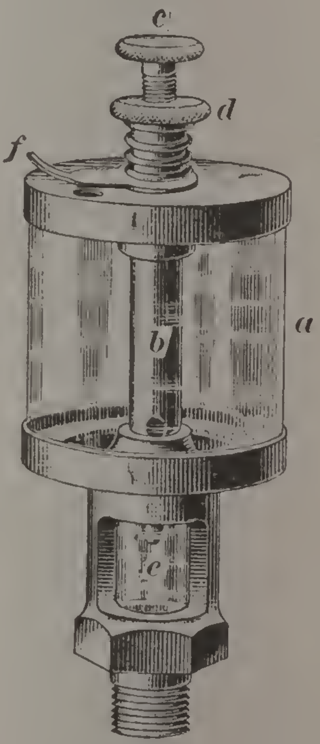


Fig. 2

The sight-feed oiler, shown in Fig. 3, is intended for use on gas-engine cylinders. In case of an excessive back pressure from the cylinder, the brass ball *a* will be raised against the seat above it, thus closing the passage. If the back pressure is not high enough to lift the ball, the gases will pass up through the tube *b,* which extends above the surface of the oil, permitting the pressure to be equalized. The lever *c* when down, closes the needle valve that regulates the feed, and the cup can easily be filled by sliding the cover *d* to one side. When the lever *c* is in a vertical position, the cup is feeding; the feed extending well into the large sight-feed glass *e* prevents the oil from adhering to or clouding the glass. The amount of feed is regulated by the thumb nut *f*, held in place by the spring *g*.

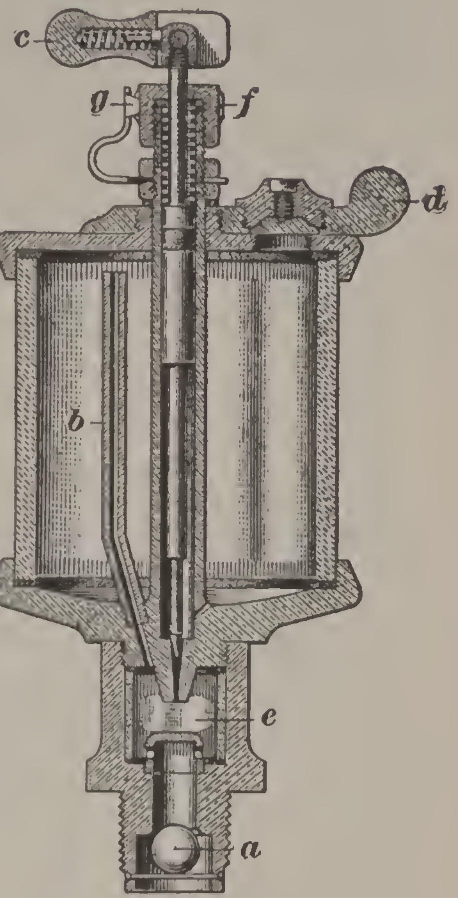


FIG. 3

**19.** A number of bearings may be oiled from one source, by means of an oiler such as shown in Fig. 4, which consists of an oil tank provided with a number of sight feeds. The oil tank is sometimes divided into two compartments, one of which may be used for cylinder oil and the other for bearing oil. Two filler holes are then provided, one for each compartment. The end *a* of the tank is made of glass, so that the level of the oil is readily visible, and a sight-feed outlet *b* is provided for each bearing and the flow of oil is controlled by the cam levers *c* in exactly the same way as in Fig. 3. Sometimes the sight feeds are provided with check-valves so that any of them can be used for the lubrication of the gas-engine cylinder; in other cases, only the sight feeds leading from one of the two compartments are provided with check-valves. Feeds that are provided with check-valves are always fitted with equalizing tubes to equalize the pressure above and below the oil in the reservoir.

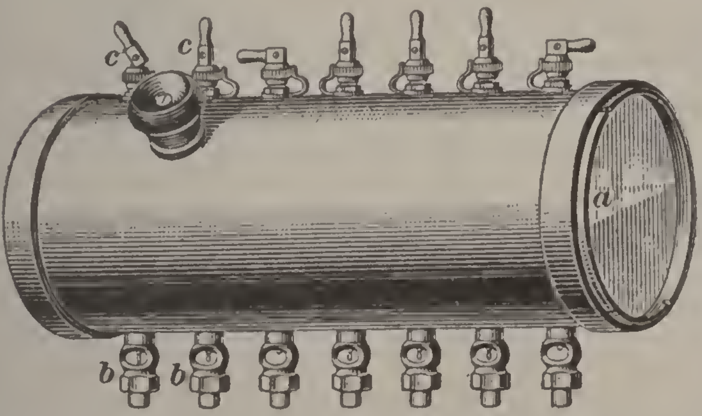


FIG. 4

### FORCE-FEED SYSTEM

**20.** In the **force-feed system** of lubrication, the required amount of oil is pumped to each bearing under a pressure sufficient to force the oil into the bearing. If there is little resistance to the passage of the oil, the pressure will not be high, but it will always be high enough to force a fixed quantity of oil into the bearing. The oil tank of a force-feed lubricator contains at least one pump for each bearing that is to be oiled. A pump such as is used for this purpose is shown in Fig. 5. The shaft *a* in the upper part of the oiler is rotated by the engine through the ratchet wheel *b*. Each oil pump, only one of which is shown, is driven by an eccentric *c* that is set at an angle on the shaft. The yoke *d* drives the pump plunger *e* which fits in the barrel *f*. Oil is delivered through the passage *g* to the pipe, not shown, attached at *h*, that leads to the bearing. The check-valve *i* prevents the oil from being forced or drawn back into the oiler, and the test plug *j* may be opened to see whether the oiler is working; but when the test plug is opened, no oil is delivered to the bearing. As the eccentric *c* is askew on the shaft, the plunger *e* has a rotary as well as an up-and-down motion. There is a slot *k* that registers with the opening to the passage *g* during the downward stroke of the plunger. The plunger is turned, when near the bottom of its stroke so that the slot *k* comes opposite the hole *l*, shown dotted, in the pump barrel, through which oil is then drawn during the

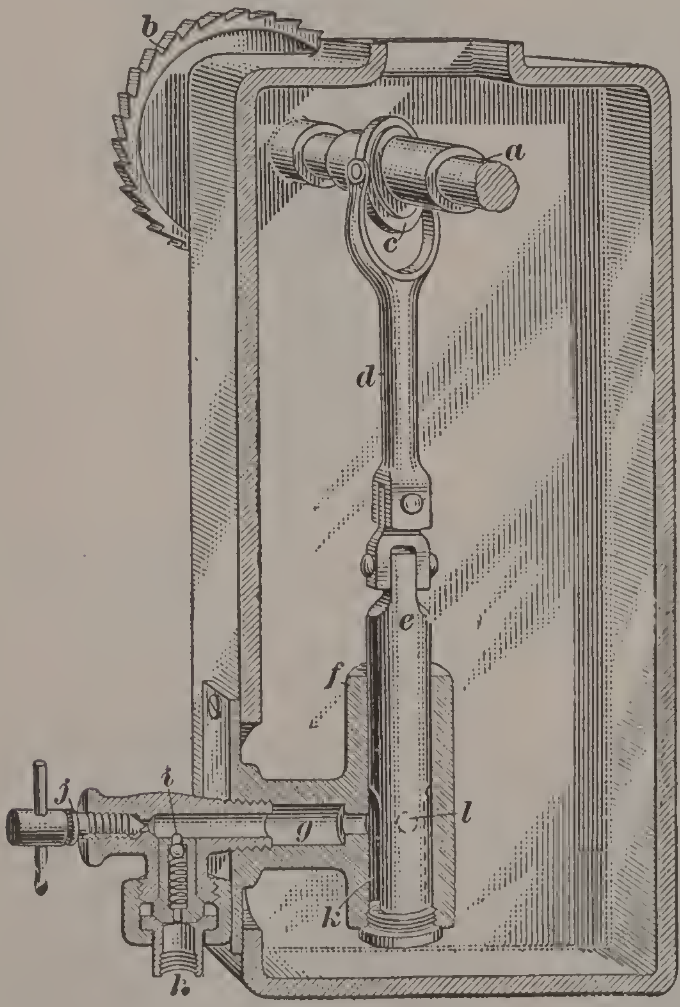


Fig. 5

upward stroke. At the top of the stroke, the slot *k* is turned back to the discharge opening. The eccentric is constructed so that the stroke of the pump can be adjusted to deliver the required amount of oil. Such an oiler can be fitted with sight feeds but the benefits of the force feed to the bearing are then lost, as the oil must flow by gravity from the sight feed to the bearing.

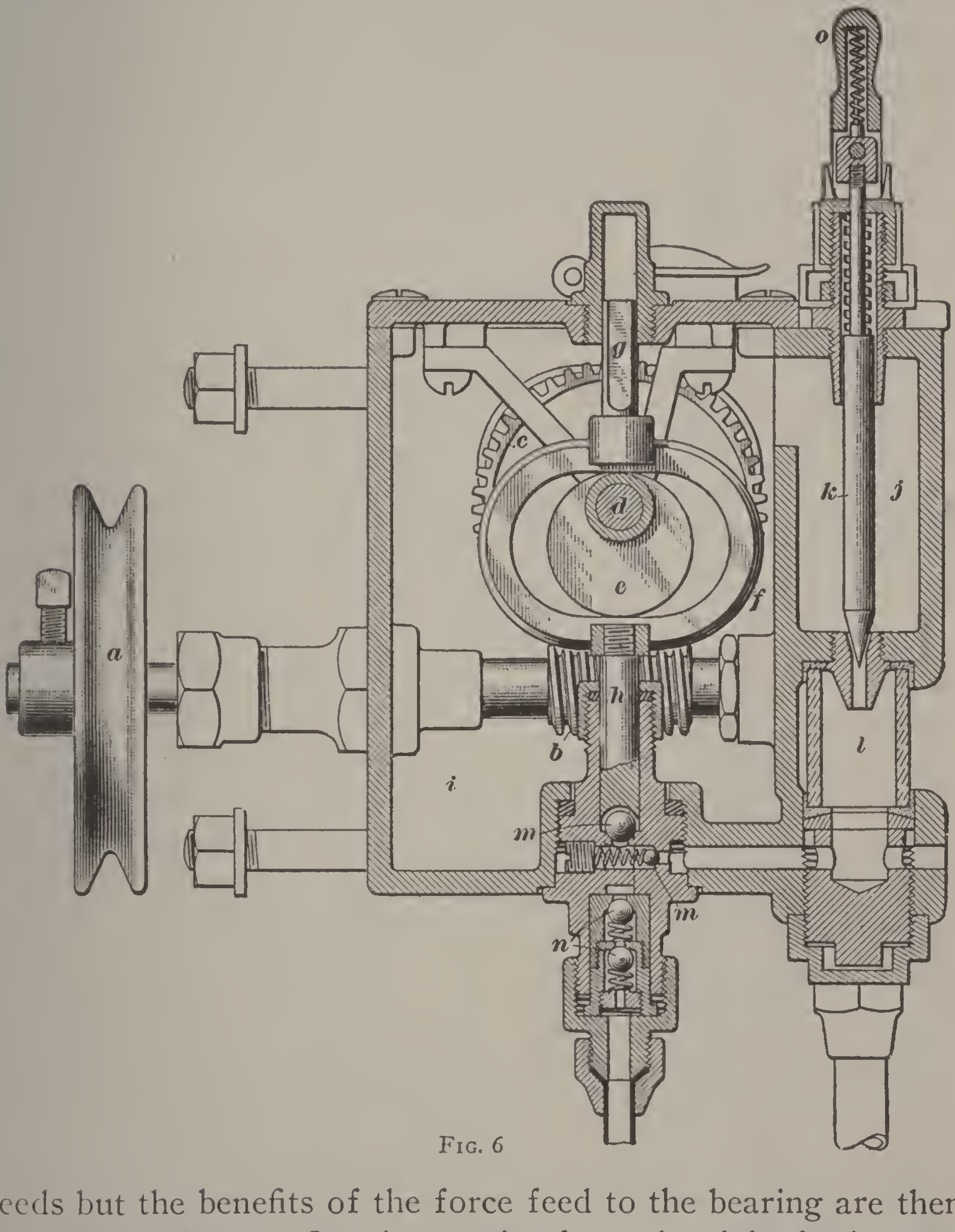


FIG. 6

**21.** An oiler that has sight feeds and force feed to the bearings used on stationary engines is shown in Fig. 6. The grooved pulley *a* is driven by a belt from any convenient shaft connected with the engine, and turns the worm *b* and worm-wheel *c,* the latter being mounted on the shaft *d.* Secured to this shaft are eccentrics *e,* whose number is one greater than the number of bearings to be supplied. These eccentrics work in oval-shaped yokes *f* that are guided by the square stems *g* above, which prevent the yokes from turning, and are connected below to the pump plungers *h.* One of these plungers, not shown, has a cross-section equal to all the others combined, and lifts the oil from the main reservoir *i* to the auxiliary reservoir, or oil space *j.* This oil space is separated from the chamber *i* by a partition, and if more oil is supplied to the oil space than the bearings take, it overflows into the chamber *i.* From the reservoir *j,* the oil flows down past the adjustable needle valves *k,* one for each bearing supplied, to and through the sight feeds *l,* and then to each pump barrel through the two ball check-valves *m,* the first a very small one working horizontally and closed by a spring, and the second working vertically and located directly under the plunger *h.*

**22.** On the down stroke of the plunger, the oil passes out through a passage shown by the dotted lines, and through the two small check-valves *n,* Fig. 6, each closed by a spring. The object of using two check-valves instead of one, both before and after the pump is reached, is to maintain the action of the pump, even if one valve should be put out of action by a particle of foreign matter. In case this occurs, the other check-valve will continue to act until the particle has been dislodged and passed on with the oil.

The oil pumps *h* are proportioned so that they can pump all of the oil that will pass through the needle valves and it is therefore impossible for oil to collect in the sight feeds. The oil feed may be shut off from any bearing at will, independently of the rest, by turning the cam-lever *o* into the horizontal position, thus closing the needle valve connected to it. Owing to the great reduction of speed produced by the use of the worm *b,* the action of the pump is very slow. It is, however, proportional to the speed of the engine, and in this respect the mechanical lubricator has an important advantage, since the average requirement of oil is roughly proportional to the engine speed.

**23.** An oiler having the sight feeds on top of the oil reservoir is shown in section in Fig. 7. This oiler is provided with as many oil-feeding units as there are bearings to be oiled, but in Fig. 7, only one unit is shown. The shaft *a* which extends through the oil reservoir *b* is rotated from a moving part of the engine through the ratchet wheel *c*. An outside crank is provided by which the oiler may also be operated by hand. Each oiling unit contains pump plungers *d* and *e*, which are connected by a yoke *f*, and are driven by the eccentric *g* through the crosshead *h* and the rod *i*. The plunger *d* raises the oil from the reservoir *b*, through a strainer, the pipe *o*, and ball valves to the sight feed *j*. From the sight feed, the oil is drawn by the plunger *e* through the passage *k* and delivered to the discharge pipe *l*, whence, it is carried to the bearing through suitable connections.

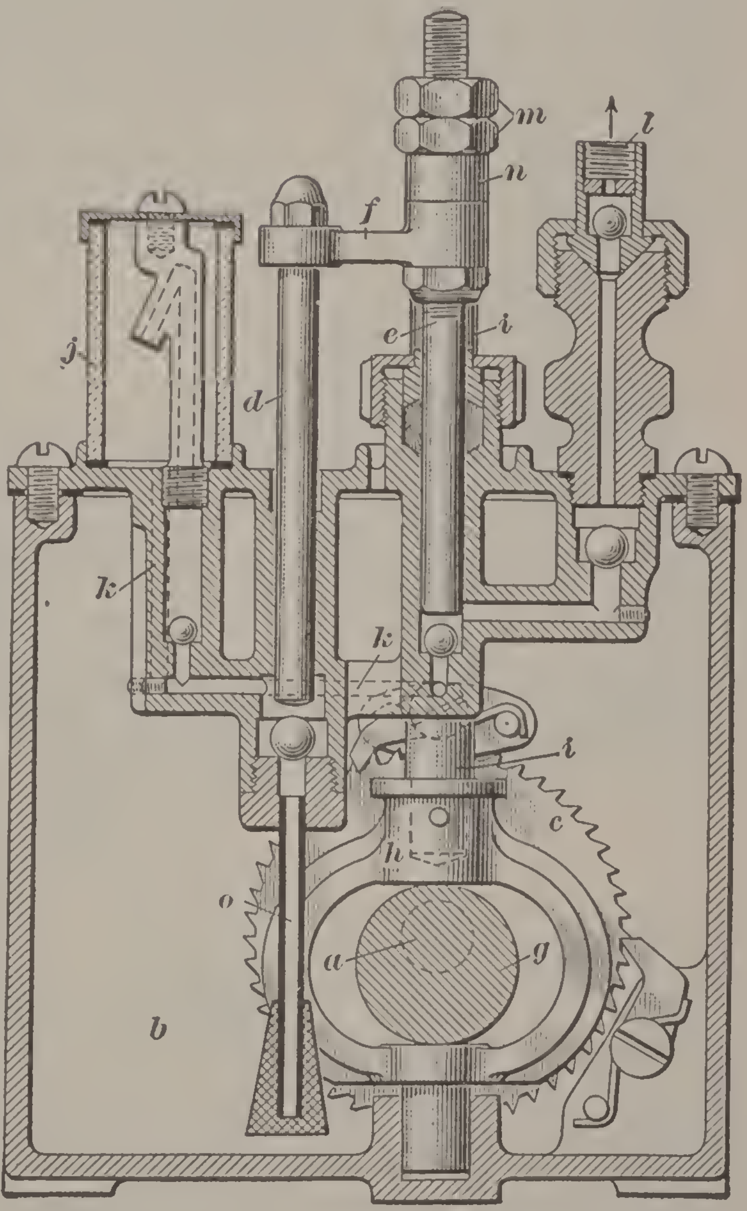


Fig. 7

The amount of oil supplied to each bearing is regulated by the position of the nuts *m*. When they are in the position shown, the stroke of the plungers will be equal to the throw of the eccentric *g*, but when the nuts are raised so that there is a space between them and the end of the arm *n* that is carried by the rod *i* and operates the plungers, the stroke of the plungers will be less than the throw of the eccentric. The greater this space, therefore, the less oil will be pumped.

### COMBINATION SYSTEMS

**24.** There are a number of lubricating systems that resemble one or another of the systems just described, but that include some different and distinctive features. For example, the system of ring oiling applied to the bearing shown in Fig. 8 (*a*) and (*b*) is a gravity-feed system in which the oil is supplied continuously from the oil chamber *a* by rings on the shaft. As the shaft *b* rotates, the ring *c* rolls over the top of the shaft, and the oil that adheres to the ring is thus carried up on the top of the shaft, from which point it is carried by the shaft to the bearing. Oil is supplied to the chamber *a* through the cup *d*. After leaving the surface of the journal, the oil flows down the end surface of the bushing *e* into the circular grooves *f*, and through the ports *g* back into the chamber *a*. When the oil becomes unfit for further use, the chamber is drained through the cock *h*. A glass gauge *i* indicates the amount of oil contained in the oil chamber.

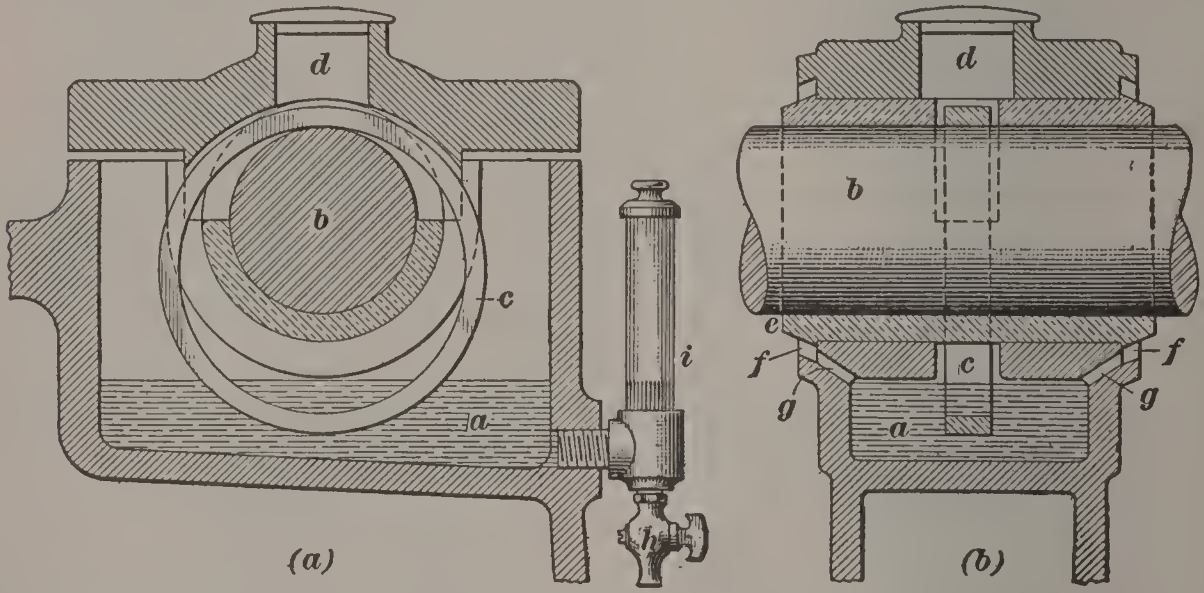


FIG. 8

**25.** Oil is frequently carried to the crankpin by centrifugal force. This method of crankpin oiling is shown in principle in Fig. 9. Oil from the sight-feed oiler flows through the tube *a* to the inside of the oil ring *b*, which is fastened to the face of the crank *c*. Centrifugal force then drives the oil out through the tube *d* and the holes *e* to the crankpin bearing.

**26.** Automobile and traction engines are usually built so that the oil drains from the various bearings into a common drip tank or reservoir placed below the lowest bearing. A pump driven by the engine draws oil from this reservoir and forces it to the various bearings. Sometimes the discharge from the pump is taken to a sight glass placed above the engine and in plain view of the operator. The oil flows by gravity from the sight glass to the various bearings. In this system of lubrication not much attempt is made to regulate the amount of oil supplied to the various bearings except to see that it is ample to prevent unnecessary heating and wear. When this system of lubrication is used, the oil gradually accumulates more or less dirt and small particles of metal so that it must from time to time be replaced with fresh clean oil.

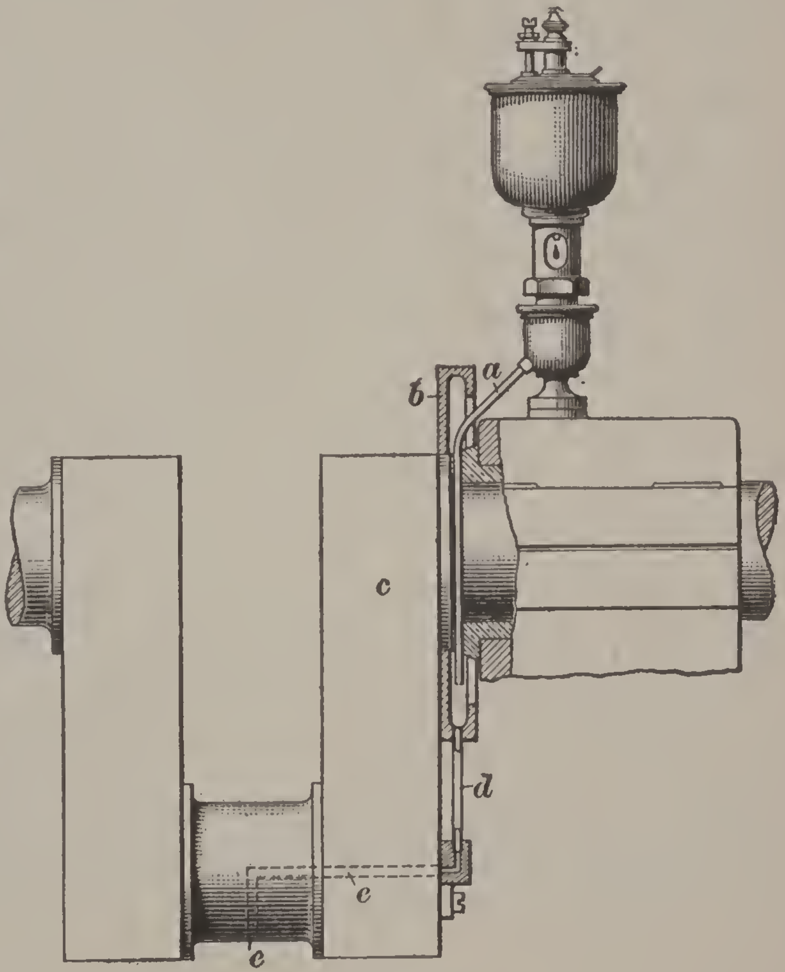


Fig. 9

**27.** Large stationary gas engines are sometimes lubricated by a system resembling the one just described but to which are added some features that are not adaptable to automobile and tractor conditions. The drips from all bearings are collected in a receiver, placed below the lowest bearing, from which they are pumped to the top of a filter tank. During its passage through the filter tank, the oil is filtered and cooled, so that, when drawn from the clean-oil storage chamber, the oil is ready for use again. The oil is pumped from the clean-oil storage chamber to a glass overflow tank where the amount of oil flowing can be observed. The overflow tank resembles somewhat a large sight-feed oil cup except that there is no sight feed. Three pipes enter the bottom of the overflow tank; one through which the clean oil is pumped into the tank, one through which the oil is distributed to the various bearings, and one through which the excess oil flows back to the clean-oil compartment in the filter tank. The end of the overflow pipe is placed so that the overflow tank is kept about half full of oil. The end of the inlet pipe is placed above the surface of the oil so that the operator can see that oil is being supplied. The pipe distributing oil to the bearings is placed at the bottom of the overflow tank so that, if necessary, all of the oil can be drawn off to the bearings. At the various bearings, the oil pipes are provided with one or more sight feeds, each of which has a needle valve with which to regulate the flow of oil. Oiling systems of this kind do not supply cylinder oil because but little of it can be returned for use the second time. Cylinders of large engines are therefore frequently oiled by such oilers as those shown in Figs. 6 and 7.

## AUTOMOBILE-ENGINE LUBRICATION

### CLASSIFICATION

**28.** The many different systems by which the moving parts of automobile engines are supplied constantly with oil while the engine is at work can be broadly divided into splash lubrication systems, pressure-feed lubrication systems, and combined splash-and-pressure-feed lubrication systems.

**29.** In the splash lubrication system, the lower part of the crank-case contains lubricating oil into which the lower ends of the connecting-rods dip at every revolution, churning the oil into a dense mist and throwing it all over the internal surfaces of the engine. The two common forms of this system are the circulating constant-level splash system, and the non-circulating constant-level splash system. In the *circulating constant-level splash system,* the oil is transferred from a reservoir, in much larger quantities than is needed, into troughs placed beneath the connecting-rods, from which troughs the oil overflows back to the reservoir, whence it is sent back to the troughs again. The oil is thus continually circulated. In some circulating constant-level splash systems, individual troughs are used, one being placed under each connecting-rod; the oil reservoir is then in the bottom of the crank-case and is open at the top. In other systems, the oil reservoir, when in the bottom of the crank-case, is closed on top by a horizontal partition in which the troughs are formed, each trough having an overflow through which surplus oil flows back to the reservoir.

The other class of splash lubrication system is spoken of as the *non-circulating constant-level system.* In this system, oil is taken from a reservoir by a pump and delivered, in the right quantity, to troughs into which the ends of the connecting-rods dip. The oil reservoir may form part of the crank-case or be entirely separate from it; the delivery of the pump is usually adjustable, and fresh oil is delivered to the splash troughs at all times, in which respect this system differs from the circulating system.

The circulating constant-level splash system is in use in the great majority of four- and six-cylinder engines. The non-circulating constant-level splash system is little used at the present time, as the chief exponents of this system have now gone over to the manufacture of eight-cylinder engines, on which the use of the splash system is not practicable.

**30.** In a **pressure-feed lubrication system,** as implied by the name, the oil is supplied to the rubbing surfaces under pressure. In the strictest sense, the oil would be supplied to all rubbing surfaces under pressure; as carried out, however, oil under pressure is usually supplied only to the crank-shaft main bearings, crankpins, wristpins, and timing gearing. The oil thrown off from the crankpins is usually relied upon to lubricate the cam-shafts, cylinders, and other rubbing surfaces. Pressure-feed lubrication systems are divided into two classes, the low-pressure lubrication system, and the high-pressure lubrication system.

In the low-pressure lubrication system, oil is raised either by a pump or other convenient means to an elevated position, whence it flows by gravity through individual tubes to the various bearings, and then drains to the bottom of the crank-case to be circulated again.

In the *high-pressure lubrication system,* oil is taken from a reservoir, usually in the bottom of the crank-case, and delivered by a pump or pumps under pressure ranging from 3 to 15 pounds per square inch to the various bearings; in racing cars much greater oil pressures are often used. In present-day practice, a single pump is employed, which discharges into a manifold from which branch pipes lead to the various bearings; individual pumps for each bearing have been employed, however, in many cars.

**31.** In **combined splash-and-pressure feed lubrication systems,** many different combinations of the various forms of splash and pressure systems are possible and have been used. One form employs pressure feed to the main crank-shaft bearings, the overflow from these bearings flowing into troughs below the connecting-rods, from which the crankpins, wristpins, cylinders, etc. are lubricated by splash lubrication. In another system, oil is supplied only to the cylinders under pressure; all the bearings are lubricated by the splash system. Other combinations than those given here may be used.

---

### SPLASH LUBRICATION SYSTEMS

**32.** A circulating constant-level splash system used in some engines is shown in Fig. 10. Other systems of this class differ in details of construction, but operate on the same general

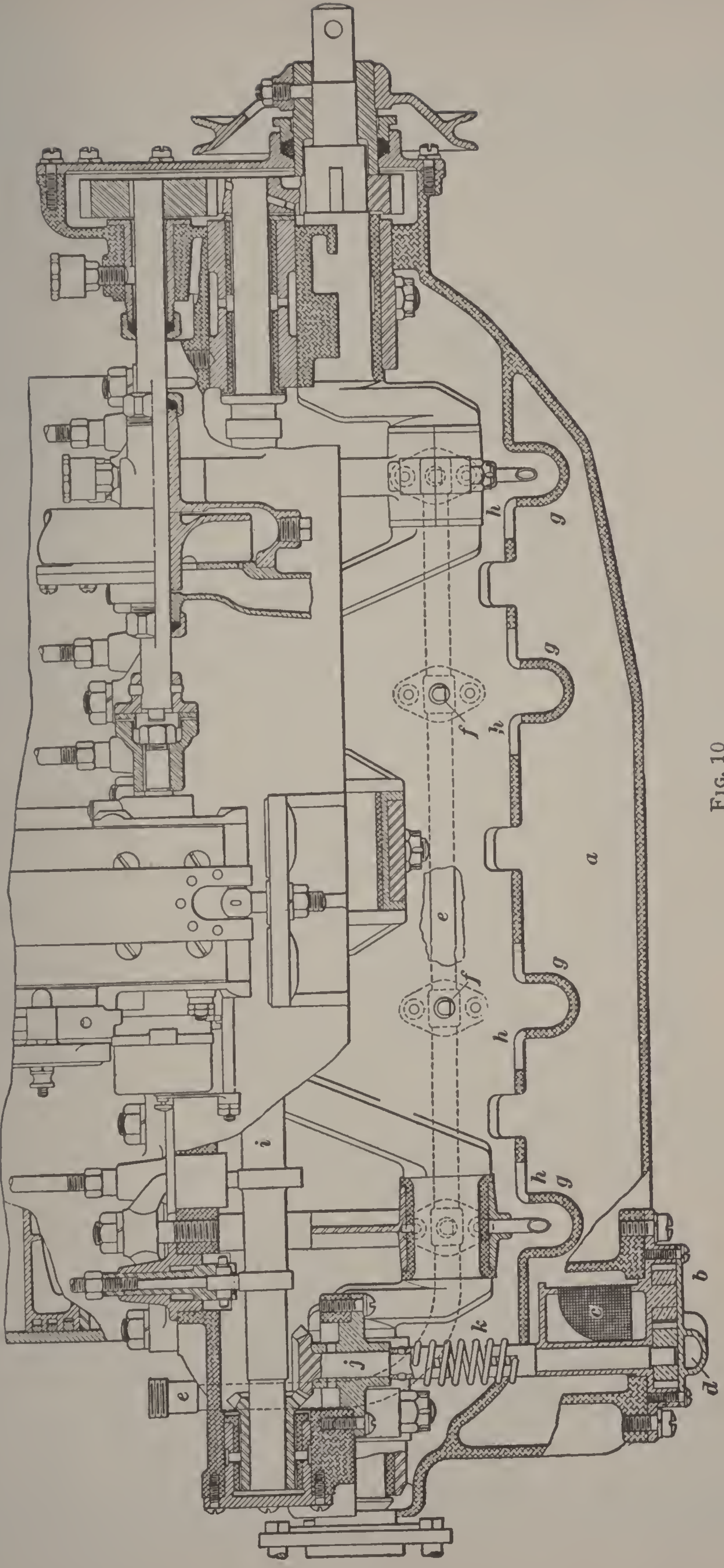


FIG. 10

principles. In this lubrication system, a gear-pump is employed for circulating the oil, but other forms of pumps could be used, and are used in other engines. The oil reservoir *a* is formed in the lower crank-case and has fitted to it, at its rear end, the oil pump *b*. The oil in the reservoir flows to the oil pump through a screen *c*, whereby it is strained, and is pumped through a pipe (not shown) connected to the passage *d* of the oil pump to a sight feed and then flows through the pipe *e*, which is on the outside of the left side of the crank-case, and four nozzles *f*, to the four oil troughs *g*. These oil troughs are formed in a horizontal partition and are located directly beneath the connecting-rods. The oil in the troughs is kept at a constant level by the oil pump delivering a larger quantity than is needed; the excess oil overflows the troughs through the openings *h* and drains back into the reservoir *a* to be circulated again. The oil pump in this case is driven from the engine cam-shaft *i* by bevel gears. The driving shaft *j* of the oil pump is made in two parts that are connected by a helical spring *k*, which acts as a universal joint and hence takes care of any lack of alinement between the two parts of the shaft. The driving shaft is made in two parts to permit quick and easy removal of the oil pump. The timing gears are lubricated by splash from the crank-case.

**33.** Non-circulating constant-level splash systems, as well as low-pressure systems, and combined splash and pressure-feed systems, have been largely superseded by the constant-level splash system, or the high-pressure system, and will therefore not be described in detail herein.

## HIGH-PRESSURE LUBRICATION SYSTEMS

**34.** Several American cars employ a pressure-feed oiling system in which the oil under quite a high pressure is delivered to the various crank-shaft bearings, and the oil thrown off of these bearings in the form of a fine mist is relied on to lubricate the cylinders and various parts of the engine. This system is used almost exclusively in the eight- and twelve-cylinder **V**-type engines, because with such engines, broadly speaking, the cylinders could not be equally lubricated by an ordinary splash system. With such a system, the connecting-rod ends would throw practically all the oil from the splash

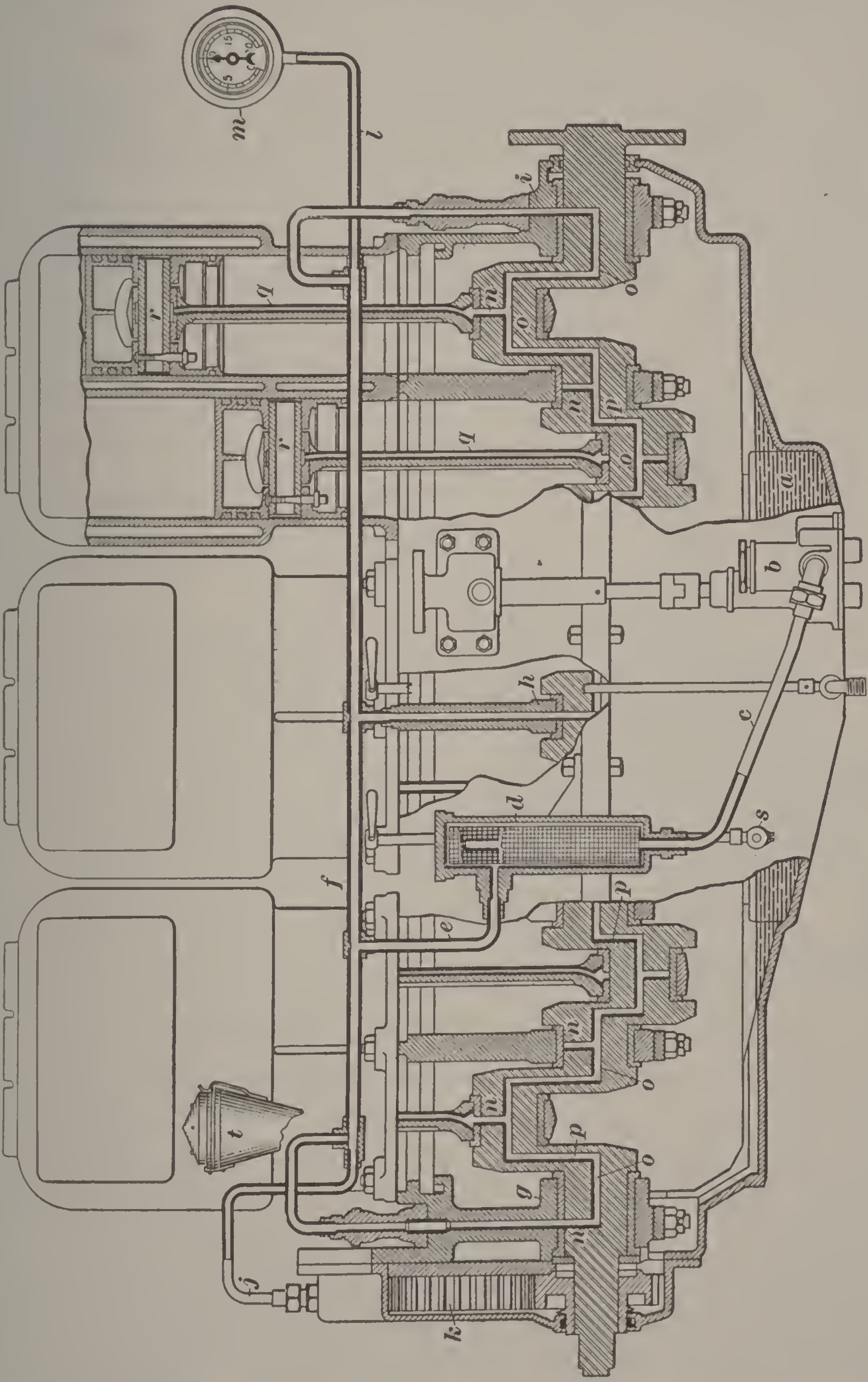


FIG. 11

troughs into the right-hand set of cylinders, the engine, as usual, running counter-clockwise when viewed from the driver's seat. For this reason, the left-hand set of cylinders would be under-oiled, and the right-hand set over-oiled.

**35.** A good example of a high-pressure lubrication system is shown in Fig. 11. The bottom of the lower crank-case forms an oil reservoir *a,* from which the oil is taken through a strainer by an oil pump *b* of the gear-type and discharged through the pipe *c* into a second oil strainer *d,* from which the oil passes through a pipe *e* into a distributing manifold *f*. This manifold, through distributing pipes, is connected to the forward bearing *g,* the middle bearing *h,* and the rear bearing *i* of the crank-shaft, which in the engine shown has seven main bearings. A pipe *j* leads from the manifold *f* to the timing gears *k,* and a pipe *l* leads to a pressure gauge *m* placed on the dashboard. The crank-shaft is drilled with radial holes *n* and axial holes *o* through the various journals; holes *p* in the crank-webs connect the axial holes *o*. From each crankpin end of the connecting-rods an oil tube *q* leads to the piston pins *r*. The excess oil drains back to the oil reservoir and is pumped back to the oil-distributing system. The oil reservoir is supposed to be kept filled to the level of the test cock *s*; it is filled through the funnel *t* and drained through the drain cock *u*.

**36.** In most pressure-feed lubrication systems of the high-pressure type and using a single pump, a *relief valve* is fitted; this valve can be adjusted by hand to any pressure that will produce satisfactory lubrication. Thus, if the engine smokes continually it is getting too much oil; the obvious remedy is to reduce the pressure in the oiling system until smoking ceases, which is done by adjusting the relief valve to open at a lower pressure. The relief valve acts by discharging some oil from the delivery side of the oil pump back to the suction side. In high-pressure lubrication systems in which an individual pump is used for each oil pipe, no relief valve is needed, as the delivery of each pump is made adjustable; this system is now quite rare in American practice.

### CYLINDER LUBRICATORS

**37.** When the oil is fed directly to the surface of the piston through the cylinder wall, the piston must be a little longer than the stroke, so that some portion of the piston will always be over the opening through which the oil enters; otherwise, the front or the back end of the piston will scrape the oil away, instead of working it between the piston and the cylinder wall. As the single-acting gas-engine piston serves also as a crosshead, it is always so long that this requirement is met. Oil is fed to the cylinders of horizontal stationary engines either from sight-feed oil cups or from some form of mechanical lubricator that delivers a fixed quantity of oil per revolution.

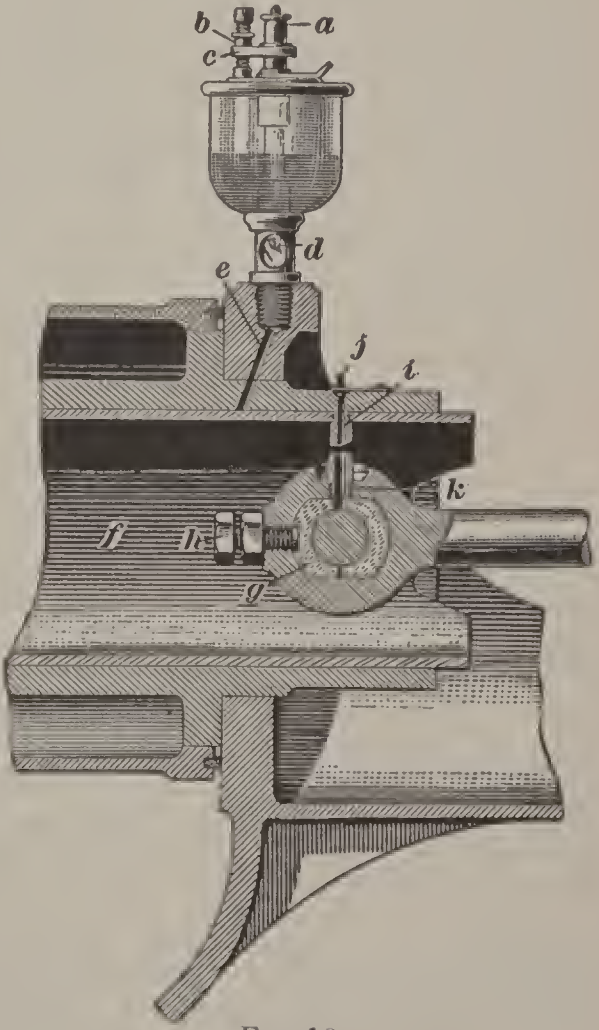


Fig. 12

**38. Sight-Feed Lubricator.** — When a sight-feed oiler is used, cylinder, piston, and piston pin may all receive their lubricating oil from the same adjustable sight-feed oiler, as shown in Fig. 12. After the glass cup has been filled, the supply is regulated by the valve stem *a*, so that about five to ten drops of oil are fed per minute. When the proper adjustment is obtained, the valve is locked by the jam nut *b*. In order to turn on or shut off the oil feed, the arm *c* is turned to one side, which can be done without disturbing the adjustment of the quantity of oil supplied to the piston. The sight glass *d* permits the operator to see whether or not the oiler is working properly. The oil passes through the hole *e* to the piston *f*, and is distributed over the surface by suitably cut oil grooves.

**39.** The piston pin is surrounded by the bronze bushing *g*, Fig. 12, and the wear is taken up by the screw *h*. Oil is supplied from the oiler to the piston pin through the tube *i* when it registers with the hole *c*, or by hand when it registers with the hole *j* in the cylinder wall. The oil tube *k*, in the connecting-rod head, receives the oil from the tube *i* in the piston, being directly below it. In order to be sure that the piston pin is well oiled from the start, the crank-shaft is turned until the piston has reached its outer dead center, when the tube *i* will register with the oil hole *j* in the cylinder wall and the oil tube *k* in the connecting-rod head. Oil can then be supplied by a hand oiler direct to the piston pin. While the engine is running, some of the oil supplied to the piston finds its way through the tube *i*, whence it is conveyed either direct to the tube *k* or to the countersink in the connecting-rod head, which communicates with the hole in the tube *k* through small holes drilled horizontally into the wall of the tube on a level with the bottom of the countersink.

**40. Pump Lubricator.**—Ordinary cylinder oil tends to grow thick in cold weather, and to avoid this disturbing influence on the rate of feed, mechanical oilers are often used, which have, instead of the arrangement just described, one or more positive pressure pumps that deliver a definite quantity of oil for each revolution. In the most approved form, these lubricators have one small pump for each cylinder supplied, and often have other pumps to feed the main bearings. The stroke of the pump may be adjusted according to the sort of oil used. Some device of this sort is always necessary for engines working under extreme variations of speed, since any other method of feeding the oil would give too much or too little, according to whether the engine was running slow or fast.

**41. Splash Lubricator.**—In many vertical engines, the oil is not fed to the piston directly as described, but is splashed to it by the cranks. This arrangement has the advantage that the same splash of oil may be made to lubricate practically all other parts of the motor, including the crank-shaft bearings, over which pockets may be cast in the crank-case to catch the oil. When the splash system of lubrication is used, the oil may be delivered to the crank-case by an automatic pump, but it is more common to feed it periodically by hand. In stationary engines, a gauge is often attached to the outside of the crank-case, which shows the level of the oil within. In these engines, the crank-case is large enough to hold oil sufficient for several days' service.

Splash lubrication is used only on vertical engines, because in horizontal engines it would be impossible to prevent an excessive quantity of oil from being carried into the cylinder, where it would cause smoke in the exhaust and cover the igniter with soot and clog the valves.

# BEARINGS

## SHAFT BEARINGS

### GENERAL CONSIDERATIONS

**42. Definitions.**—When it is the regular duty of a machine part to rotate, as when an axle or a shaft turns, it must be restrained or held at a definite place by a suitable support. A portion of the rotating part is in direct contact with the support that holds it and to which it fits. This contact portion of the rotating part is called the **journal,** and the part that surrounds and carries the journal is called the **bearing.**

When the bearing is made separate, it is called a **bushing,** or **sleeve,** if in one piece, and a **box,** if in two or more pieces. The term *bearing* is sometimes used, rather loosely, to mean both the journal and the bearing proper; the distinction made here, however, has the support of the best authorities.

**43. Metals for Bearings.**—Journals are commonly made of either iron or steel, while bearings are generally made of a softer metal. This is done for two reasons. There is less friction between a journal of hard metal and a soft-metal bearing than between two hard metals, and it is cheaper to repair or replace a worn bearing than a worn journal. The principal bearing metals are brass, bronze, and Babbitt metal, commonly called babbitt. Brass is an alloy of copper and zinc; it varies in color from a bright yellow to a dark copper color. Some brasses are quite soft, while others are too hard for use as bearings. Bronze is an alloy of copper and tin, though lead is also added, at times.

Since brass and bronze are so extensively used for bearings, it has become common practice to call the two parts of an ordinary brass or bronze bearing the *brasses*.

**44. Babbitt** is much softer than either brass or bronze. Its low melting point is an element of safety because the babbitt will melt and run out of the bearing before a temperature high enough to make the bearing seize and damage the journal has been reached. There are in general three kinds of babbitt. *Tin babbitt* is an allo yin which tin is the chief metal. This is frequently called *genuine babbitt,* though that must not be understood to mean that tin babbitt is necessarily any better than other babbitts. In fact there are certain uses for which it is not so well suited as are some of the other babbitts. Tin babbitt, as a rule, melts at a lower temperature than the other babbitts and it is very fluid when melted. Bearings lined with this metal may therefore have a thin lining.

*Zinc babbitts* contain so much zinc that its properties are more evident than are those of tin. Zinc babbitt melts at high temperature and is not very fluid when melted. Bearing linings made of this metal must therefore be rather thick which sometimes makes the bearings look rather cumbersome. This babbitt is tough and wears well.

*Lead babbitt* is composed of lead alloyed with small amounts of other metals to give certain desirable qualities. Lead babbitt is largely used because it is cheap. When a suitable grade of lead babbitt is used, it will be found to have satisfactory toughness and wearing qualities. Lead babbitts are of four grades, known respectively as Nos. 1, 2, 3, and 4, of which No. 1 is the hardest and No. 4 is the softest.

**45. Phosphor-bronze,** made according to the specifications of the Society of Automobile Engineers, is an alloy containing approximately 80 per cent. of copper, 10 per cent. of lead, 10 per cent. of tin, and a quantity of phosphorus not exceeding one-quarter of 1 per cent., nor less than five one-hundredths of 1 per cent. This bearing metal stands up well under heavy loads and lasts well even under scanty lubrication. In automobile engines, it is used for both cam-shaft and wrist-pin bearings and in other places where it may be in contact with a hardened-steel journal. The use of phosphor-bronze boxes in connection with soft-steel journals is inadvisable, owing to the rapid wear of the soft steel, even under ample lubrication, when this combination of box and journal exists.

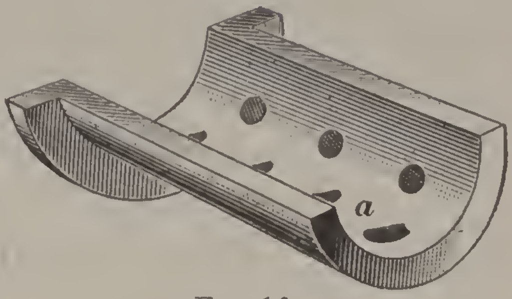


Fig. 13

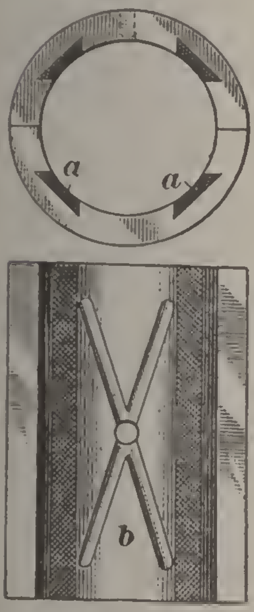


Fig. 14

**46. White brass** is an alloy that contains from 3 to 6 per cent. of copper, not less than 65 per cent. of tin, and from 28 to 30 per cent. of zinc. This alloy is often used for main crank-shaft bearings and for connecting-rod crankpin bearings, giving excellent results in conjunction with soft-steel journals when generously lubricated at all times.

**47.** Very excellent bearings are sometimes made by putting babbitt inserts over the inside surface of a brass box, as shown at *a*, in Fig. 13. Holes are drilled nearly through the brass and sometimes they are threaded roughly to give the babbitt plugs a hold, the threads being battered to keep the plugs from working loose.

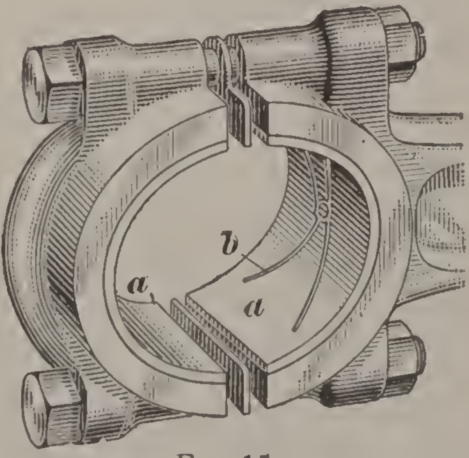


Fig. 15

The bearing shown in Fig. 14 also has babbitt inserts. In this bearing, the babbitt is held in dovetailed slots *a* which sometimes run spirally around the bearing. Some bearings have full babbitt linings as shown in Fig. 15 at *a*. Sometimes the babbitt lining is cast in the bearing and at other times it is cast separately and fastened in the bearing with screws. When the lining is cast in the bearing, the lining must be fastened to the bearing. This may be done by drilling holes at intervals in the bearing, as shown in Fig. 13, and threading the holes to give the babbitt a hold, or by making one or more dovetailed slots in the bearing.

## OIL GROOVES IN BEARINGS

**48. Form and Arrangement of Grooves.**—To insure uniform distribution of the lubricant over the bearing surface, it is common practice to cut oil grooves in the surface, especially when the bearing is to sustain heavy pressures. In a long bearing, a shallow straight groove is cut extending each way from the oil hole or holes to within ½ inch of each end of the bearing cap. In some bearings the grooves are arranged in **H** shape, in others in **X** shape as at *b* in Figs. 14 and 15, and sometimes in **V** shape. They are semicircular in cross-section, and the oil or grease flows toward the outer ends, lubricating the journal.

In stationary gas engines, it is good practice to provide grooves in bearings that are 6 inches long or over. In bearings less than 6 inches long provided with a single oil hole, the chamfering of the edges where the two parts of the bearing come together is depended on to distribute the oil, and no oil grooves are required.

**49. Lubrication of Plain Bearings.**—The lubricant is supplied to the bearing in a liquid form, and it flows through channels provided for it. Grease is rather plastic, especially when cold, and needs to be forced into the bearing. This is done by the use of an automatic grease cup having a spring-loaded piston, attached to the cover, that forces the grease down. When the bearing becomes warm, the grease becomes more fluid, and flows to the rubbing surfaces more rapidly.

**50.** Oil should always be fed to a bearing on the unloaded side, and the oil grooves in a bearing should be on that side. It is a somewhat common but poor practice to cut oil grooves in the loaded side of a bearing. The effect of this arrangement is that the oil is squeezed out from the bearing under the load. If the oil is supplied in abundance to the unloaded side of the bearing, it will be carried around by the turning of the shaft. In oiling systems in which the oil is fed rapidly to a bearing, and is collected and used over again after it works out, the best plan is not to extend the oil grooves the length of the bearing, as is often done, but to limit the grooves to about one-half of the length of the bearing and locate them as near the middle as possible. This will cause the oil to flush the bearing continually as it works out at the ends, thereby carrying with it the metal worn from the bearing surfaces.

**51.** It is particularly common to find the crankpin brasses grooved on the pressure side as well as on the cap side, the reason generally being that, when the splash system is used the oil is introduced on this side. If trouble is experienced with crankpin bearings arranged in this manner, in a vertical motor with splash lubrication, it will be well to fill up the grooves in the pressure brass with solder, and supply the oil wholly through the bottom brass. To do this, a hole should be drilled and tapped in the cap for a piece of brass tubing $\frac{5}{16}$ inch outside diameter, as shown in Fig. 16. The tube *a* should be bent so that, when it dips into the oil on the bottom swing of the crank, it will act as a scoop, and the lower end of it is preferably beveled off as the sketch indicates, so as to give an elongated opening. The tube is firmly fastened in the cap *b*, and the brass *c* has an oil hole *d* about $\frac{5}{16}$ inch in diameter

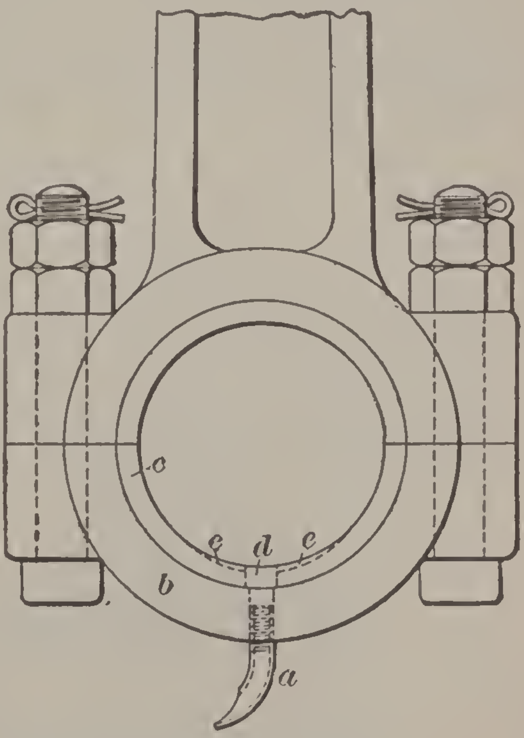


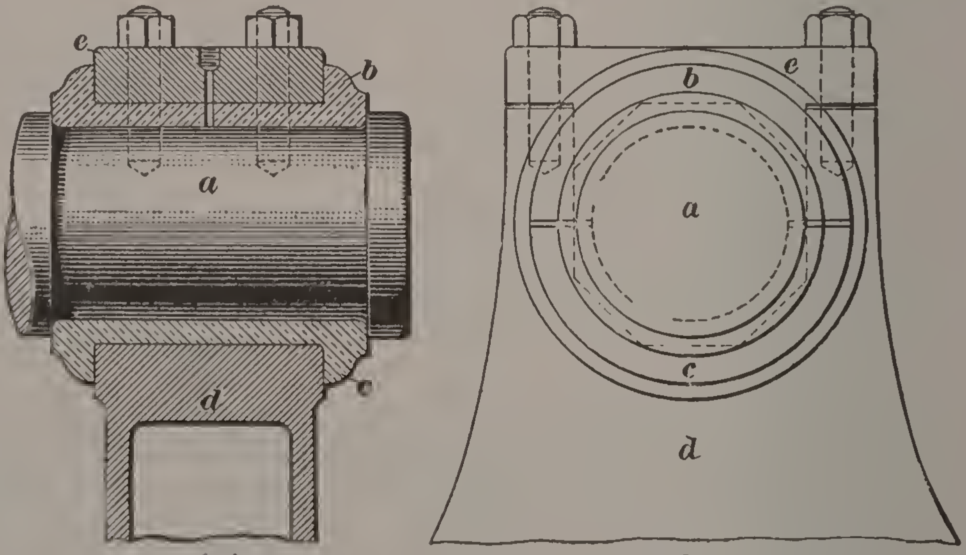
Fig. 16

drilled through it, connecting with a deep, cross-shaped groove *e*. On the bottom swing, the oil will be scooped up into the groove, which will retain enough of it during the remainder of the revolution to lubricate the bearing. Another arrangement is to cut a square hole through the cap brass, and fill it with a felt pad a little thicker than the brass itself, so that it will be under slight compression. This pad will absorb the oil and transmit it to the bearing. Unless provision is made by one of these methods for retaining the oil as it comes up, it is likely to be thrown out by centrifugal force. Practically all modern automobile engines depending on the splash system for their lubrication, have a small projection made on the large end of the connecting-rod to assist in the lubrication of the connecting-rod bearing, and also to increase the force of the splash.

---

## TYPES OF BEARINGS

**52. Classification of Main Bearings.**—The oldest and simplest form of bearing used in gas-engine practice is the **plain bearing,** in which the journal of the shaft fits in a sleeve called the *bearing,* or *box,* and touches the supporting surface along its entire length. A type closely related to the plain bearing is the **ring-oiled bearing,** in which oil is carried to the journal by means of a ring, as already described. In **roller bearings,** rollers are interposed between the bearing and the journal, thus reducing the bearing surface and having



(a) (b)

FIG. 17

rolling instead of sliding friction. In **ball bearings,** a number of balls surround the journal and lie between it and the bearing proper. Each ball thus touches the journal and the bearing surface in single points, instead of along lines. There is rolling friction, however, and the frictional resistance is much less than in ordinary bearings.

**53. Plain Bearing.**—The earliest bearings were of the plain type, and probably more bearings of this type are used than of any other. A plain bearing is shown in Fig. 17, which in (*a*) shows a section through the axis of the journal, and in (*b*) an end view. The journal is shown at *a* and the brasses at *b* and *c*. The bearing is divided into two parts, the lower, which shows a part of the frame or pedestal *d*, and the upper part *e*, known as the *cap*. A plain bearing will give excellent results when well made and properly fitted. When worn, new brasses can be fitted and the bearing will be as good as when new. The brasses of a plain bearing may be provided with babbitt inserts or linings as shown in Figs. 13, 14, and 15. Plain bearings are usually lubricated by allowing oil to flow between the rubbing surfaces by gravity from an oil cup.

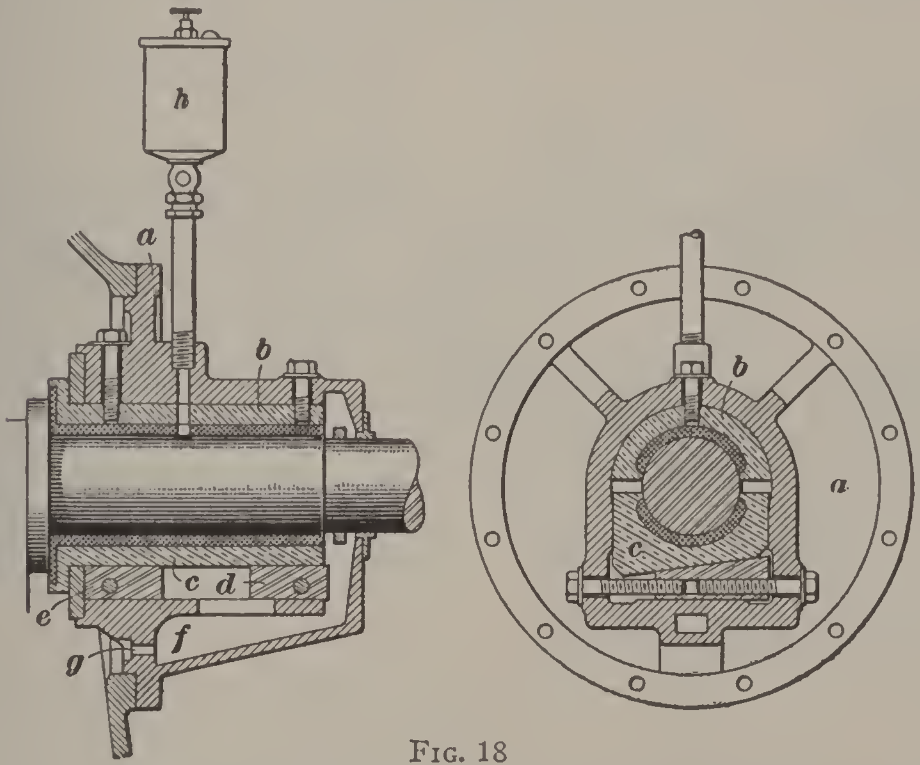


Fig. 18

**54. End-Plate Main Bearing.**—In Fig. 18 is shown a plain main bearing as used in a vertical engine. The box is made in two parts, of brass or bronze, and is lined with babbitt. The end plate *a* is circular and turned to fit the opening in the crank-case, to which it is bolted. The upper brass *b* is held in a central position on the shaft by two capscrews. There is little or no pressure on this brass, hence it does not wear; its duty is to prevent the shaft from lifting off the lower bearing and to aid in the distribution of the oil. The lower brass *c* is held in position by the weight of the shaft and the wedges *d* and *e*, which also serve to adjust the brass to the shaft so as to give as even a bearing between the shaft and the lower brass as possible. The screws on either side of each wedge are for the purpose of moving the wedges laterally to adjust the brass and also to hold the wedges in position when once properly adjusted. The chamber *f* below the bearing catches the surplus oil, and the hole *g* permits it to flow to the crank-case. Any surplus oil in the crank-case is drained off to a purifier or filter.

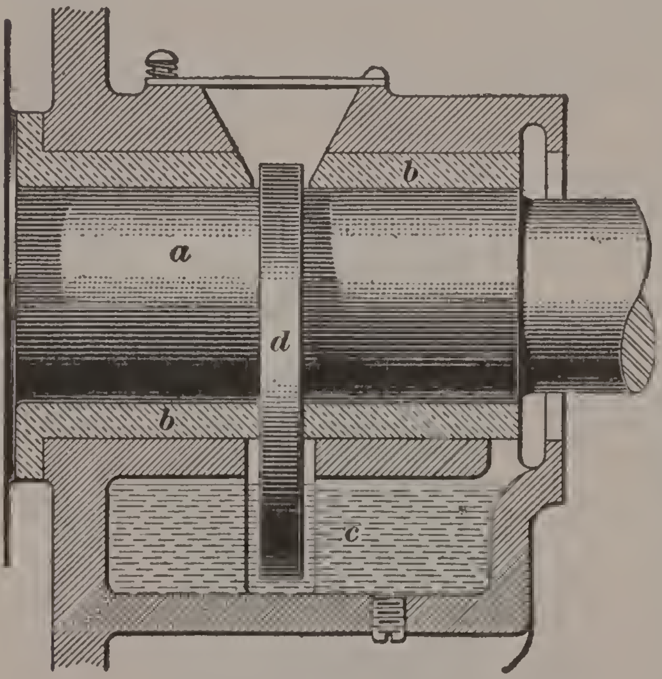


Fig. 19

The adjustment of the lower brass permits the alinement of the shaft to be maintained. Any wear of the journal or bearing can be easily and quickly taken up by changing the position of the wedges. The bearing is oiled by means of the sight-feed lubricator shown at *h*.

**55. Ring-Oiled Bearing.** — A ring-oiled bearing is shown in Fig. 19, with the journal at *a* and the brass sleeve at *b*. An important part of this bearing is the oil reservoir *c* below the bearing, and the ring *d* that rests on the journal and extends down into the oil. The ring is narrow and light, and when the engine is running, the upper part of the ring moves with the shaft; so that the lower part picks up the oil and raises it to the top of the shaft. By this means, a good supply of oil is continually brought to the journal, keeping it well lubricated. Light chains are sometimes used for such work, instead of rings, and they have the advantage that they may be put in place when the shaft is in the bearing.

**56. Roller Bearings.**—There are three types of rollers used in roller bearings, the plain cylindrical, the spiral, and the conical. The **plain cylindrical** roller bearing consists of a set of cylindrical rollers between the journal and a casing, or between a sleeve and a casing, as shown in Fig. 20. This bearing is made up of a cage *a*, with rollers *b* extending nearly the whole length, a casing *d* outside the rollers, and a sleeve *e* inside. The cage simply holds the rollers, and does not come in contact with the sleeve *e*. The ends of the rollers are provided with balls *c*, which reduce the friction and wear, and keep the rollers in true alinement with the shaft. This prevents all twisting of the bearing, and makes it more reliable and satisfactory.

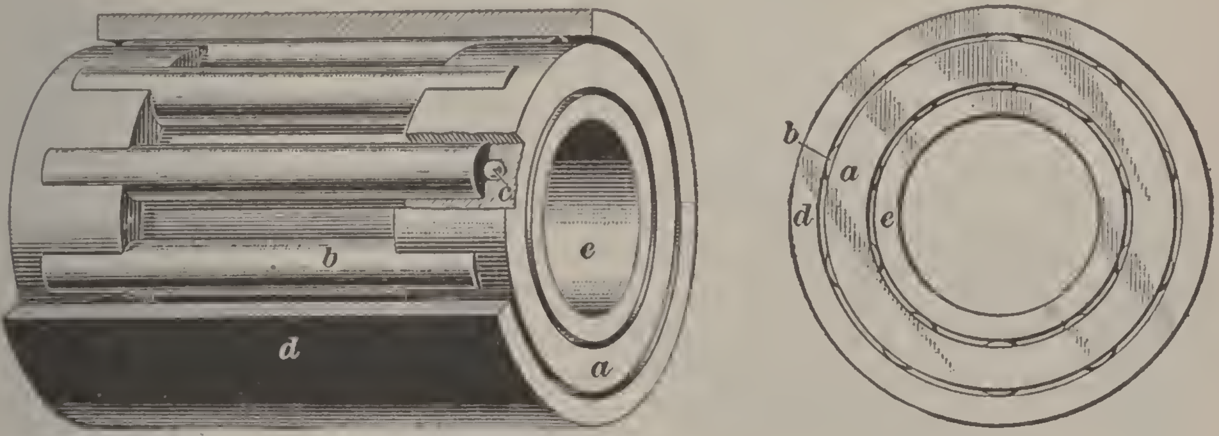


FIG. 20

The roller bearing will not sustain as much of a load for the same size of journal as will the plain bearing. It will, however, reduce the friction for light or moderate loads when running at moderate speed. The plain rollers for bearings are made either hollow or solid, with the ends hollowed out for the supports that hold them in place. Solid rollers are cheaply made, and will sustain more weight than hollow rollers of the same size.

**57.** A **spiral roller bearing** is shown disassembled in Fig. 21. The rollers *a* are wound helically from flat steel and are ground cylindrical after hardening. They are set in a cage *b* made of two washers properly spaced by ribs *c*, to which the washers are securely riveted. Projections *d* on each washer enter the ends of the rollers and thus prevent them from falling out of the cage. The rollers are sometimes run directly on the journal and the box of the bearing; in better work, both the journal and the box are protected by removable liners. A liner for the journal is shown at *e*, and a liner for the box at *f*. These liners are formed from soft sheet steel, and since they are split as shown, they are easily forced into place or removed when worn enough to need replacement. The outer liner should be held from turning in the box by making the conical projection *g* enter a hole drilled for this purpose into the box.

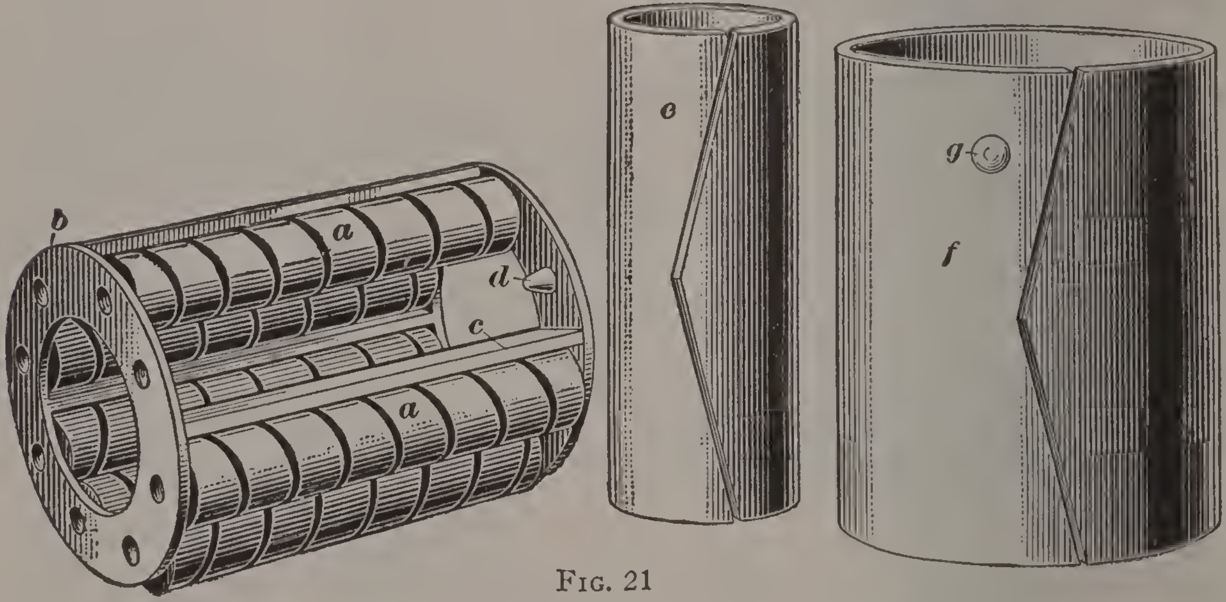
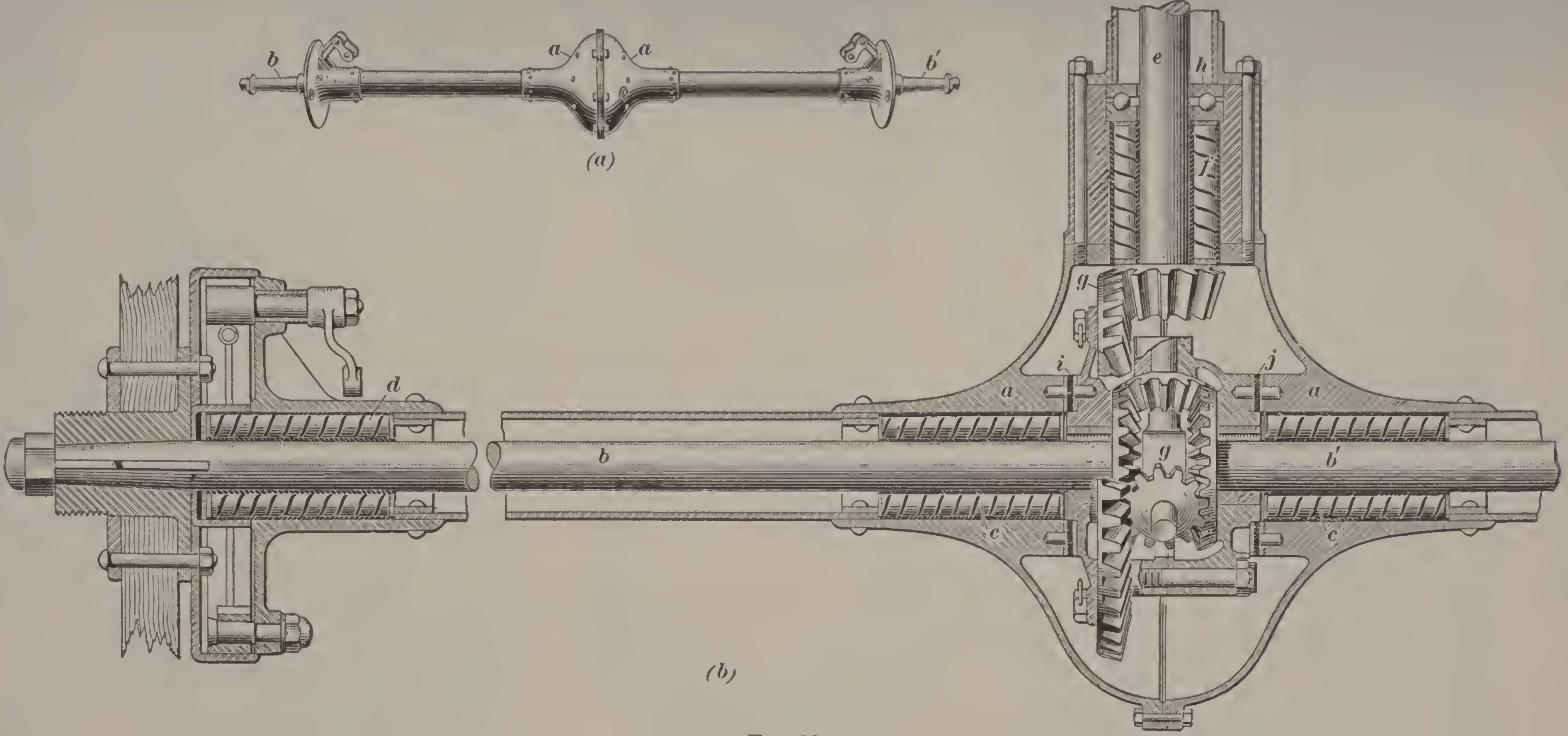


FIG. 21

A liner for the journal is often omitted; when the metal of the journal is very soft, however, a case-hardened steel liner is necessary. This liner may have the form shown at *e* or it may be in the form of a solid bushing that is pressed on the journal. Likewise, the outer liner may be in the form of a solid bushing.

**58.** The rear axle of an automobile, shown in Fig. 22, illustrates the use of roller bearings in practice. In the small view (*a*) is shown the external appearance of the axle and in (*b*) the interior construction. The two views are not shown to the same scale but when a part appears in the two views, the same reference letter is given. The housing *a* encloses the whole axle, keeps the dust out and holds a quantity of oil or



(a)

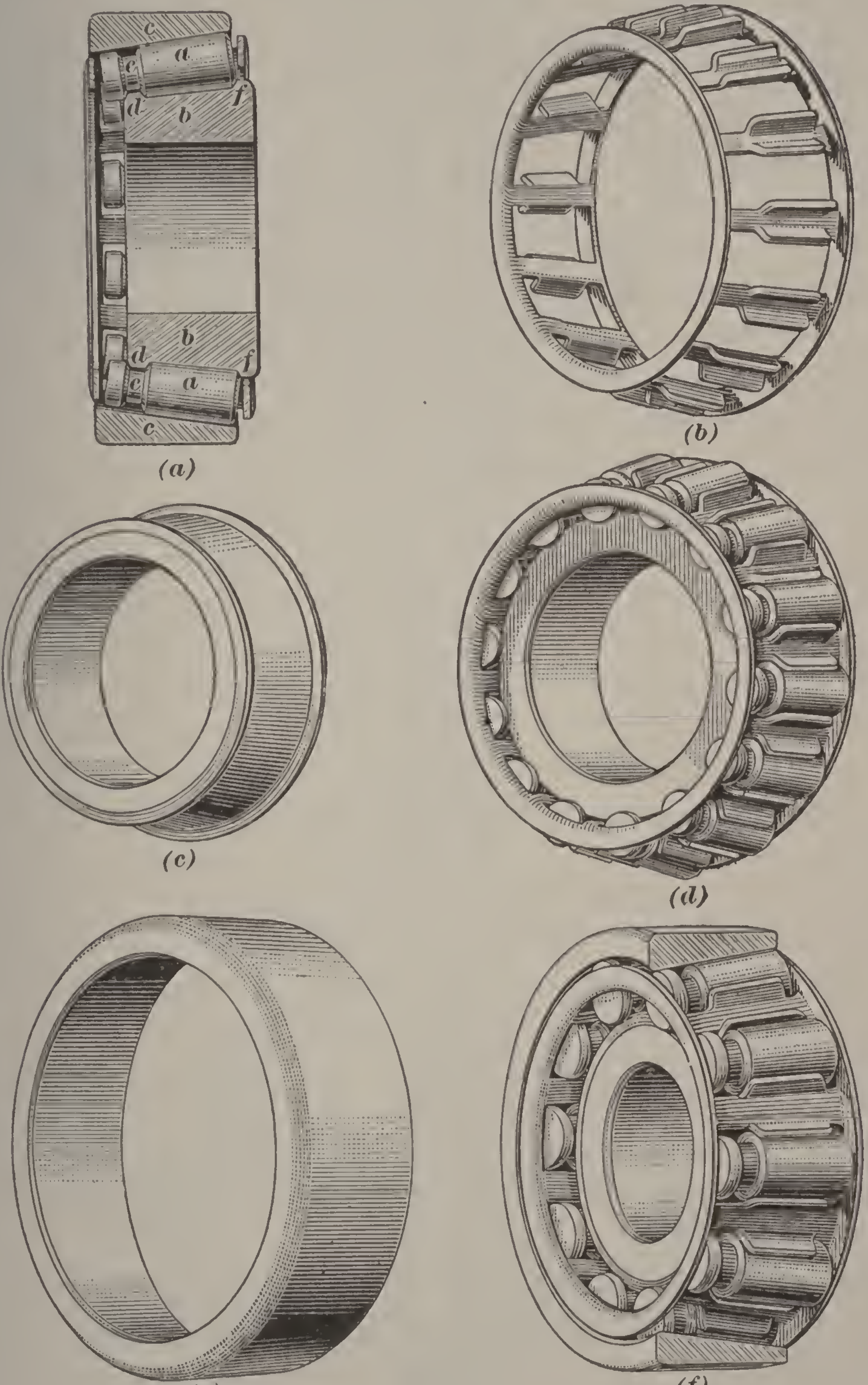
(b)

FIG. 22

grease for purposes of lubrication. The axle shaft is in two parts *b* and *b′* each of which is supported in two roller bearings *c* and *d*. Power is transmitted to the axle through the propeller shaft *e*, which runs in a roller bearing *f*, and drives the differential gears *g*. There is a thrust that tends to force the propeller shaft and each part of the axle shaft away from the differential. This thrust is counteracted by three thrust bearings *h*, *i*, and *j*. The bearing at *h* is a ball thrust bearing but the bearings at *i* and *j* are plain babbitt rings. The axle housing is kept partly filled with grease in which the gears run and which works out to the other bearings. The bearing *d* at the end of the axle does not always receive sufficient lubrication from this source and a small grease cup, not shown, which makes up the deficiency, is put on each end of the axle.

**59.** A **conical-roller bearing,** as implied by the name, employs conical, or tapered, rollers, that is, rollers that are frustums of cones, running in contact with tapered inner and outer races. A bearing of this form, widely used in automobile work, is shown in Fig. 23. In (*a*) is shown a section through the inner and outer race with a roller *a* between the conical (tapered) surfaces of the inner race *b* and the outer race *c*. The inner race is cylindrical on its inside, and the outer race on its outside. The inner race has two ribs with conical sides, the rib *d* entering a corresponding groove *e* in the small end of the roller *a*. The conical face of the rib *f* bears against the conical large end of the roller, as shown. The ribs *d* and *f*, in conjunction with a cage in which the rollers are set, hold the rollers in proper alinement with the races. The cage is shown separately in (*b*); it is pressed in one piece from sheet steel into the form shown. The inner race is shown in perspective in view (*c*), and assembled with the cage and rollers, in (*d*). When thus assembled, the inner race, cage, and rollers cannot separate. The outer race is shown separately in (*e*), and the whole bearing assembled in (*f*).

The outer and inner races have their bearing surfaces formed as frustums of cones whose apexes coincide and lie on the center line of the journal; the center lines of the rollers lie on the surface of a cone whose apex coincides with that of the inner and outer races, and consequently the rollers have a true



(a) (b) (c) (d) (e) (f)

Fig. 23

rolling motion. As in cylindrical roller bearings, the cage for the rollers prevents their sidewise displacement.

A tapered roller bearing carries radial and axial loads, and any radial looseness due to wear is readily taken up by forcing the inner race farther into the outer race. This form of bearing is always mounted so as to permit this operation to be easily done. The races and rollers are made of hardened steel and are very accurately ground after hardening. Tapered roller bearings are largely used in the construction of rear axles.

**60.** The use of the conical-roller bearing in the rear axle construction of an automobile is shown in Fig. 24. The axle shaft *a* is made in two parts, as is the common custom, and the two outer ends of the axle shafts are supported by the roller bearings *b* placed on the inside of the ends of the rear axle housing *c*. The whole differential *d*, including the driving gear *e* riveted to the differential housing *f*, instead of being carried by the axle shaft is supported by its own bearings *g*, one on each side, the bearings being placed in this case in the removable differential carrier *h*, which is bolted to the rear-axle housing. The inner ends of the halves of the axle shaft are *splined*, that is, have a number of rectangular keyways cut into them, and enter the correspondingly splined hubs of the differential side gears *i*, which drive the halves of the axle shaft. While the inner axle-shaft ends are splined in this case, some manufacturers use squared ends entering squared holes of the differential side-gear hubs, but in neither case are the inner axle ends rigidly fastened to the differential side gears as is the case with the plain live axle. The bevel driving pinion *j* tends to thrust the whole differential to the left; this thrust is resisted by the left bearing *g*, which being a tapered roller bearing is adapted in itself for carrying thrust loads.

**61. Ball Bearings.**—A ball bearing consists of at least three elements, an inner casing, known as the *inner race*, an outer casing, known as the *outer race*, and one or more rows of balls. The inner race is attached to the shaft, and forms the journal; the outer race is attached to the bearing housing, and serves as a box; the balls provide for the rolling friction.

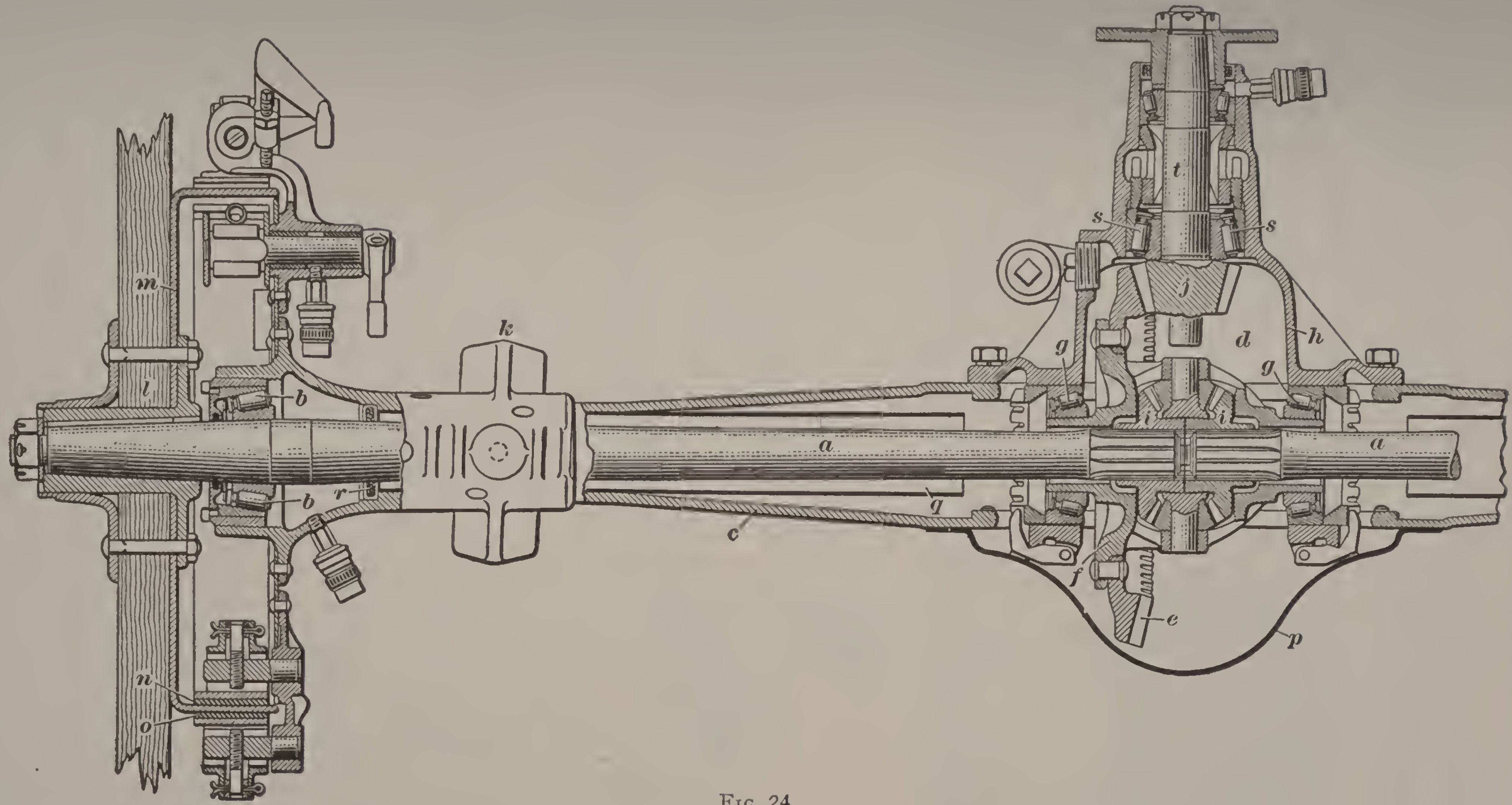
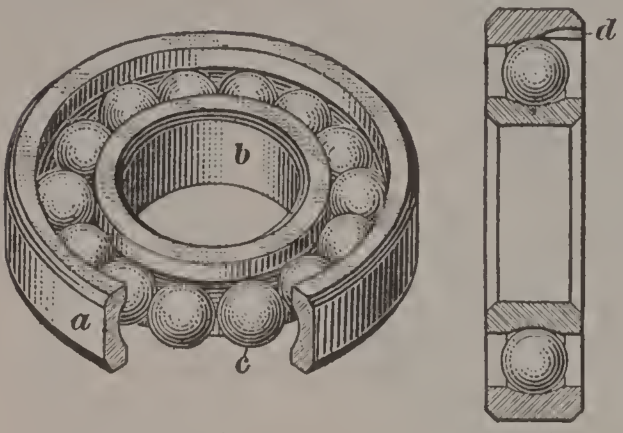


FIG. 24

**62.** A typical ball bearing is shown in Fig. 25 (*a*), in which illustration part of the outer race *a* is cut away in order to show the assembly. The outer race *a* and the inner race *b* are grooved to a larger radius than that of the balls *c* in order that the balls may be in contact with each race at a single point in the same plane as the centers of the balls. The balls are introduced between the races through a slot in the outer race, which slot cannot be seen in view (*a*), but is indicated at *d* in the cross-section shown in (*b*).



(*a*) (*b*)

Fig. 25

#### TAKING UP WEAR IN BEARINGS

**63.** Some forms of connecting-rods are provided with means of taking up wear on the bearings by the use of *shims,* or thin strips of copper or brass, which are interposed between the large end of the connecting-rod and the bearing cap. The cap is bolted down tight against these shims, and when the bearing becomes worn one or more shims are taken out on each side. Provided that the bearing has not been cut and is not badly worn out of shape, this will take up the wear satisfactorily. Care must be taken to remove shims of the same number or thickness from each side of the bearing. After the bolts are tightened there must be not the slightest evidence of tightness or binding in the bearings; for if there is, the oil will squeeze out and the bearing will begin to overheat and cut.

If the crankpin bearing is not provided with shims, it becomes necessary to file the flat face of the cap where it abuts against the large end of the rod, in order to close up the bearing. This must be done with great care, in order to avoid taking off more metal at one end of the bearing than at the other, which would cause it to be tight at that end. The work should be done slowly, the cap replaced frequently, and the tightness of the bearing tried.

If the bearing is already cut, or if it is worn badly out of shape, so that the connecting-rod will rock sidewise when the brasses are brought together as close as they will come without binding, it is necessary to scrape the bearing to a fit.

**64.** The **scraping** of a bearing, whether a crankpin bearing or a main bearing, is done with tools called scrapers, two of which are shown in Fig. 26. Old three-cornered or half-round files, with the teeth ground off and the edges worked down smooth on an oilstone, make very good scrapers. When a bearing has been scraped approximately true, the crankpin should be rubbed lightly with red lead or graphite mixed with oil, and the bearing replaced. The shaft should then be revolved a couple of times, and when the bearing is taken apart again the high spots on the brasses will be indicated by the red lead on them. These should be scraped down, the brasses again fitted on the pin, and the operation repeated until the brasses bear evenly on the journal.

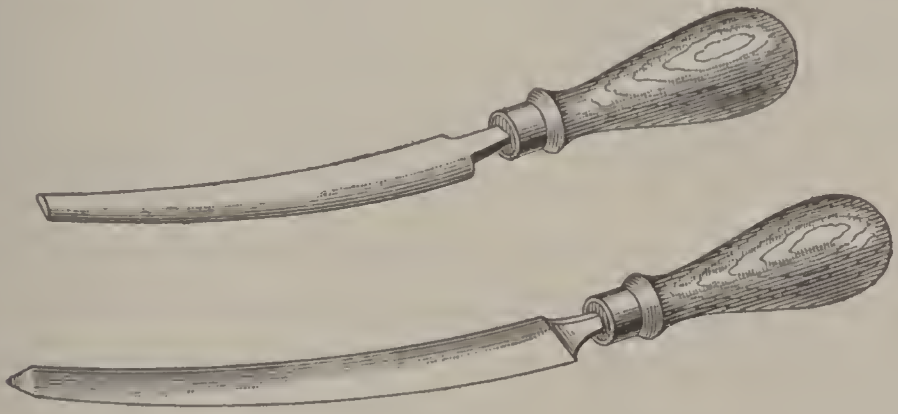


FIG. 26

It is very essential that the bearing be scraped true, so that the connecting-rod will be perfectly square with the shaft. Unless this is done, the pressure will come at one end of the bearing, which is likely to be speedily ruined. For this reason, the novice should not undertake the work, but should employ an experienced machinist, or send the engine to a repair shop.

**65.** Frequently, the meeting edges of the crankpin brasses are beveled, as shown at *a*, Fig. 27. This is done to prevent possible binding of these edges, which receive little, if any, of the pressure on the piston. It is better, however, not to extend the bevel out to the ends of the bearing, as that permits the oil accumulating in the grooves formed by the bevels to escape instead of being carried around the pin.

It will sometimes be found that the crankpin itself has been worn out of round, being flattened on one side. When this is the case, it is useless to take up the lost motion in the bearing before the crankpin itself has been trued up.

**66. Adjustment of Bearings.**—It is sometimes thought unwise to make bearings adjustable because it gives an opportunity for inexperienced men to do damage through lack of judgment. One of the principal causes of hot bearings is setting up the brasses too tightly. Sometimes as soon as a pound or noise about an engine is heard, the man in charge concludes that a bearing is slack and proceeds to tighten it. There are numerous other causes of pounding in engines besides slack bearings, and the engineer should be fully convinced that the pound is caused by slack brasses before setting them up. Bearings on an engine that is in line and in good order, if properly adjusted, will run smoothly and noiselessly for months without further adjustment, and it should be the object of an engineer to get his engine into that condition as soon as possible and to keep it so.

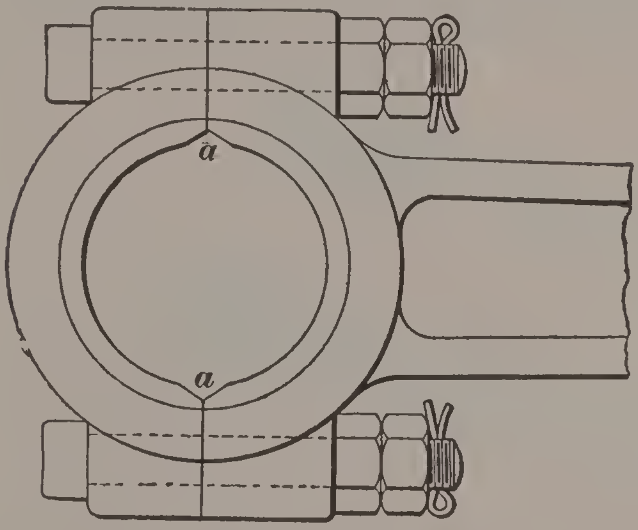


FIG. 27

---

## HOT BEARINGS

**67. Observation of Bearings.**—Bearings, particularly those of large engines, require constant watching. The engineer or oiler should know at all times the condition of every bearing and oil cup; this will make it necessary that the oil cups be examined frequently, to ascertain if they are feeding and if they contain sufficient oil, and that the oil in the cups be replenished whenever necessary. While making his rounds the engineer should feel with the palm of his hand the brasses of those bearings that have shown a tendency to heat and those that are most liable to heat.

## GENERAL TREATMENT OF HOT BEARINGS

**68. Treatment When Bearing Begins to Heat.** Should the temperature of any bearing rise much above the temperature of the surrounding atmosphere, the oil feed should immediately be increased; if the oil does not feed freely, the oil tubes should be opened by running a wire through them. If the bearing continues to get hotter, it may indicate that the brasses have been expanded by the heat and are therefore gripping the journal harder and harder the hotter they get. Sometimes the trouble may be avoided before the temperature has risen very high by loosening the bearing by backing off the capscrews a little and then supplying oil liberally.

**69. Dangerous Heating.**—Should a bearing become so hot as to scorch the hand or burn the oil, there is immediate danger that the brasses will be damaged beyond repair and deep grooves be cut in the journals; if the brasses are babbitted, the soft metal will soon melt out and the engine will be disabled until new brasses can be substituted or the old ones rebabbitted.

**70. Remedies for Increased Heating.**—If the means just described fail to reduce the temperature of the bearing, the engine should be relieved of its load and slowed down as much as possible, the cap nuts or key of the hot bearing should be slacked back, and the engine be allowed to run slowly until the bearing has cooled off. The engine should not, however, be allowed to stop while the bearing is excessively hot or the bearing will seize so that the engine cannot be started until the bearing is refitted.

If necessary, the cooling may be hastened by pouring cold water upon the bearing, though this is objectionable, as it may cause the brasses to warp or crack by unequal contraction.

Putting water on a very hot bearing should be resorted to only in an emergency, that is, when an engine *must* be kept running regardless of a spoiled pair of brasses. Water may be used on a moderately hot bearing without doing very much harm.

If the engine is not started again until the faulty bearing has become perfectly cool, the cap nuts or key should be set up a little before starting; otherwise, the brasses that have been slacked off may be too loose, and excessive thumping and pounding will result.

**71. Keeping Engine With Hot Bearing Running.** If it is absolutely necessary in an emergency to keep the engine running under load while a bearing is very hot, the engineer must exercise his best judgment as to how he shall proceed. After slacking off the brasses, about the best he can do is to flood the inside of the bearing with a mixture of oil and graphite, sulphur, soapstone, etc., and the outside with cold water from buckets, sprinklers, or hose, taking the chances of ruining the brasses and cutting the journal. Of course, the engine must be stopped as soon as the emergency has passed, and the journal then stripped. It is to be expected that the journal will be found to be deeply grooved and the brasses cut and warped. If the brasses are babbitted, most of the babbitt will have melted out. But if the brasses are made solid, they can be refitted for at least temporary use or until new ones can be procured.

**72. Refitting a Cut Bearing.**—The wearing surfaces of the brasses and journal must be smoothed off as well as circumstances will permit; but if the grooves are very deeply cut, it will be useless to attempt to work them out entirely, and if the brasses are very much warped or badly cracked, it will be best to put in new ones if any are on hand. If not, the old ones must be refitted and used until a new set can be procured, which should be done as soon as possible. As for the journal, temporary repairs can be made by smoothing it with fine emery cloth, but at the first opportunity the journal should be trued up in a machine shop and the brasses properly refitted or replaced with new ones.

After a bearing has once been heated sufficiently to cut the brasses and journal or to warp or crack the brasses, it is afterwards constantly in danger of heating again, and the engine is thereby rendered unreliable.

## CAUSES AND PREVENTION OF HOT BEARINGS

**73. Causes.**—The methods of prevention or cure of hot bearings will now be described in detail. Hot bearings are produced by the following causes:

Brasses newly fitted
Brasses refitted
Brasses imperfectly fitted
Brasses bearing unevenly
Engine out of line
Springing of bedplate
Springing or shifting of outboard bearing
Brasses too long
Brasses pinching at edges
Brasses set up too tightly
Brasses too loose
Brasses or journal cut
Brasses warped and cracked
Cut brasses and journals
Oil feed stopped
Oil feed insufficient
Oil unsuited
Oil dirty or of poor quality
Grit in bearing
Premature ignition
Journal too small
Engine overloaded
External heat

**74. Brasses Newly Fitted.**—The bearings of new engines are particularly liable to heat, due to the wearing surfaces of the brasses and journals not having reached a perfect fit; therefore, if a new engine or one with new brasses is run at moderate speed and under light load, with rather loose brasses, until the journals and bearings adapt themselves to each other, there will be little danger of the bearings heating thereafter, if proper attention is given to their adjustment and lubrication.

**75. Brasses Refitted.**—The bearings of an engine that has just been thoroughly overhauled and the journals and brasses of which have been refitted are liable to heat. The wearing surfaces of the brasses having been newly worked or machined, the surface of the metal is not smooth, and the brasses have not yet had a chance to adjust themselves to the journal. The engine, therefore, is in about the same condition as a new engine, so far as the bearings are concerned, and should be treated in the same manner; that is, it should be run moderately until the brasses have accommodated themselves to the journal.

**76. Brasses Imperfectly Fitted.**—Faulty workmanship is a common cause of the heating of a bearing. The brasses in that case do not bear fairly or set squarely in their beds, and while they appear right to the eye, they may not be square in the bearing. A crankpin brass must set squarely on the end of the connecting-rod and the rod itself must be square. If the key, when driven, forces the brasses to one side or the other and twists the strap on the rod, the brasses will not set squarely on the pin and will bear harder on one side than on the other. The same is true of the shaft bearings. If the brasses do not bed fairly on the bottom of the casting or do not go down evenly, without springing in any way, they will not run as they should, and heating will result. Continual heating of bearings is almost always caused by badly fitting brasses. This is a defect that should be looked for and, if found to exist, should be remedied at once.

In many cases, trouble with connecting-rod bearings can be traced to crankpins that are not perfectly round. With crankpins from .003 inch to .005 inch out of round, it would become absolutely impossible to keep the bearings in good working order.

**77. Brasses Bearing Unevenly.**—In order that a bearing may run freely, there must be a little play between the brasses and their beds; this permits a slight movement of the brasses when pressure is exerted on them by the shaft; and notwithstanding the fact that they may have been most carefully fitted in the shop, they must be run a certain amount in order to adjust themselves properly. This is especially the case with the bearings of large engines, and the same conditions will obtain every time the brasses are removed. It seems almost impossible in practice to put the brasses of a large bearing back again just where they were before removal; it always requires time for them to settle into their old places; therefore, they should not be disturbed unless there is a positive necessity for doing so. The direct cause of the tendency to heat in this instance is that the brasses do not bear evenly on the journal after the several parts of the bearing are assembled.

**78. Engine Out cf Line.**—If an engine is not well lined—that is, if the bearings are not lined up properly—the brasses do not bear fairly upon the journals. This will reduce the area of the wearing surfaces in contact to such an extent that the friction is in excess of the practical limit, and will necessarily cause heating.

If the engine is not greatly out of line, the working condition may be considerably improved by refitting the brasses by filing and scraping down the parts that bear most heavily on the journal.

The crosshead guides of an engine out of line are liable to heat, and they will continue to give trouble until the defect is remedied. The guides may also heat from other causes; for instance, the gibs may be set up too tightly. Of course, if such is the case, they should be slacked off. The danger of the guides heating may be very much lessened by chipping zigzag oil grooves in their wearing surfaces and by attaching to the crosshead, oil wipers made of cotton lamp wicking arranged so as to dip into oil reservoirs at each end of guides if they are horizontal, and at the lower end if they are vertical. These wipers will spread a film of oil over the guides at every stroke of the crosshead that will keep them well lubricated.

**79. Springing of Bedplate.**—If the bedplate of an engine is not rigid enough to resist the vibration of the moving parts, or if it is sprung from being set unevenly or by the unstable condition of the foundation, the engine will be thrown out of line either intermittently or permanently, and the bearings will heat; but it will do no good to refit the brasses unless the engine bed is stiffened in some way and leveled up if necessary. The form of the bedplate and foundation must generally suggest the best way to meet this difficulty.

**80. Bearing Spring or Shift.**—The effect of the springing or shifting of the outboard bearing—that is, an outer bearing supported on the foundation away from the engine frame—is similar to the springing of the engine bed; namely, the bearing will be thrown out of line, with the consequent danger of heating. As the pedestal forming the foot of the bearing is usually adjustable, it is an easy matter to readjust it, after which the holding-down bolts should be screwed down tight. This is one of the few instances where it is permissible for the engineer to use his strength on the wrench. As a rule. a nut or bolt should just be set up solid; with very rare exceptions, a sledge hammer should not be used in driving a wrench, as 3-inch steel bolts have been broken in this way. It is also very bad practice to drive up a nut with a cold chisel and hammer, unless the nut is in a position where it is impossible to turn it with a wrench.

If a pedestal is not stiff enough to resist the forces acting on it and it springs, measures should be taken to stiffen it. The method to be used can only be determined from the conditions, and calls for the exercise of judgment on the part of the engineer.

**81. Brasses Too Long.**—If the brasses are too long and bear against the collars of the journal when cold, they will surely heat after the engine has been running a short time; it is hardly possible to run bearings entirely cold, they *will* warm up a little and the brasses will be expanded thereby, which will cause them to bear still harder against the collars. This, in turn, will induce greater friction and more expansion of the brasses.

This trouble may be overcome by filing a little off each end of the brasses until they cease to bear against the collars while running. A little side play is a good thing, since it promotes a better distribution of the oil and prevents the journal and brasses from wearing into grooves.

**82. Brasses Pinching the Journal at Their Edges.** When first heated by abnormal friction, brasses tend to expand along the surface in contact with the journal; this will tend to open the brass and make the bore of larger diameter if it is not prevented by the cooler part near the outside and by the bedplate itself.

If the brass becomes hot very quickly, the resistance to expansion produces a permanent set of the metal near the journal, so that, on cooling, the brass closes and grips the journal; it will then set up sufficient friction to heat again and expand sufficiently to ease itself from the journal, and so long as that temperature is maintained the journal runs easily in the bearing. This is why some bearings always run somewhat warm and will not work cool. A continuance of heating and cooling will set up a mechanical action at the middle of the brass, which must eventually end in cracking it, just as a piece of sheet metal is broken by continually bending it backwards and forwards about a certain line.

The heating by the brasses pinching the journal may be prevented by chipping off the brasses at their edges parallel to the journal, as shown at *a* and *b*, Fig. 28, in which *c* is a sectional view of the journal and *d* and *e* represent the top and bottom brasses.

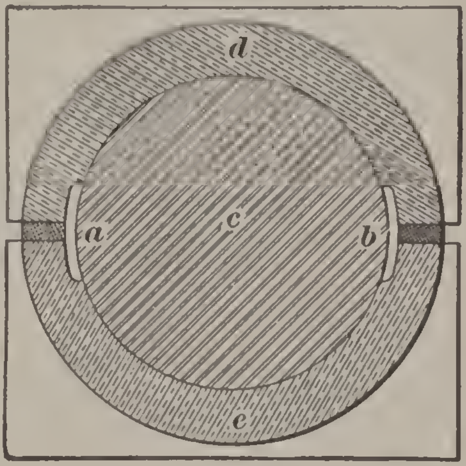


Fig. 28

**83. Brasses Set Up Too Tightly.**—When the brasses of an engine bearing are set up too tightly, heating is inevitable, and probably more hot bearings result from this cause than from any other, and with less excuse. It is often the case that an attempt is made to stop a knocking or pounding in an engine by setting up the brasses when the pounding could and should be stopped in some other way.

The direct cause of heating of bearings when the brasses are set up too tightly is the abnormal friction that is produced by the pressure of the brasses on the journal. The prevention and cure are obvious. The brasses should not be set up too tightly, and if they are, they should be slacked off as soon as possible. Hot bearings should never occur from this cause. Only a competent person should have charge of the bearings, and no one else should be permitted to adjust them. The bearings should be examined at the first signs of undue heating.

**84. Brasses Too Loose.**—Bearings may heat on account of the brasses being too loose. The heating is caused by the hammering of the journal against the brasses when the crankpin is passing the dead centers. This fault is easily remedied, however, by setting up the cap nuts or key. Here the experience and judgment of the engineer are called into play to decide just how much to set up, as it is very easy to overdo the matter and set up too far, with a hot bearing as the result.

Most engineers have their own particular views regarding the setting up of bearings. One method is to set up the cap nuts tight and then slack them back a half turn; if the brasses are still too loose, they are set up again and slacked back less than before, repeating the operation until the ideal position is reached—that is, when there is neither pounding nor heating. It is important that this desired point be approached very gradually and carefully, else the chances are that it will be overreached and the operation will have to be repeated.

**85.** Another method of setting up journal brasses is as follows: Fill up the spaces between the brasses with thin metal liners, say from 18 to 22 Birmingham wire gauge in thickness, and a few paper liners for fine adjustment; put in enough of them to cause the brasses to set rather loosely on the journal when the cap nuts or keys are set up solid. Run the engine for a while in that condition and note the effect; then take out a pair of the liners and set up solid again. Repeat this operation until there is neither thumping nor heating. If this system of treating bearings is carefully carried out, there will be very little danger of their heating. When the proper adjustment is reached, the engine should run a long time without requiring any further adjustment of the bearings. In removing the liners, great care should be exercised not to disturb the brasses any more than is absolutely necessary, and to remove liners of equal thickness from each side. A pair of thin, flat-nosed pliers will be found useful in slipping out the liners. This method is preferable to the first one mentioned, because there is not so much danger of setting the brasses up too far.

**86. Brasses Warped and Cracked.**—Warped and cracked brasses will cause heating, because they do not bear evenly on the journal, and hence the pressure is not distributed over the entire surface, as it should be. The remedy will depend on the extent of the distortion of the brasses. If the distortion is not too great, the brasses may be refitted to the journal by filing and scraping; but if they are twisted so much that they cannot be refitted, new brasses must be put in.

**87. Cut Brasses and Journals.**—Brasses and journals that have been hot enough to be cut and grooved are liable to heat again at any time, on account of the undue friction produced by the roughness of the wearing surfaces. As long as the grooves in the journal match the grooves in the brasses, the friction is not greatly increased; but if a smooth journal is placed between a set of brasses that are cut and pressure is applied, the journal crushes the ridges on the brasses, the friction becomes very great, and heating results.

The way to prevent heating from this cause is to work the grooves out of the journal and brasses by filing and scraping as soon as possible after they occur.

**88. Oil Feed Stopped.**—It does not take long for a bearing to get very hot if it is deprived of oil. The two principal causes of a bearing becoming dry are an oil cup that has stopped feeding, either because it is empty or because it is clogged by dirt in the oil, and oil holes and oil grooves closed by dirt or by the gumming of the oil. Both of these conditions are the direct result of negligence, and their existence can always be prevented by the exercise of reasonable care.

In circulating constant-level splash oiling systems, as used in many automobile engines, the oil pump may have broken down, although with gear-pumps this defect is rather uncommon. More frequently the trouble is due to a broken oil-delivery pipe or a clogged oil inlet. When plunger pumps are used for circulating the oil, the pumps being submerged in oil all the time, the pumps may partly or entirely stop working, on account of dirt or a thread or two of waste finding its way to the suction-valve seats. If an oil pump of a circulating oiling system is located above the oil reservoir, it may refuse to pump when the engine is started because it is air-bound, in which case it requires priming with oil in order to start it working.

**89. Oil Feed Insufficient.**—The effect produced on a bearing by an insufficient oil supply is similar to that of no oil, only in a lesser degree. Of course it will take longer for a bearing to heat with insufficient oil than with none at all, and the engineer has more time in which to discover and remedy the difficulty. As a rule, however, more oil is used on bearings than is actually necessary, and a waste of oil is the result. A steady feed, a drop at a time, gives the best results.

In automobile pressure-feed oiling systems of the high-pressure type, too low an oil pressure, due to wrong adjustment of the relief valve or a broken relief-valve spring, may be the cause of insufficient cylinder lubrication. In pressure-feed oiling systems not having an oil pump, insufficient lubrication is usually due to failure to keep sufficient oil in the reservoir; but it may be due to clogged oil screens, provided these are used. In the constant-level splash system the parts may get insufficient lubrication because the oil in the splash troughs is not kept at the proper level due to lack of oil in the crank-case, or partial clogging of the feedpipes.

**90. Oil Unsuitable.**—When a properly designed bearing is supplied with oil that is not suitable, that is, an oil that is too heavy or too light, a sufficient quantity cannot be retained in the bearing to lubricate it properly. Large quantities of thin oil may be fed to the bearing, but it will be squeezed and leaving only a thin film, and thus not properly lubricate the bearing. On the other hand, too-heavy oil will not enter the bearing in sufficient quantity to lubricate it properly. The effect of unsuitable oil is more pronounced in engines of the high-speed type, as used in automobiles, aeroplanes, etc., than in the slower running stationary type, although it is vitally important that oil of the proper quality be used in all cases.

If gas-engine cylinder oil of the kind recommended by the maker of the car, such as is sold at retail in sealed cans and by reliable dealers, is used at all times for the engine, no trouble on account of the oil itself will ever be experienced. If, however, use is made of ordinary machine oil, lard oil, or steam-engine cylinder oil, which is usually bought because it is cheaper than gas-engine cylinder oils, trouble will be experienced almost immediately, and if this trouble is not attended to at once, the cylinders, pistons, and bearings may be ruined in a short time. Machine oil, lard oil, and steam-engine cylinder oil are excellent lubricants for the purpose for which they are intended, but they are utterly unsuitable for the lubrication of the high-speed gasoline engines used in automobiles.

The trouble symptoms produced by the use of oil unsuited for lubricating the piston are white or yellow smoke in the exhaust, rapid fouling of spark plugs, partial clogging of inlet and exhaust valves, and rapid accumulation of carbon on the valves in the combustion chamber and about the piston rings.

To remedy the trouble, inject kerosene freely through the priming cocks or spark-plug holes to loosen the carbon deposit on the piston rings, and use kerosene to free the valves if they stick. Drain the oil reservoir, and also the splash troughs in case of non-circulating constant-level splash system, and the crank-case if this does not form the oil reservoir; in short, drain all oil from the whole lubrication system and wash it out twice with kerosene. Drain off all kerosene and refill the oiling system with good gas-engine cylinder oil, not forgetting the splash troughs if they have to be filled separately. In case excessive carbonization has taken place in the cylinders, remove the carbon deposit. Then clean the spark plugs, and the engine will be ready again.

**91. Dirty and Gritty Oils, and Oils of Poor Quality.**—Oils containing dirt and grit or that are deficient in lubricating quality causes hot bearings; but it is within the power of the engineer to guard against such causes. There is a great deal of dirt in lubricating oils of the average quality; therefore, all oil should be strained through a cloth or filtered, no matter how clear it looks. All oil cups, oil cans, and oil tubes and channels should frequently be thoroughly cleaned. Oil may be removed from the cups by means of an oil syringe.

All oil removed from the cups and cans should be strained or filtered before it is used. If these instructions are strictly followed, most of the danger of bearings heating from the use of dirty or gritty oils will be avoided.

There is such a great variety of lubricating oils on the market whose quality cannot be definitely decided on without an actual trial that it is a difficult matter to avoid getting poor oil sometimes. About the only way to meet this trouble is to pay a fair price to a reliable dealer for oil that is known to be of good quality. Cheap oils are generally very deficient in lubricating qualities, and hence should be avoided, as should also gummy oils, which choke the oil channels and cause the brasses and journals to stick together when the engine is stopped over night.

**92. Grit in Bearings.**—Grit is an ever-present cause of heating of bearings; it is only by persistent effort on the part of the engineer that he can keep his machinery running cool in a dusty atmosphere. The causes of this condition are innumerable; it is, therefore, only possible to mention a few of them here. Work done on a floor over an engine shakes dirt down upon it at some time or other; all floors over engines should therefore be made absolutely dust-proof by laying paper between the flooring. A prolific cause of hot bearings from grit in producer-gas engines, especially when the engine and producer rooms communicate, is carelessness in handling the ashes and clinkers. If piles of red-hot clinkers and ashes are deluged with buckets of water, the water is instantly converted into a large volume of steam that rises suddenly, carrying with it large quantities of small particles of ashes and grit that penetrate wherever it has access, and will find its way into the engine bearings. Throwing large quantities of water on hot clinkers and ashes should be avoided; sprinkle them instead, and close the producer-room door while the ashes and clinkers are being hauled or wet down or while the fire is being cleaned or hauled.

**93.** If emery, emery cloth, Bath brick, or other gritty cleaning material is used about a bearing, it is sure to get inside and cause trouble; it is, therefore, better not to use them close to a bearing.

As a precaution against grit getting into a bearing, all open oil holes should be closed with wooden plugs or clean cotton waste as soon as possible after the engine is stopped, and should be kept closed until ready to oil the engine again preparatory to starting up. Plaited hemp or other suitable covering should also be laid over the spaces between the ends of the brasses and the collars of the journals of every bearing on the engine and kept there while the engine is standing still.

Bearings are now in use that, it is claimed by their makers, are dust-proof, but their use does not relieve the engineer from the responsibility of taking every precaution possible to keep grit and dirt out of the bearings of his engine.

**94. Premature Ignition.**—Bearings designed to stand a given amount of pressure will begin to heat if this pressure is greatly and constantly exceeded. Premature ignition of the incoming charge caused by various conditions will result in abnormally high initial pressure and severe shocks upon the bearings. Experience shows that the crankpin especially will heat under such conditions. The remedy consists in finding the actual cause of the premature firing and using the proper means to stop it.

**95. Journals Too Small.**—Journals that have insufficient area of wearing surface will heat. In practice, only a certain amount of pressure per square inch of area can be sustained by a bearing before the friction reaches the point that will cause heating.

The pressure that a bearing will sustain per square inch of area of rubbing surface without heating depends on the materials of which the journal and brasses are composed, the fineness of their finish, the accuracy of their fit, the adjustment of the brasses, and the lubricant used.

Pressure and friction have a direct relation to each other. The total amount of friction of two bodies in contact depends on the pressure of the one on the other and is nearly independent of the area of the surfaces in contact. The total pressure on the bearing divided by the projected area, that is, the product of the length and the diameter of the bearing, in inches, gives the bearing pressure per square inch. If the allowable bearing pressure per square inch is exceeded, heating is liable to occur, for the heating is proportional to the friction produced, and the friction per square inch depends on the bearing pressure per square inch. Hence, less friction is produced per square inch of surface by a long journal than by a short one of equal diameter with the same total pressure; therefore, a long journal is not nearly so liable to heat as a short one of the same diameter, and a journal of large diameter is not so liable to heat as one of small diameter of equal length. It is the aim of the designer so to proportion the journal that the pressure per square inch of bearing surface shall not exceed the safe limit for the given conditions.

There is only one cure for a bearing that heats constantly because it is too small, and that is to make it larger if circumstances permit this to be done. If this is impossible the best of lubrication must be used, and, if necessary, water must be run constantly on the bearing.

**96. Overloaded Engines.**—The effect produced by overloading an engine is similar to that when the journal is too small. The pressure on the brasses being increased to a point beyond that for which they were designed, the friction exceeds the practical limit and the bearing heats. The only thing to do to remedy this difficulty is to reduce the load on the engine.

When an engine is being run under a load that is near or equal to the maximum for which it is designed, it is wise to keep a set of new brasses on hand, to be put in place when required. This precaution is especially important in a plant where the shutting down of the engine for any great length of time will incur a large loss, and it should be observed especially if it is known that the journals are too small, or the engine is somewhat overloaded.

**97. External Heat.**—Bearings may get hot from external heat. This may be the case if the engine is placed too near furnaces or in an atmosphere heated by uncovered steam pipes or other means. The excessive heat of the atmosphere will then expand the brasses until they bind on the journals, which will generate additional heat and cause further expansion of the brasses, resulting in a hot bearing.

If the engine is placed close enough to a furnace to cause heating from that source, a tight partition should be put up between them, if possible; this will also prevent dirt and grit from the furnace from getting into the bearings. If steam pipes in the room are bare, they should be covered with some good non-conducting material; and in some cases ventilating fans may be used to advantage. Other remedies depend on the conditions and require the judgment of the engineer.

# CARBURETERS

Serial 1861 Edition 1

## FORMATION OF EXPLOSIVE MIXTURES

### EFFECTS OF CHANGES IN PROPORTIONS

**1.** An **explosion** is an extremely rapid burning of a substance, and is accompanied by the formation of gases and a considerable increase of pressure. Any mixture of two or more substances that will burn in this way is called an **explosive mixture,** or simply an **explosive.** The mixture of gasoline vapor and air in the cylinder of a gasoline engine is a familiar example of an explosive mixture. The burning is started by means of an electric spark, and the explosion that results raises the pressure of the gases in the cylinder. The pressure of these gases pushes the piston forwards in the cylinder and so enables the engine to do work.

**2.** The operation of setting fire to the gaseous mixture in the engine cylinder by means of a device called an *igniter* or a *spark plug* is known as **ignition.** The moment that ignition begins is called the *time of ignition.* The quantity of the mixture of gas and air taken into the cylinder at one time is called the **charge,** and when all of it is ignited, it is said to be *wholly inflamed.* The time elapsing betwen the time of ignition and the moment when the gas is wholly inflamed is known as the *duration of inflammation,* or duration of the explosion. The velocity with which the flame is generated in the charge is called the *rate of flame propagation.*

**3.** When the burning mixture has reached its greatest pressure, a short time may elapse before the pressure begins to fall to that of the atmosphere. This time is called the *duration of maximum pressure.* The time from the moment when the pressure commences its fall from the maximum pressure to the moment when the pressure reaches that of the atmosphere is known as the *duration of fall of pressure.* The velocity with which this fall of pressure takes place is the *rate of fall of pressure.*

**4.** Gases available for engine purposes vary so much in their behavior when ignited in the gas-engine cylinder that a knowledge of their performance is of great value to the operator. Certain effects are produced when an explosive mixture is confined in a closed vessel without the opportunity of expansion such as it has in the gas engine. These effects relate to inflammation of the gas, duration of maximum pressure, and rate of fall of pressure. The relation of these to the proportions of gas and air in the cylinder of a gas engine is very important.

**5.** The relative proportions of gas and air in the charge affect the duration of inflammation, the rate of flame propagation, the duration of maximum pressure, and the rate of fall of pressure. To learn something of the effects produced by changes in the quality of the mixture, a number of experiments were made, using a cast-iron explosion chamber 7 inches in diameter and 8½ inches long. Explosive mixtures of different qualities were introduced into the chamber and ignited, and a recording instrument similar to an indicator was used to show the change of pressure that resulted. There was no piston in the cylindrical explosion chamber and consequently no expansion of the gases could occur. Instead, the pressure decreased as the heat of explosion was conducted away by the metal walls. The mixtures used varied from 14 parts of air and 1 part of gas to 4 parts of air and 1 part of gas, by volume. The mixture containing a large volume of air to a small volume of gas is a *lean mixture* and that containing more nearly equal volumes of air and gas is a *rich mixture.* The pressures obtained from these various mixtures are given in Table I.

**6.** The rate of flame propagation is measured approximately by the time from the moment of ignition to the moment at which the maximum pressure is reached. In the experiments referred to, the rate of flame propagation was greatest in the mixture containing 6 volumes of air to 1 volume of gas. As the mixture was made leaner by increasing the proportion of air, the rate of flame propagation became lower; that is, the mixture burned more slowly as the proportion of air was increased, and the maximum pressure was not reached so soon. On the other hand, the rate of fall of pressure was less rapid, and the gases had a higher pressure at the end of 1 second than was the case with gases resulting from the burning of richer mixtures. Mixtures richer than the one containing 6 volumes of air to 1 of gas had slower rates of flame propagation than the 6-to-1 mixture, indicating that the burning was most rapid with proportions of about 6 of air to 1 of gas.

### TABLE I

**PROPORTIONS OF MIXTURES AND RESULTING PRESSURES**

| Volumes of Air to 1 Volume of Gas | Proportion of Gas in Mixture | Maximum Pressure per Square Inch | Area of Piston to Each Cubic Inch of Gas | Total Maximum Pressure per Cubic Inch of Gas | Pressure per Square Inch .2 Second After Maximum | Pressure Total to Each Cubic Inch of Gas, .2 Second After Maximum | Mean Pressure on Piston During the First .2 Second |
|---|---|---|---|---|---|---|---|
| 14 | $\frac{1}{15}$ | 40 | 15 | 600 | 31 | 465 | 532 |
| 13 | $\frac{1}{14}$ | 51.5 | 14 | 721 | 40 | 560 | 640 |
| 12 | $\frac{1}{13}$ | 60 | 13 | 780 | 42 | 546 | 663 |
| 11 | $\frac{1}{12}$ | 61 | 12 | 732 | 44 | 528 | 630 |
| 9 | $\frac{1}{10}$ | 78 | 10 | 780 | 44 | 440 | 610 |
| 7 | $\frac{1}{8}$ | 87 | 8 | 696 | 47 | 376 | 536 |
| 6 | $\frac{1}{7}$ | 90 | 7 | 630 | 52 | 364 | 497 |
| 5 | $\frac{1}{6}$ | 91 | 6 | 546 | 50 | 300 | 423 |
| 4 | $\frac{1}{5}$ | 80 | 5 | 400 | 46 | 230 | 315 |

**7.** The best proportions of gas and air to use for any gas, in an engine having no compression, is not usually that which has the greatest explosive power. The best proportion is that which gives the highest pressure for the quantity of gas used. For the purpose of illustration, suppose that the distance between the end of the cylinder and the end of the piston is exactly 1 inch; then, for each cubic inch contained in this space, there will be 1 square inch on the surface of the piston. The mixture that will give the highest pressure for the same quantity of gas can be calculated as follows: For instance, take the mixture containing one volume of gas to five volumes of air. In Table I, in which the results of the before-described experiments are tabulated, the maximum pressure for this mixture is given as 91 pounds per square inch. Since there are five volumes of air and one volume of gas, for each cubic inch of gas there will be six volumes of the mixture; and to each cubic inch of gas, in a layer 1 inch deep, there will be 6 square inches of the mixture. Hence, the pressure of 91 pounds per square inch is exerted on 6 square inches, and the total pressure exerted by each cubic inch of gas is $91\times6=546$ pounds.

The mixtures giving the highest pressure for 1 cubic inch of gas are seen to be those having one volume of gas to twelve of air, and one volume of gas to nine of air.

**8.** The mixture giving the best average pressure for the first .2 second is that giving 663 pounds to each cubic inch of gas, or the mixture containing one volume of gas to twelve volumes of air. If the power stroke could be considered as taking place without increasing the volume of the space occupied by the gaseous mixture, the pressure remaining at the end of .2 second after the maximum pressure has been reached would be that given in the seventh column, and the mean, or average, pressure at the end of .2 second after explosion would be that given in the last column. The last column gives a means of comparison of the power to be obtained in using the mixtures indicated in the first column. Thus, the mixture having one volume of gas to thirteen of air is more than twice as powerful as that having one volume of gas to four volumes of air, or in the ratio of 640 to 315, considering the power available during the first .2 second after explosion. Of course, there is no such thing as an engine running without increasing the volume of the gases, but this assumption is made in order to give a method of comparing the various mixtures.

**9.** The conditions under which these experiments were carried out are not those under which combustion takes place in an engine cylinder; but the results given will serve to indicate, to some extent, the effect of changing the quality of the charge in an internal-combustion engine. In an actual engine the charge is compressed before ignition takes place, and the result is that the rate of flame propagation is very greatly increased. Moreover, ignition is so timed that the point of maximum pressure occurs at the end of the stroke. The rate of fall of pressure is more rapid, because the gases expand as the piston moves forwards; therefore, there is loss of heat from the gases, not only by the cooling effect of the walls, but also by the conversion of heat into work during expansion.

## DEVICES FOR MAKING EXPLOSIVE MIXTURES

### CARBURETERS FOR STATIONARY ENGINES

**10.** The explosive mixture in the cylinder of an internal-combustion engine must be composed of gas and air or of vapor and air in such proportions that it will burn when once ignited. If the fuel used is a gas, such as producer gas or blast-furnace gas, the explosive mixture is made by admitting the correct proportions of gas and air to the cylinder through a mixing valve. The object of the mixing valve is to cause the gas and the air to mix thoroughly, so that combustion will be rapid and complete. If the fuel used is a liquid, such as gasoline or kerosene, there is greater difficulty in forming the explosive mixture. Liquid fuels will not burn while they remain liquid. Before liquid fuel can be burned, it must be changed to a vapor or a gas, and then the vapor or the gas must be mixed with air in the proper proportions to form a combustible mixture. The device that is used to change the liquid to a gas or to a vapor is called a **carbureter** or a **vaporizer.**

**11.** Heat must always be added to a liquid in order to change it to a gaseous form. If the quantity of heat necessary to vaporize a given quantity of liquid is comparatively small, the liquid is said to be volatile. Gasoline is a familiar form of volatile liquid, and of all the liquid fuels used in internal-combustion engines, it is the most easily vaporized. The passage of a current of air at ordinary temperatures over the surface of gasoline is sufficient to cause vaporization of a part of the liquid and to produce an explosive mixture with the air. The heat required to cause the vaporization in such a case is contained in the air that passes over the gasoline. With less volatile oils, such as kerosene, distillate, and crude oil, greater difficulty is experienced in obtaining satisfactory vaporization and mixing with air; therefore, carbureters used for vaporizing gasoline will be described first.

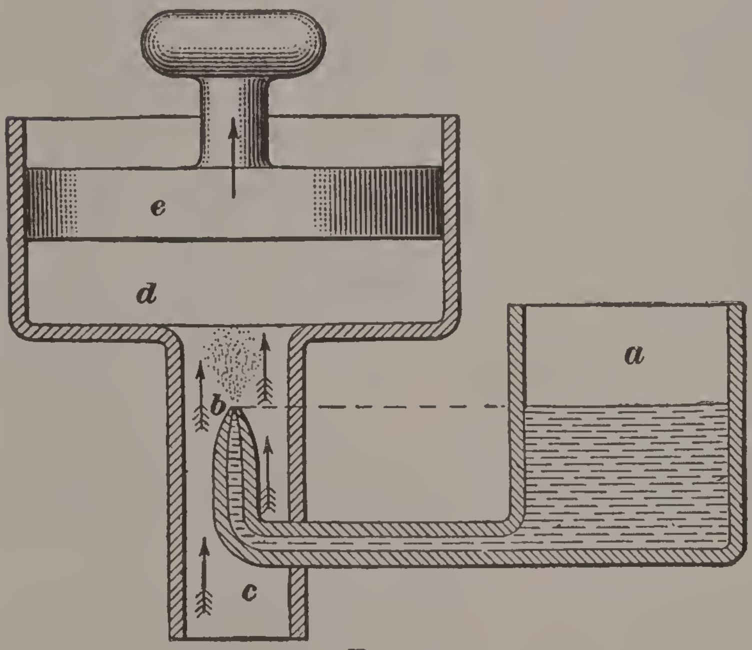


Fig. 1

**12.** The most widely used form of carbureter for gasoline is the **spray carbureter,** so called because it injects a jet or spray of gasoline into the air-current that passes through the carbureter on its way to the cylinder of the engine. The principle on which the jet carbureter acts may readily be understood by reference to Fig. 1. This illustration does not show an actual form of carbureter, but simply represents the essential parts. The gasoline is contained in a tank *a,* from which it flows through a suitable passage to a nozzle *b,* the tip of which is at the level of the surface of the gasoline in the tank. The nozzle *b* is in the center of a pipe *c* that leads to a cylinder *d* in which is fitted a piston *e*. If the piston is drawn upwards suddenly, a partial vacuum will be formed in the cylinder *d* and air will rush up the tube *c* past the nozzle *b*. The suction thus produced around the nozzle will cause some of the gasoline to be drawn out in the form of a spray, as shown, and the spray will be taken up by the air-current and carried on into the cylinder *d*.

**13.** In actual service, the suction that causes the flow of air through the carbureter is due to the outward, or downward, movement of the piston in the engine cylinder, a partial vacuum thus being produced in the cylinder. The spray of gasoline thrown into the air-current in the carbureter is carried along by the air into the cylinder through a suitable pipe connecting the carbureter with the cylinder, and during this travel the finely divided spray evaporates into gasoline vapor. The result is that the air and the vapor enter the cylinder thoroughly mixed, and form an explosive mixture. If the carbureter were actually made like that shown in Fig. 1, the suction of gasoline from the nozzle *b* would eventually lower the level in the tank until no more fuel could be drawn out of the nozzle. In the forms of carbureters in use on engines, therefore, some means is provided whereby the level of the gasoline in the reservoir and the nozzle is maintained.

**14.** One very common way of maintaining a constant level of gasoline in a carbureter is by the use of a float, such a device being known as a **float-feed carbureter.** The principle of construction of a float-feed carbureter is shown in Fig. 2. Fuel from the supply tank enters the bottom of the carbureter at *a* and flows up past the valve *b* into the float chamber *c*, which must not be perfectly air-tight above the float. Part of the fuel flows into the passage leading to the spray nozzle *d*. As the fuel rises in the float chamber it lifts the float *e* and also the valve *b* attached to the float. When the fuel reaches a level slightly below the top of the spray nozzle *d*, the valve *b* closes the inlet passage to the float chamber and thus stops the inflow of gasoline. The upper end of the chamber *h* is connected to the engine intake. The suction of the engine draws in air at the opening *f* of the air passage *g*, past the nozzle *d*, with considerable velocity, into the mixing chamber *h* and out at the top, as indicated by the arrows. On account of the velocity of the air passing the nozzle *d*, and the suction at *d*, which is lower than that upon the surface of the fuel in the float chamber *c*, fuel is drawn out from the spray nozzle; the float *e* therefore descends slightly by the lowering of the fuel in the float chamber, and the float valve *b* is slightly opened, so as to allow more fuel to enter and thus maintain a nearly constant level in the float chamber. Either a hollow metallic float or a cork float may be used.

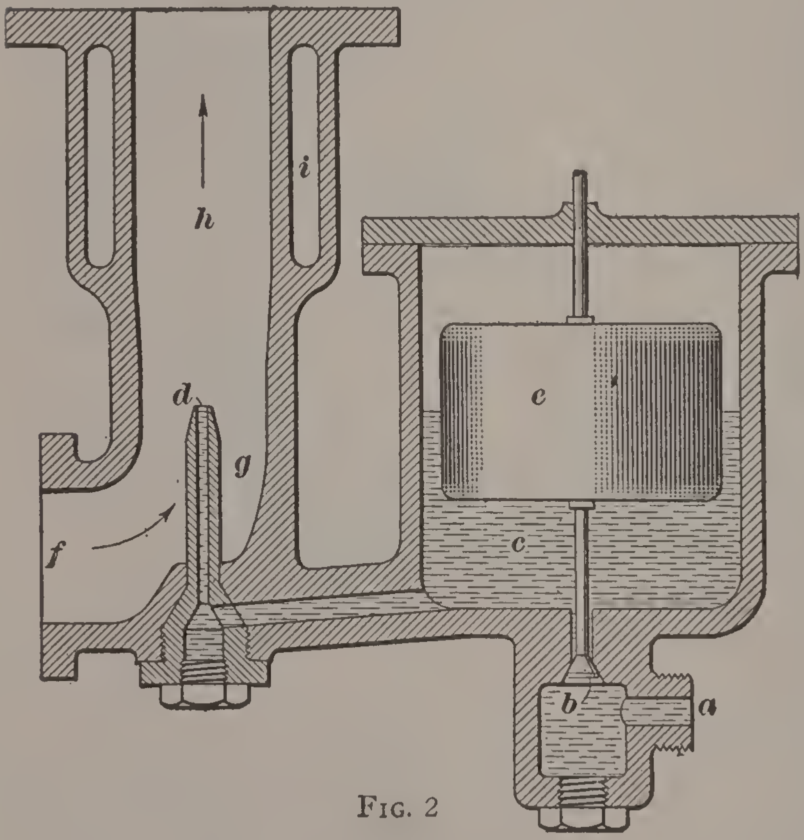


Fig. 2

**15.** The vaporization of the fuel requires heat, part of which is drawn from the walls of the air passage or mixing chamber *h*, Fig. 2. This withdrawal of heat leaves the metal around the air passage cold, even at times below the freezing point of water. The coldness retards the rapidity of vaporization, and in some cases interferes with the satisfactory operation of the carbureter. In order to prevent this, a jacket space *i* may be provided around the mixing chamber, and exhaust gas from the engine or water from the cylinder water-jackets may be circulated through this jacket space to keep the carbureter warm.

**16.** A very simple form of mixer, used on engines of small power, is that shown in section in Fig. 3. The casting *a* forming the body of the mixer is attached to the top of the gasoline tank *b*. A pipe *c* leads from the opening *d* to a point beneath the level of the gasoline and carries at its lower end a cage *e* containing the ball check-valve *f*. A needle valve *g* having a knurled head *h* is used to regulate the amount of opening at *d*. Air is drawn in at *i* on the suction stroke of the engine and passes the needle valve *g* on its way to the cylinder, which is connected at *j*. The partial vacuum formed in the mixing chamber *k* causes gasoline to be drawn up in the pipe *c* and out through the opening *d* past the needle valve. As soon as the suction ceases, the gasoline tends to run down the pipe *c* and back into the tank; but the ball *f* drops to its seat and prevents any flow downwards. The pipe *c* is thus kept full of gasoline at all times, and the amount of gasoline fed is regulated by adjusting the needle valve *g*. The needle valve

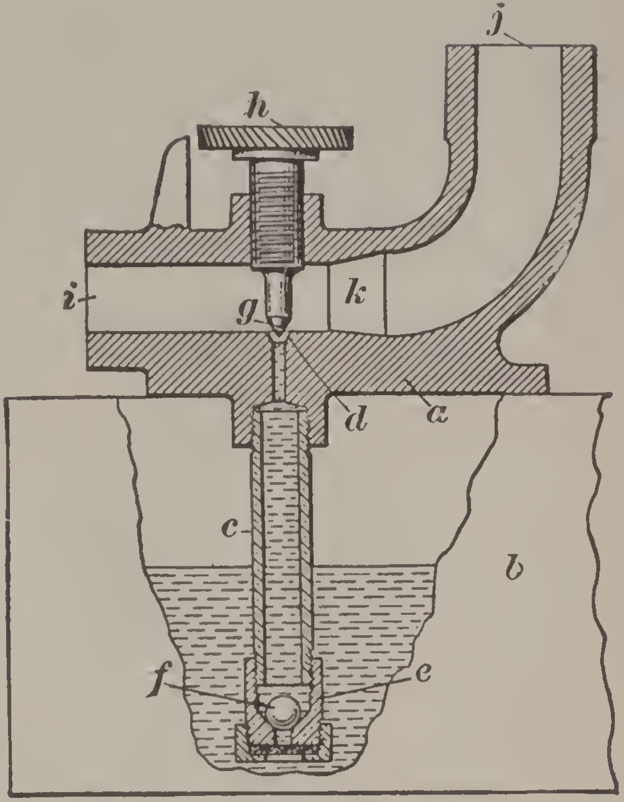
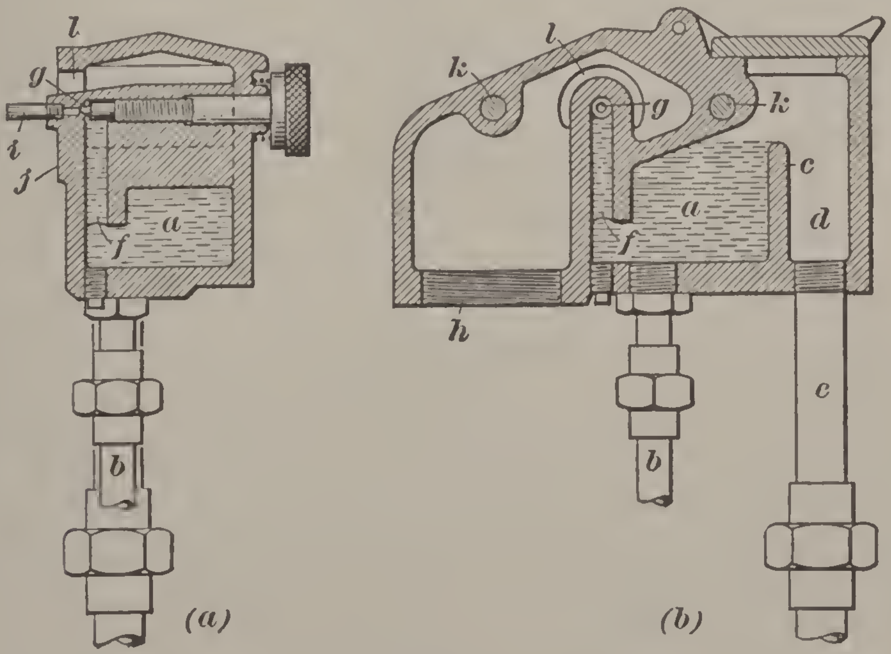


FIG. 3



(a) (b)

FIG. 4

should be set with the least opening that will suffice to keep the engine running smoothly under its normal load.

**17.** Still another method of keeping the level of the gasoline in the carbureter fairly constant is to provide an overflow, and to use a pump to force the gasoline into the carbureter. A form of carbureter in which the level is maintained in this way is shown in section in Fig. 4 (*a*) and (*b*). The gasoline is pumped into the fuel reservoir *a* through the pipe *b*. As soon as the reservoir is filled to the level of the top of the partition *c*, any extra amount supplied by the pump runs over the partition into the chamber *d* and is drained back to the tank through the pipe *e*. A passage *f* leads from the reservoir *a* to the needle valve *g* by which the flow of gasoline is regulated. The air enters at *h* and is drawn past the nozzle *i* on its way to the cylinder. The suction thus produced draws the gasoline out past the needle valve. The face *j* of the carbureter is bolted against the side of the engine cylinder by means of bolts *k* that pass through the carbureter casting, and the nozzle *i* projects into the passage leading to the inlet valve. The air chamber *l* above and around the nozzle also opens into this passage, and thus the air flowing past the nozzle *i* carries the fuel into the cylinder.

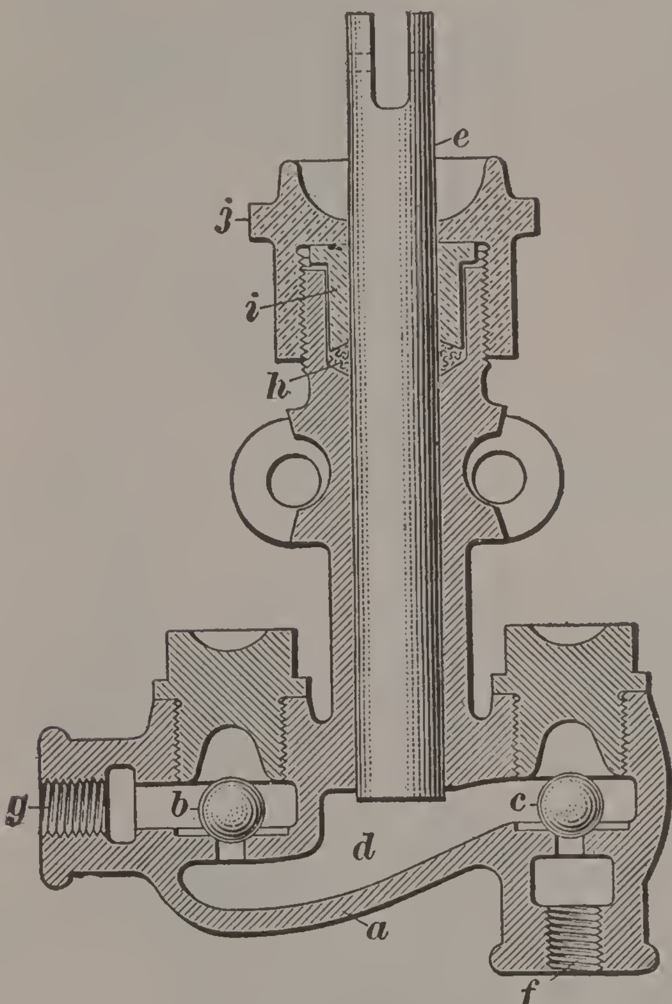


Fig. 5

**18.** A form of fuel pump is shown in section in Fig. 5. The body *a* is formed with two valve seats on which rest the ball valves *b* and *c*, and a passage *d* leads from one valve to the other. At the middle of the pump is a plunger *e* that is given an up-and-down motion from some part of the engine. A suction pipe attached at *f* leads to the fuel tank, and a discharge pipe connected at *g* leads to the carbureter. When the plunger is moved upwards a partial vacuum is created in the passage *d*, and fuel is drawn up from the tank past the valve *c* into the passage. The valve *b* is held closed by the pressure that acts on top of it. As soon as the plunger starts to descend, the valve *c* drops to its seat, and the fuel cannot return to the tank. A pressure is thus produced in the passage *d*, causing the valve *b* to rise, and the fuel is forced out into the pipe at *g* and so to the carbureter. At the end of the downward stroke the valve *b* closes, and the fuel is prevented from running back into the pump from the carbureter. The plunger is surrounded by packing *h* that is compressed by a gland *i* held down by the nut *j*. A tight joint is thus made and leakage is prevented.

**19.** The great trouble experienced with engines using kerosene as fuel is that kerosene is less volatile than gasoline and is therefore much more difficult to vaporize. It is possible to spray kerosene into the air-current with an ordinary carbureter such as is used for gasoline; but the finely divided particles of kerosene will not change to vapor readily and are apt to be carried into the engine cylinder as spray. Once they have entered the cylinder, the heat of the metal walls and the heat developed during compression may be sufficient to change all of the spray to vapor, in which case the engine will work satisfactorily; but if the heat is not great enough to vaporize the kerosene completely, and the charge is fired while some of the fuel is still in the liquid form, the burning will not be perfect and trouble will result. The outer layers of the drops of kerosene spray will be vaporized by the heat of the explosion and will burn, but the centers will not, because they remain liquid, and the liquid will be changed by the heat to carbon and a sort of tar, both of which will be deposited on the cylinder, the piston, the spark plugs, and the exhaust passages, fouling them and necessitating frequent cleaning. The exhaust gases will be smoky and will have a very offensive smell.

**20.** To overcome the difficulties met with in the vaporization of kerosene, the plan of heating the air supply has been adopted. The heated air, on meeting the spray of kerosene, gives up its heat and thus causes the spray to vaporize much more rapidly than would be the case if the air were at an ordinary temperature. Another method is to heat the kerosene before it leaves the spray nozzle. This may be done by surrounding the fuel reservoir with a jacket through which hot water from the water-jacket is circulated. A third way of improving the vaporization of kerosene is to spray it in a finer form, so that the liquid particles will be much smaller and thus more readily converted into vapor. The injection of water vapor into the cylinder along with the charge of air and vapor has been found to improve the action of the kerosene engine. The water vapor is changed to steam by the heat of the burning charge, and thus lowers the temperature in the cylinder somewhat, and prevents pounding. It also prevents the deposit of carbon and tar, and the inside of the cylinder stays clean. Many engines that use kerosene as fuel are so arranged that they can be started on gasoline, which is used until the engine is warm enough to run on kerosene.

**21.** A form of vaporizer for an engine using kerosene is shown partly in section in Fig. 6, in which (*a*) is the arrangement for running the engine on gasoline and (*b*) is the arrangement for regular running on kerosene. The gasoline is stored in a small tank *a* on top of the kerosene tank *b*, and each tank is connected to the supply pipe *c* that leads to the spray nozzle *d*. The amount of opening of the nozzle is regulated by the needle valve *e*. When the engine is to be started on gasoline, the cylindrical shutter *f* is turned so that the web on its outer end is horizontal, with the word *GASOLINE* at the top, as shown in (*a*). The air supply is then drawn in at *g*, through the opening *h* in the side of the shutter, and so out past the spray nozzle. The kerosene valve *i* is closed and the gasoline valve *j* is open, and so the suction draws gasoline from the spray nozzle and carries it along with the air into the mixing chamber *k* and thence through the inlet valve *l* into the cylinder.

**22.** After the engine has been running on gasoline until it is thoroughly warmed up, the shutter *f*, Fig. 6, is given a quick turn half-way around, bringing the word *KEROSENE* on top as shown in (*b*). The air opening *g* is thus closed and the opening *h* is brought over the top of the passage *m*, which leads from the chamber *n* formed inside the sleeve *o* and around the exhaust pipe *b*. The exhaust gases are discharged

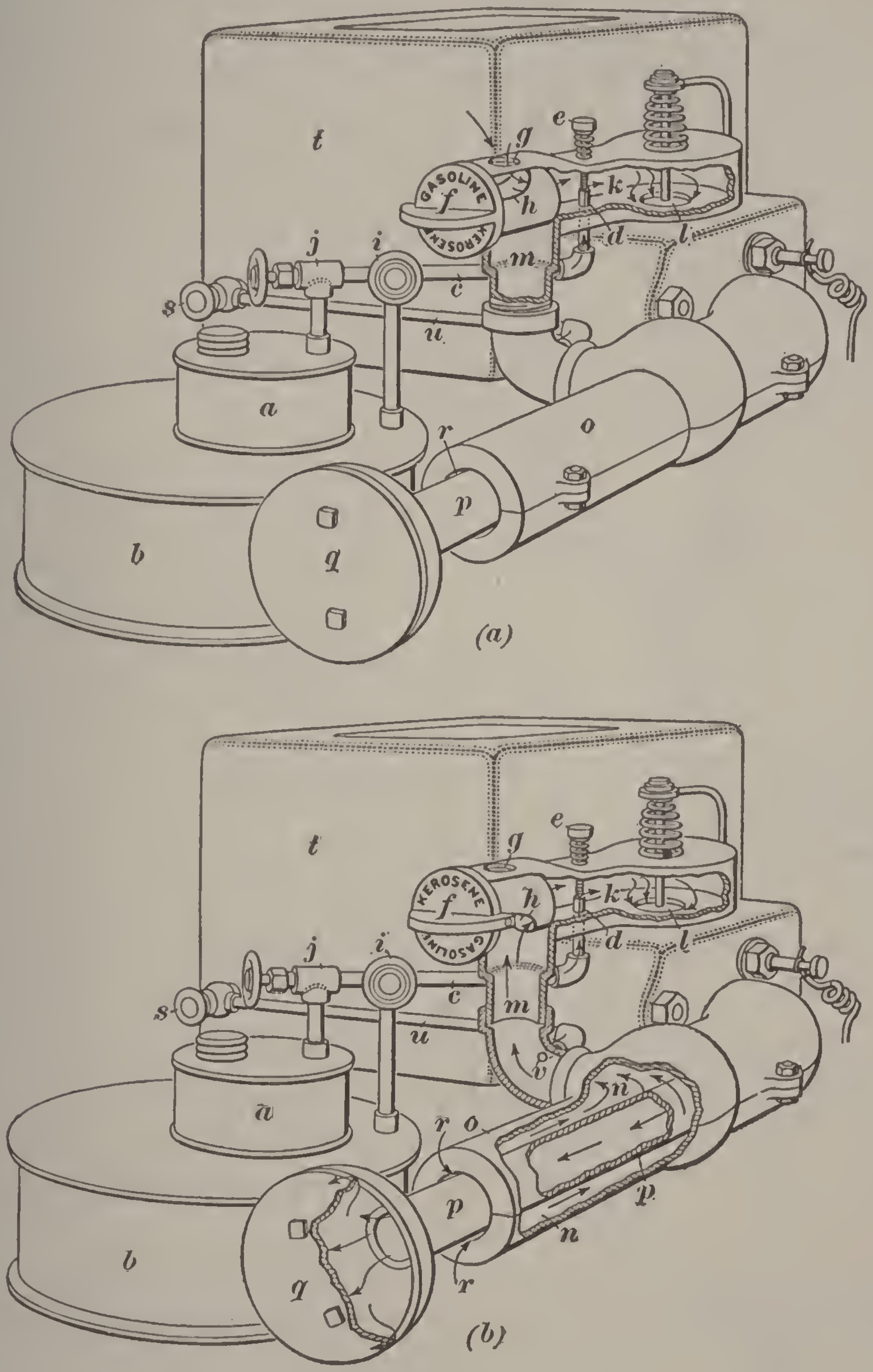


Fig. 6

from the cylinder through the inner pipe *p* into the muffler *q*. The air supply is drawn in at the opening *r* between the sleeve *o* and the pipe *p* and passes along the chamber *n* into the passage *m* and thence past the spray nozzle to the mixing chamber. In passing over the hot exhaust pipe *p* the air is heated and the fuel is thus vaporized far more easily and rapidly. If the engine begins to pound when the change to hot air is made, the valve *s* should be opened slowly. Hot water will then flow from the tank *t* through the pipe *u* and into the passage *m* through the nozzle *v*. This water will be sprayed by the current of air and will be carried into the cylinder. As soon as the valve *s* is opened so as to admit the proper quantity of water, the pounding will cease.

**23.** The engine should be allowed to run for several minutes on gasoline and hot air, with the water-injection valve open. Then the gasoline valve *j*, Fig. 6, should be closed about half way and the kerosene valve *i* should be opened. As both fuel tanks are then in communication with the supply pipe *c*, the fuel drawn past the spray nozzle will be a mixture of gasoline and kerosene. After the engine has been running for a few minutes on the mixture of both fuels, the valve *j* may be closed completely and the operation will continue on kerosene alone. The needle valve *e* should be adjusted until the explosions are regular. It is probable that a somewhat greater opening of the valve will be required when using kerosene than when using gasoline. The water valve *s* must be handled carefully and only enough water should be admitted to stop the pounding. If too much water is admitted, the engine will stop.

The foregoing explanation applies particularly to the type of combined gasoline and kerosene carbureter illustrated. There are other forms of combined carbureters that differ in details of construction and operation from that shown. In general, however, the principle of action is the same; that is, the engine is started on gasoline and warmed up, and then the change to kerosene is made by manipulating the valves in the fuel pipes.

**24.** The vaporizer shown in Fig. 7 (*a*) and (*b*) is called a **mixing valve** and is intended for use on stationary engines running on kerosene as fuel. There are two pipe connections, that at *a* for the kerosene pipe and that at *b* for the water pipe. From the connection *a*, a passage *c* leads to a spray opening *d* that is regulated by a needle valve *e*. A similar passage leads from the water connection to another spray opening controlled by the needle valve *f*. Both of the spray openings are in the beveled seat *g* of the valve *h*, so that, when the valve is closed, the spray openings are covered by the edge of the valve disk. A light spring *i* on the lower end of the valve stem holds the valve to its seat except on the suction stroke of the piston, when a vacuum is formed in the mixing chamber *j*. The pressure of the atmosphere on the under side of the valve *h* lifts the valve, and air is drawn through from the opening *k* past the spray nozzles into the mixing chamber and thence out to the cylinder by way of a pipe connected at *l*. As soon as the valve *h* is lifted, the vacuum causes kerosene and water to be sprayed from the spray openings, and the air-current picks up the spray and carries it into the

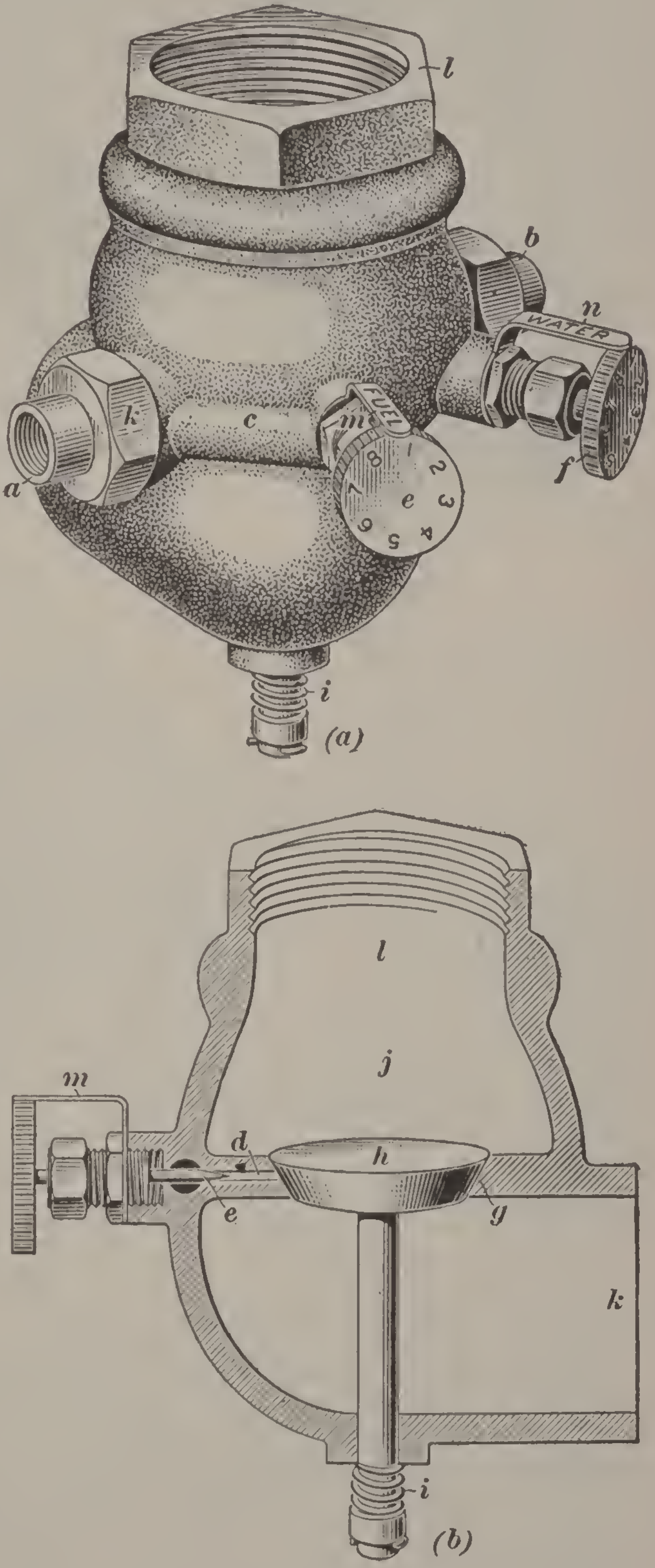


Fig. 7

cylinder. The connections *a* and *b* are alike, and either can be used for fuel or water. If they are interchanged, the removable indicators *m* and *n* should be transposed.

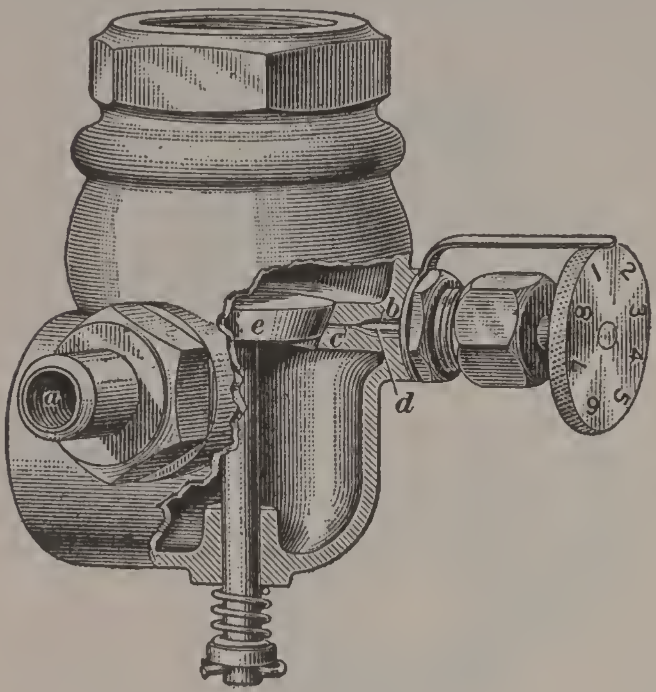


FIG. 8

**25.** A mixing valve for use on small gasoline engines is shown partly in section in Fig. 8. The construction is very much like that of the kerosene mixing valve just described. There is but one fuel inlet *a*, from which the gasoline flows through a passage to the chamber *b*, and through the opening *c* controlled by the needle valve *d*. The valve opening *c* is in the seat of the valve *e*, and this valve lifts only during the suction stroke of the piston of the engine. The flow of gasoline is checked, therefore, whenever the valve *e* is seated. The gasoline may be fed from a constant-level chamber or it may be fed under slight pressure by having the reservoir slightly above the level of the spray opening. As a rule, a mixing valve does not give as perfect a mixture as does a carbureter with a nozzle; but if it is used on a two-cycle engine with crank-case compression a better mixture can be obtained, because the gas and the air will be more thoroughly mixed while passing through the crank-case.

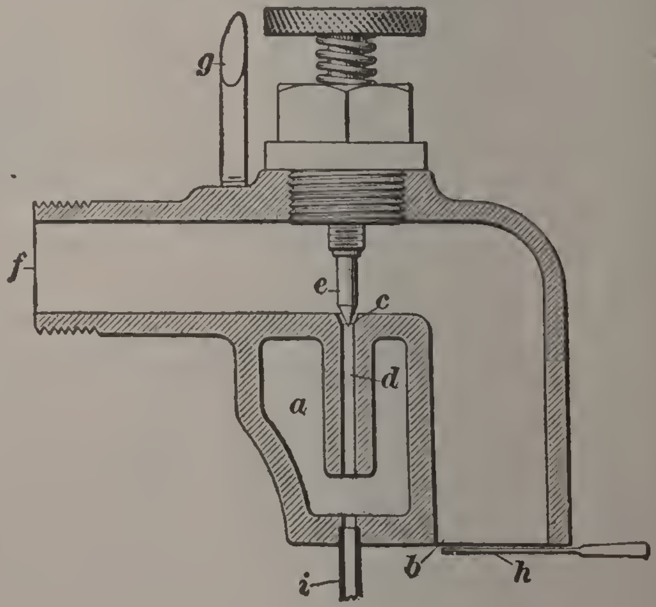


FIG. 9

**26.** A very simple form of gasoline mixing valve for use on engines of small power is shown in Fig. 9. The gasoline is maintained at a constant level in the reservoir *a* by means of a pump and an overflow pipe not shown, but similar to those already described. The gasoline enters the chamber *a* from the pipe *i* through an opening protected by fine wire gauze. The air is drawn in at *b* and passes the mouth of the spray opening *c* on its way to the cylinder. Gasoline is sucked up the passage *d* and is sprayed into the air-current past the needle valve *e,* the mixture leaving the mixing valve at *f*. The post, or pointer, *g* enables the needle valve to be set to certain known positions to correspond to different running conditions. A sliding damper *h* is placed at the air inlet to make starting easy. When the engine is to be started, the damper is placed so as to close the air inlet. The first suction stroke of the piston will then draw a rich charge into the cylinder. As soon as the engine has started, the damper is opened and the air permitted to enter the air inlet freely.

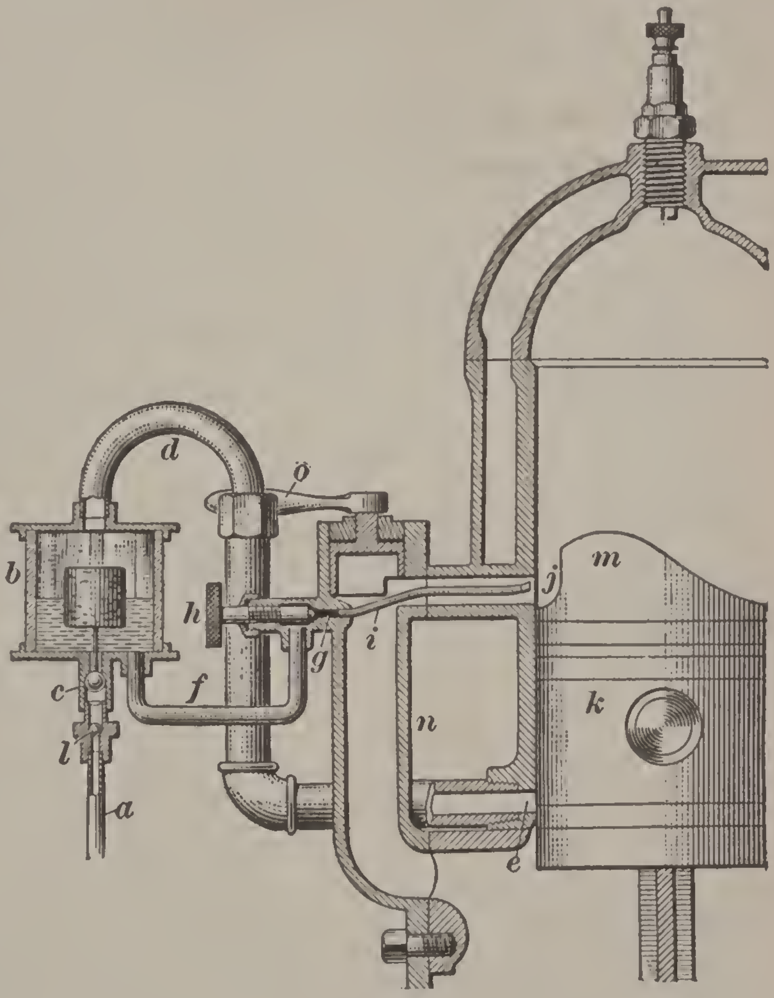


FIG. 10

**27.** The carbureter shown in Fig. 10 is built especially for use with a two-cycle engine. The fuel flows from the supply tank through the pipe *a* to the float chamber *b,* in which a constant level is maintained by a cork float attached to the stem of the valve *c*; the float chamber is surrounded by glass, so that the gasoline level can be seen. From the top of the float chamber, a pipe *d* leads to the port *e* near the bottom of the engine cylinder, and from the bottom of the chamber a pipe *f* leads to the spray nozzle *g* governed by the needle valve *h*. A tube *i* leads from the spray nozzle to the inlet port *j* of the cylinder. When the piston *k* moves upwards and uncovers the port *e,* the partial vacuum created in the crank-case is transmitted to the float chamber through the pipe *d,* and the suction draws fuel up from the supply tank. On the downward stroke of the piston a pressure is created in the crank-case, and consequently in the float chamber; but the fuel cannot flow back to the tank, because the ball check-valve *l* seats itself under the pressure from above. The result is that, as soon as the port *j* is uncovered, the pressure on the fuel in the float chamber forces some of the fuel past the needle valve and through the tube *i* into the cylinder, where it strikes the hot deflector *m* on the top of the piston and is rapidly vaporized. At the same time, compressed air from the crank-case flows through the pipe *n* into the cylinder by way of the port *j* and mixes with the vaporized spray. A shutter that can be moved by the handle *o* is placed in the upper end of the air pipe *n* to regulate the amount of air admitted to the cylinder.

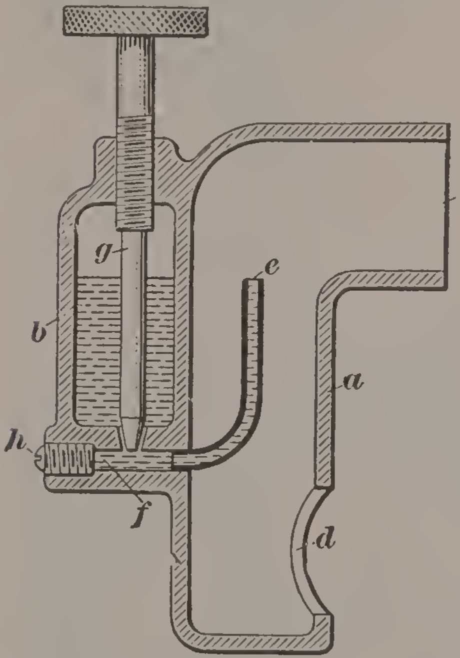


Fig. 11

**28.** Another very simple design of carbureter is shown in section in Fig. 11. The body *a* consists of a right-angled bend, on the back of which is cast the fuel reservoir *b*. The fuel is maintained at a constant level by means of a force pump and an overflow pipe, which are not shown but which are like those already described. The carbureter is bolted to the cylinder at *c* and the air enters through the opening *d*. The spray nozzle is a bent tube *e,* the tip of which is central in the air pipe and the lower end of which communicates with the passage *f* leading to the fuel reservoir. A needle valve *g* controls the rate of flow of fuel to the spray nozzle. The plug *h* may be removed when it becomes necessary to clean the passage *f*.

**29.** Inasmuch as the spray of fuel is drawn out of the nozzle by the suction caused by the rush of air past the nozzle, a strong suction at the tip of the nozzle is desirable. To increase the suction, the tube in which the nozzle is located is often made of a special form, known as a Venturi tube. The **Venturi tube,** as shown diagrammatically in Fig. 12, consists of two tapering tubes joined at their small ends so as to form a continuous tube. A fluid entering at *a,* and flowing in the direction of the arrow, passes first through a rapidly narrowing part until it reaches the narrowest cross-section at *b,* known as the *throat,* and then passes through a gradually widening part to the discharge orifice at *c.* This form of tube derives its name from an Italian named Venturi, who experimented with various modifications of it and discovered certain peculiar facts with reference to its influence on the rate of flow and the quantity of discharge of fluids passing through it.

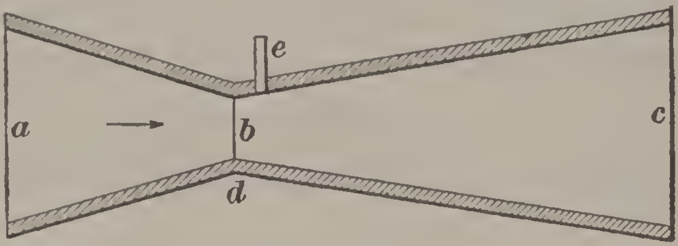


FIG. 12

**30.** When a fluid under constant pressure flows through a short tube of uniform diameter, the velocity of flow is practically the same at all points; but when the flow occurs in a Venturi tube, the velocity varies, being least at the cross-section of greatest area and greatest at the cross-section of least area. In Fig. 12, the flow of fluid through the tube in the direction from *a* to *c* results in the formation of a slight vacuum just beyond the throat *d,* and if a small pipe *e* were attached at this point, as shown, air would be drawn in through it. In other words, the pressure at a point just beyond the throat is less than the pressure outside the Venturi tube. On account of this peculiar action, the velocity of flow through the throat of a Venturi tube is greater than that through a straight pipe of equal diameter, under the same conditions as to pressure, and so the discharge from the Venturi tube is also greater.

**31.** The method of applying the principle of the Venturi tube to a carbureter may be illustrated by the diagram in Fig. 13. The main air supply to the carbureter enters at *a,* passes to the throat *b* of the Venturi tube and flows through the expanding passage *c* to the engine. The gasoline is supplied to the spray nozzle *d,* which is inserted into the lower end of the Venturi tube and is of such length that the opening *e* is central in the tube at a point just beyond the throat. In other words, the upper end of the nozzle *d* is located at the point where the pressure is least, so that, when the carbureter is working, the gasoline is discharged from the opening *e* into a partial vacuum, thus insuring a greater flow.

**32.** The gasoline in the float chamber to which the nozzle *d,* Fig. 13, is connected is acted on by atmospheric pressure, or about 15 pounds per square inch at sea level; whereas, the gasoline issuing from the orifice *e* is subjected to a pressure that may be less by several pounds per square inch. As a result of these unbalanced pressures, the gasoline is forced rapidly through the nozzle *d* and is discharged from the orifice *e* in the form of spray, which is caught up by the air supply and carried on toward the mixing chamber. The reduction of pressure at the end of the nozzle *d* also insures a more rapid vaporization of the gasoline. It is a well-known fact that the temperature at which a liquid boils and changes into vapor is lowered by reducing the pressure on the liquid. Thus, water will boil at a temperature of 212° F. at sea level; but at the top of a mountain 1 mile above sea level, where the pressure is less because the air is rarer, water will boil at 202° F. Similarly, when the gasoline is discharged into the throat *b,* where the pressure is reduced, its boiling point is lowered considerably and the result is that it flashes into vapor much more readily than when subjected to atmospheric pressure.

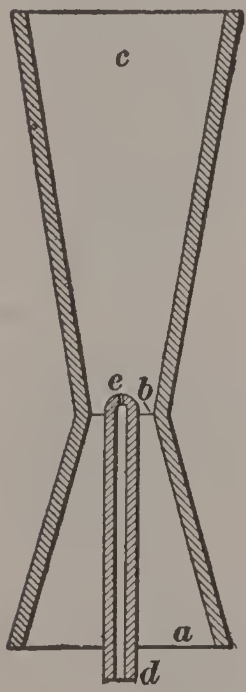


Fig. 13

**33.** The flow of gasoline from the spray nozzle does not increase or decrease in proportion to the increase or decrease of flow of air through the Venturi tube. As the suction increases, due to greater engine speed, the flow of gasoline increases more rapidly than the flow of air; consequently, to obtain the desired mixture, it is necessary either to reduce the suction, by permitting additional air to enter between the nozzle and the engine, or else to alter the rate of flow of the gasoline. By proper loading of the valve or valves controlling the auxiliary air supply, the suction exerted at the gasoline nozzle may be kept very close to that required to produce a uniform mixture at all speeds. The size of the orifice in the tip of the gasoline nozzle bears a definite relation to the size of the Venturi tube at its throat, and these proportions are determined by the designer. If, through imperfect fitting of parts and unskilful workmanship, there are air leaks in the engine, the nozzle orifice will need to be somewhat larger.

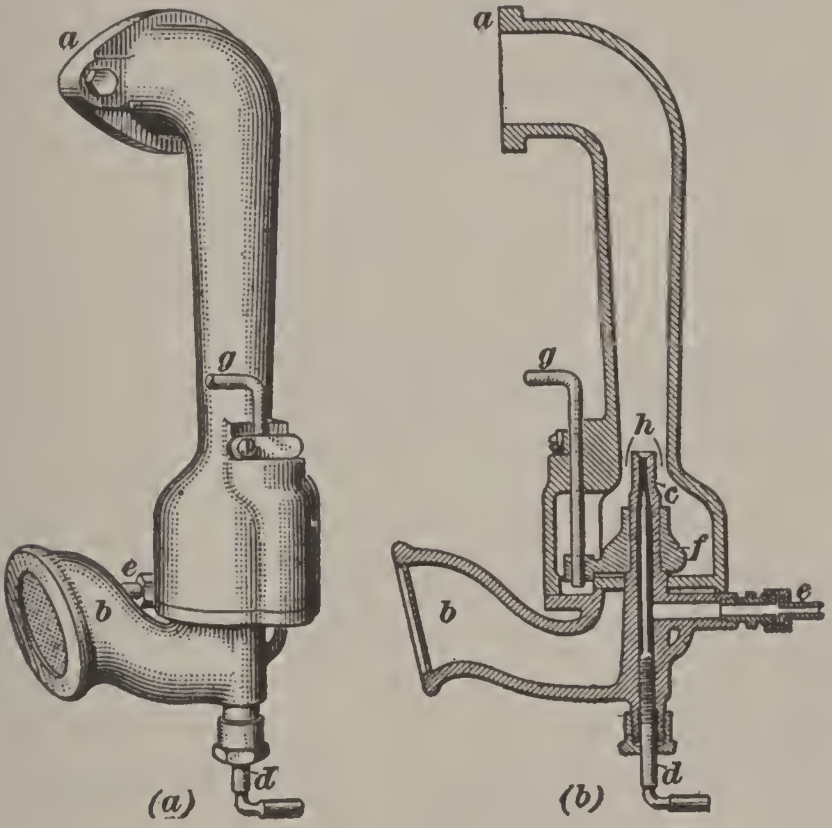


FIG. 14

**34.** A Venturi-tube type of gasoline carbureter for stationary engines is shown in Fig. 14, (*a*) being a perspective and (*b*) a sectional view. The carbureter is bolted directly to the cylinder inlet by the flange *a*, and the air supply is drawn in through the horn *b*, which may be covered with a screen to prevent the entrance of dirt and grit. The gasoline spray nozzle *c* is central in the Venturi tube and the flow of gasoline is regulated by the needle valve *d*. The supply of fuel is kept in a tank formed in the base of the engine and is drawn up by suction through a pipe connected at *e*. A ball check-valve in this pipe serves to keep the level constant in the spray nozzle. Surrounding the nozzle is a sleeve *f* that may be moved up or down by the handle *g*. When the engine is to be started, and a rich mixture is desired, the sleeve *f* is drawn up, thus partly closing the throat *h* of the Venturi tube. The flow of air is thus restricted and the suction exerted on the gasoline causes a heavy spray of it to be drawn into the mixing tube.

**35.** A form of carbureter used on stationary gasoline engines is shown in Fig. 15, (*a*) being an outside view and (*b*) a section. Corresponding parts in both views are marked with the same reference letter. The gasoline enters at *a* and the air at *b*, so that the air flows downwards past the spray nozzle, instead of upwards as is more usual, and passes through the throttle valve and out at *c*. The float *d* is shaped so that it goes on each side of the mixing chamber. It is secured to a lever pivoted at the right, and in rising closes the regulating valve *e*. In the passage *b* is an automatic air-inlet valve *f*, closed by means of a spring *g*, as shown. This valve does not entirely close the air passage when it rests against its seat, but at the bottom is left an opening through which is supplied the necessary air for keeping the engine in operation under the slowest running conditions. As the suction increases, this valve opens against the spring *g*, thereby admitting a larger quantity of air.

**36.** The gasoline passes directly from the float chamber to the spray nozzle *h*, Fig. 15, the opening of which may be regulated by the needle valve *i*. As the opening of this nozzle is exactly in the center of the float chamber, the carbureter is not affected by being tilted. The throttle valve *j* is opened and closed by means of the lever *k*; the mixture of air and gasoline passes through in the direction indicated by the arrow. Adjustment of the automatic air valve *f* is obtained by modifying the tension of the spring *g*, by screwing up or unscrewing the shouldered stem *l*, which extends through the valve *f* to guide it, but is not attached to it. A drain cock *m* is provided

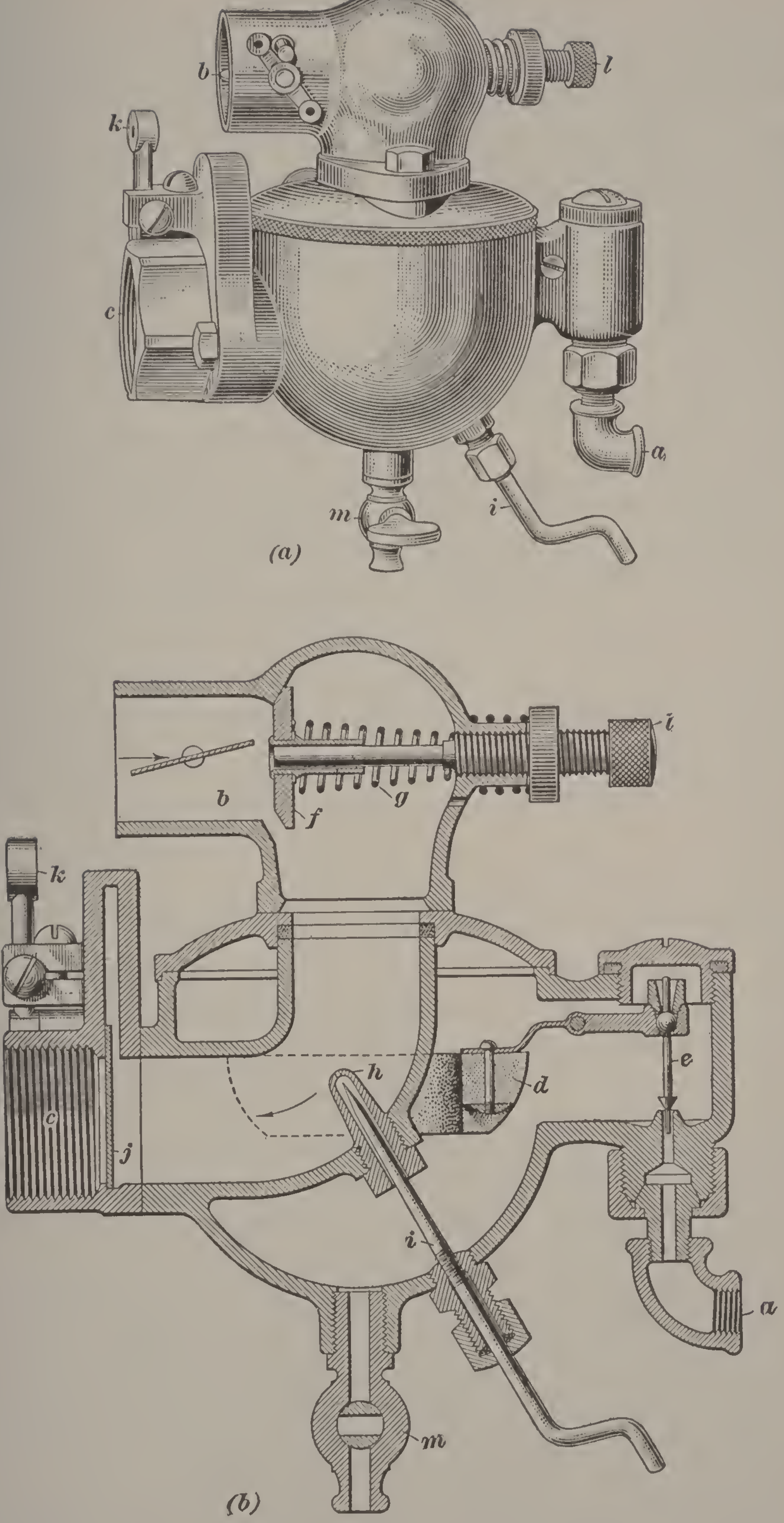


Fig. 15

at the bottom of the float chamber, for the purpose of emptying it or for drawing off water that may have got into it.

**37.** A stationary gasoline engine usually runs at a nearly uniform speed, and therefore the carbureter or vaporizer is more easily adjusted to the running conditions than is the case with an automobile carbureter, which must give a fairly uniform mixture over a wide range of speeds. To obtain the adjustment for the most economical use of fuel, the engine should be run at its usual speed under the load that it is to carry regularly. Then the needle valve that controls the flow of gasoline to the spray nozzle should be closed, a little at a time, until a point is reached at which further closing will reduce the speed and the power of the engine. At this point the amount of fuel supplied through the spray nozzle is just enough to keep the engine in motion at the desired speed and doing the required work. The carbureter will then be adjusted for economical service under those particular conditions of speed and load. If the load or the speed is altered, the engine will probably continue to run, but not necessarily with the same economy.

## CARBURETERS FOR AUTOMOBILE AND AEROPLANE ENGINES

**38.** The greatest problem in connection with the carburation of liquid fuel for use in automobile engines is to obtain a carbureter that will give a uniform mixture at all speeds. A float-feed carbureter of the elementary form shown in Fig. 2 cannot do this, because the flow of fuel from the nozzle increases at a greater rate than the flow of air through the air tube when the engine is speeded up. In other words, if the ratio of fuel vapor to air is correct at a low engine speed, it will be too large at a higher speed, or, as it is commonly expressed, the mixture becomes *too rich.* This is just the opposite of the way the mixture should be; it will be most satisfactory if it is a little rich at very low engine speeds and becomes less rich as the engine speed increases.

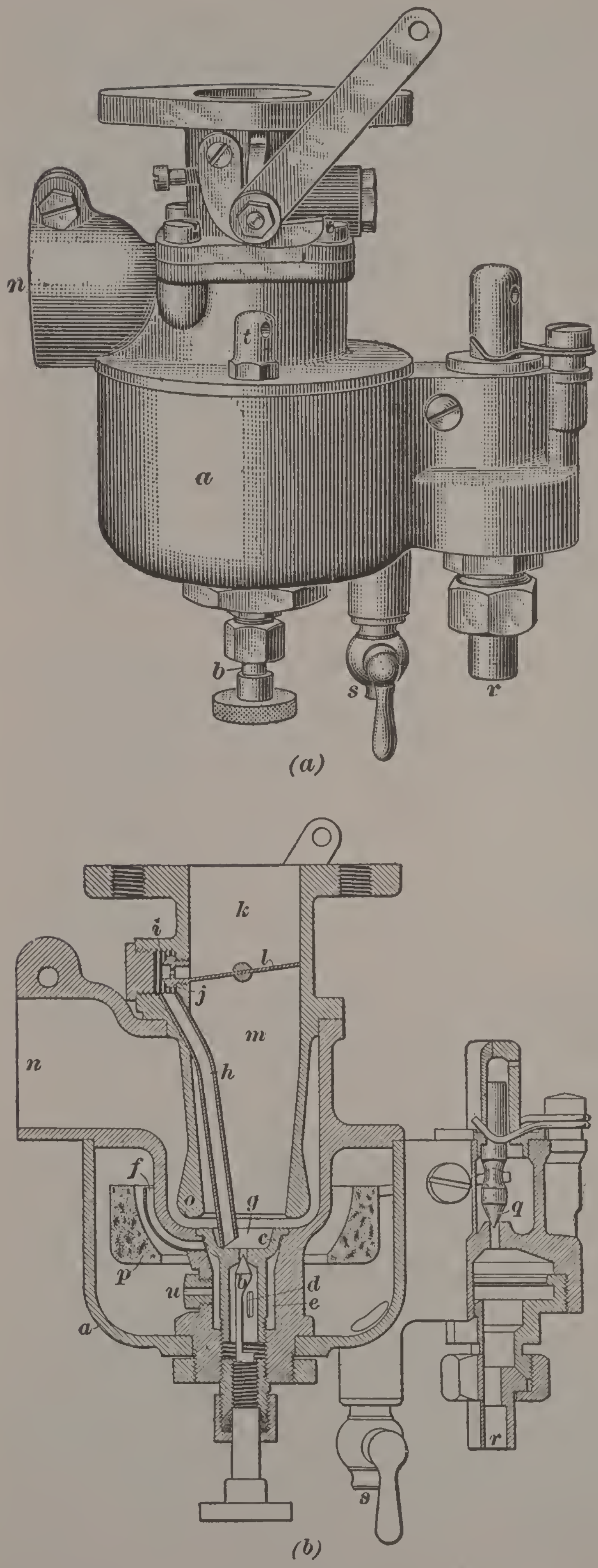
**39.** This statement about a carbureter of the elementary form shown in Fig. 2 must not be taken to mean that it is impossible to use a form so simple; its true meaning is that it will furnish a mixture substantially correct over only a rather narrow range of engine speeds and throttle openings. Thus, if the nozzle and the air tube are correctly proportioned for an engine speed of 400 revolutions per minute, the carbureter will probably deliver a substantially correct, although theoretically incorrect, mixture anywhere between perhaps 250 and 500 revolutions per minute.

The quantity of mixture flowing from the carbureter to the engine is governed by a hand-operated throttle valve, which is usually made a part of the carbureter. Opening this valve allows more mixture to flow to the engine, which then increases its speed or power; and closing the throttle valve cuts down the quantity of mixture flowing to the engine and hence slows it down or decreases its power.

**40.** A carbureter that controls the mixture over only a very small speed and throttle-opening range is said to lack flexibility; and a carbureter controlling the mixture properly over a very large speed and throttle-opening range is said to be very flexible. Flexibility in a carbureter can be secured only by providing means of compensating for the more rapidly increasing flow of the fuel over that of the air as the engine speed or throttle opening increases. A carbureter provided with such means is called a *compensating carbureter,* and if the means adopted work without the attention of the operator, it becomes an *automatic compensating carbureter.*

**41.** The carbureter shown in Fig. 15 is an automatic compensating carbureter, because it automatically adjusts the air supply to an increased flow of gasoline. It does this through the automatic air valve *f*. After the carbureter has been set and connected to the fuel supply and to the engine, it should be adjusted, first for low speed and then for high speed. The air valve is seated firmly but lightly by screwing down the knurled screw *l,* and the needle *i* is screwed shut and then opened about three-fourths of a turn. The carbureter is then ready for low-speed adjustment. The spark should be retarded and the throttle opened about one-fourth. The gasoline should then be turned on and the engine started, after which the needle valve should be opened until a point is reached at which the engine will run smoothly without missing explosions. The stop-screw on the throttle should be set so that the throttle cannot be closed completely. The carbureter is then adjusted for low-speed running.

**42.** To adjust the carbureter shown in Fig. 15 for the high speed of an automobile engine, the throttle *k* should be opened wide and the spark should be advanced about one-fourth. If the engine does not run smoothly, but backfires, the fault is due to the fact that the air valve *f* lifts too easily and admits too much air. The screw *l* should therefore be turned right-handed to increase the pressure of the spring *g*. If the engine continues to fire irregularly after the screw *l* has been given



(a)

(b)

Fig. 16

two full turns, the needle valve *i* should be opened a very slight amount more, to feed more gasoline. After these adjustments have been made, the screw *l* should be held by turning down the locknut against the body of the carbureter. The adjustment of the needle *i* can be locked by screwing up tightly the packing nut through which the needle passes into the bowl of the carbureter.

**43.** An outside view and a sectional view of another form of carbureter are shown in Fig. 16 (*a*) and (*b*), respectively, corresponding parts in both views being lettered alike. The float chamber *a* forms the body of the carbureter and the needle valve *b* is centrally located in it. The needle valve has a seat in the casting *c*, in the side of which is a slot *d* leading to the annular chamber *e*. The chamber *e* is connected with the upper part of the float chamber by a small passage *f*. In the upper end of the casting *c* is formed a cup *g* into which dips the lower end of the tube *h*. The upper end of this tube is led into a chamber *i* that communicates, through a hole in the plug *j*, with the space *k* above the throttle valve *l*. The mixing chamber *m* is so formed that the air must pass from the inlet *n* down under the lower edge *o*. The float *p* is ring-shaped and controls the valve *q* through which gasoline is admitted by way of the connection *r*. The cock *s* allows the float chamber to be drained, and the vent *t* shown in (*a*) admits air to the upper part of this chamber.

**44.** The carbureter illustrated in Fig. 16 has no air valves, and all of the air admitted must pass the spray nozzle. The gasoline level in the float chamber *a* is constant, and from this chamber the gasoline passes through the small opening *u* into the chamber *c*. It then flows through the slot *d* and rises past the needle valve *b* into the cup *g*, in which it stands at the same level as in the float chamber. When it is desired to start the engine, the throttle valve is opened very slightly, until it occupies the position shown. Then, on cranking the engine, a strong suction is exerted through the hole in the plug *j* and through the tube *h*, causing the small supply of gasoline in the cup *g* to be drawn up and sprayed into the intake manifold, and furnishing the desired rich mixture. This action is bound to take place, no matter what may be the condition of the weather. The cup *g* is quickly emptied at starting, and the gasoline is afterwards supplied from the chamber *e* through the orifice surrounding the tip of the needle valve.

**45.** The flow of gasoline from the float chamber *a*, Fig. 16, to the spray nozzle is limited by the size of the opening *u*, which is made large enough to supply enough gasoline for normal running. As the speed of the engine increases, the suction increases, and the level of the gasoline in the chamber *e* falls, because the flow through the orifice *u* is restricted. The distance through which the gasoline must be lifted is thus made greater, and the amount of gasoline issuing from the spray nozzle is decreased. If the speed increases still further, the level of the gasoline in the chamber *e* is lowered to such an extent that the slot *d* is partly uncovered. As soon as this occurs, air is drawn from the top of the float chamber through the pipe *f* and the slot *d*, and this stream of air reduces the suction around the needle valve. As a result, less gasoline is drawn up, and the mixture is maintained practically uniform. If it were not for this auxiliary stream of air, too much gasoline would be drawn up at the higher speeds. The air supply to this carbureter should be preheated, by passing it over the exhaust pipe, if the best results are desired.

**46.** The carbureter shown in Fig. 16 has only one adjustment, which is made by turning the milled head fastened to the needle valve *b*. After the engine is started, the regulating sleeve on the hot-air pipe should be turned so as to supply a mixture of equal parts of hot and cold air. The engine should be allowed to run until the intake manifold gets warm. Then the throttle control lever on the steering wheel should be opened about one-eighth of its throw, and the gasoline needle valve *b* should be screwed in until the engine begins to misfire, due to lack of gasoline. The valve *b* should then be screwed out slowly, which gradually increases the supply of fuel, until the point is reached at which the engine picks up speed and runs regularly without misfiring. The carbureter is then correctly adjusted.

**47.** Some makes of carbureters are fitted with compensating jets to regulate the flow of gasoline for varying speeds. Fig. 17 shows a carbureter of this type. It has a compound nozzle, which is really made up of two nozzles, one within the other. A main nozzle or jet *a* of the usual form is surrounded by an outer tube or cap jet *b*. The supply of gasoline for this outer jet passes through the small opening *c* and is limited to the amount that can flow through that opening, which is known as the compensating jet. Air from outside of the carbureter is allowed to enter freely through two holes, one of which is shown by the dotted circle *d*, which admit air freely to the well *e*, and through the passage *f*. This free passage of air prevents any great increase of suction on the jet *c* when the speed of the engine increases, and therefore gasoline flows through the jet *c* at approximately the same rate when the engine is running at 2,000 revolutions per minute as when running at 500 revolutions per minute. This part of the nozzle therefore produces a much weaker, or leaner, fuel mixture at the higher speed than at the lower speed, thus balancing, or compensating, the increased flow of gasoline from the inner jet *a* at the higher

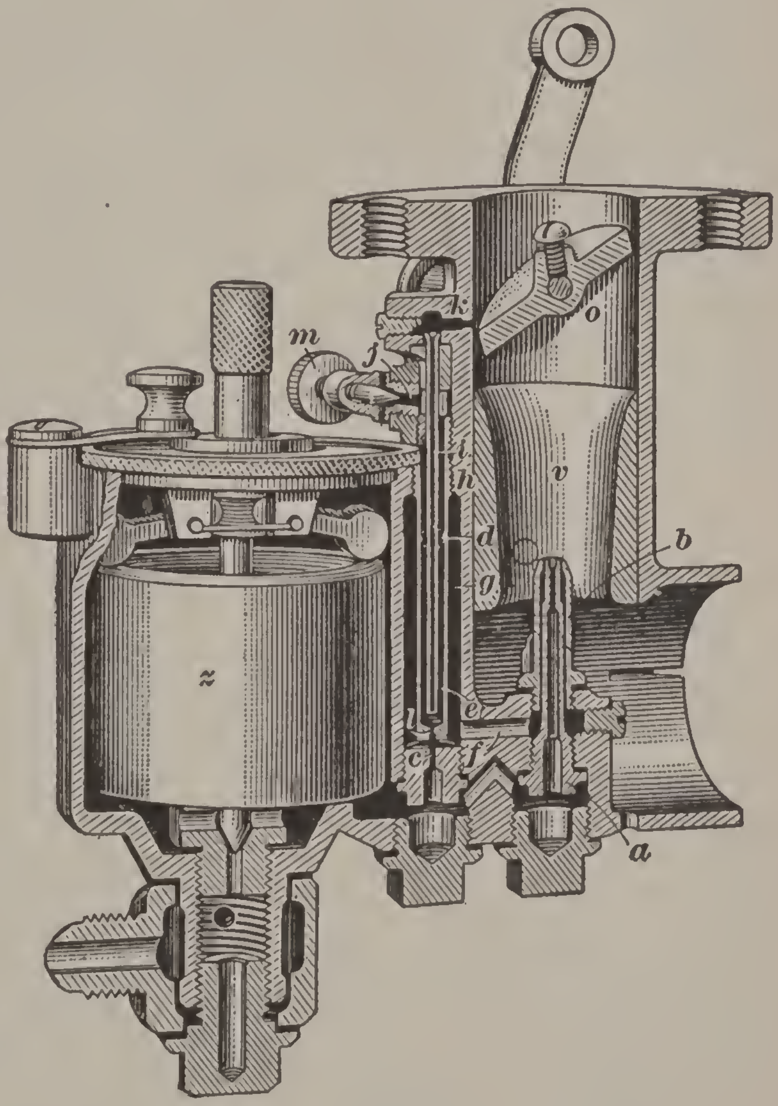


Fig. 17

engine speeds. This is due to the fact that the suction on the inner jet *a* increases as the engine speed increases, owing to the higher velocity of the air past the nozzle, whereas the suction on the compensating jet *c* does not increase as the engine speed increases. It will be seen that by selecting the correct sizes for both jets an adjustment can be made that will give an approximately correct fuel mixture at all of the varying working speeds of the engine.

**48.** The flow of gasoline at the idling speed or slow speed without load is controlled by the idling device, consisting of a tube *g,* called the idling well, or secondary well, which is screwed into the body of the carbureter at *h,* and a small inner tube *i,* called the primary tube, to conduct the fuel to the passage *k*. The richness of the mixture is limited by the amount of gasoline that can flow through the small hole or jet *l,* and is regulated by the adjusting screw *m,* which admits more or less air.

The idling device operates only when the throttle *o* is nearly closed, or when the engine is running at idling speed. The suction is then very strong at the point *k* and very slight on the nozzle *a b*. The adjusting screw *m* has, however, only a limited effect, and when considerable change of speed is needed, the outer tube, or secondary well, *g* is removed by unscrewing the tube and substituting a tube having a smaller or larger jet *l*. Some carbureters do not have the secondary well *g,* but limit the fuel supply by restricting the passage in the tube *i,* the air in this case being measured, or regulated, entirely by the regulating screw *m*. Turning this screw out admits more air past the screw and reduces the suction on the tube *i* so that it draws less gasoline and makes the mixture leaner; screwing it in gives a richer mixture.

**49.** The idling wells *g* and *e,* Fig. 17, fill with gasoline to the level of the gasoline in the float chamber as soon as the suction is stopped. Then, when the engine is cranked with the throttle nearly closed, or set for idling speed, the suction is greatest at the edge of the throttle and draws gasoline from the idling device instead of from the main nozzles, and delivers a rich mixture until the supply of gasoline in the secondary well *g* is exhausted. It will then deliver the regular idling-speed mixture so long as the throttle remains at the position for idling speed. As the throttle is gradually opened, the suction on the idling device is lessened and the suction at the mouth of the nozzles *a* and *b* is increased until the point is reached where the fuel comes entirely from the nozzles *a* and *b* and no fuel is then delivered through the idling device. The outer well *e* remains filled with gasoline while the engine is running at idling speed, but if the throttle is opened suddenly a very rich mixture is delivered from the jet *b* during the first few turns of the engine and until the supply of gasoline in the well *e* is exhausted, thus furnishing the desired rich mixture which the increasing speed of the engine requires. If the throttle is opened gradually, the supply of gasoline in the well *e* is gradually diminished and when exhausted the part *b* of the nozzle can deliver only the amount of gasoline that can flow through the jet *c*.

**50.** If the main jet *a* is too small, the mixture will be too lean when the engine is running at high speed. If it is too large, it will give too rich a mixture at high speed. The jet *a* may thus be thought of as the high-speed adjustment, because the flow of gasoline through it is most affected when the suction of air through the Venturi tube, or choke tube, *v* is strongest, as it will be when the engine is running at high speed. Similarly, the compensating jet *c* may be thought of as the adjustment for loaded slow speed, or slow speed when the throttle is open, as it will be when the engine is making a hard pull. If the engine is running slow without load, the throttle will have to be nearly closed, which will bring into use the idling device, as previously explained. If the choke tube *v* is too large, the gasoline will not be fully vaporized, owing to the low velocity of the air, which will result in particles of raw fuel being drawn into the engine and making a slow burning mixture; the engine will also not respond quickly when the throttle is opened. If the choke tube *v* is too small, the passage of air will be restricted, with an effect similar to that when the throttle is partly closed, and the engine will be prevented from developing its full rated power.

**51.** These four adjustments, or *variables,* as they are called, the choke tube *v,* main jet *a,* compensating jet *c,* and idling jet *l,* seldom need changing after the carbureter is once fitted to an engine. Their sizes are designated by the diameters of the holes through them. The size of the choke tube is indicated in millimeters at the throat diameter, or smallest part of the inside diameter, and the jets are marked in *hundredths* of a millimeter. A compensating jet marked 150 would mean that the hole in the jet has a diameter of 150 hundredths of a millimeter, or one and one-half millimeters.

**52.** Some carbureters compensate for different engine speeds by means of what are called *air-bled jets,* which have been proved experimentally when properly constructed to give a constant proportion of gasoline and air at all speeds. The principle of construction of the air-bled jet is shown in Fig. 18. Placed in the center of the usual Venturi tube *a,* called in some carbureters the choke tube, through which the air passes at high velocity, is a second but smaller Venturi tube *b* the mouth of which is at the throat of the tube *a.* Eight very small holes *c* are drilled through the wall of the tube *b* slightly above its throat; it will be understood that, owing to the two Venturi tubes being in series, a very high air velocity is obtained under the suction of the engine at the throat of the Venturi tube *b,* even at fairly low engine speeds, which greatly aids the atomization of any fuel leaving the jet holes *c.* These holes *c* communicate with a passage *d* leading to the float chamber of the carbureter; this passage *d,* through holes *e* drilled into its wall, communicates with the air by way of the passage *f* and holes in the cap *g.* With the engine running, liquid fuel is forced by

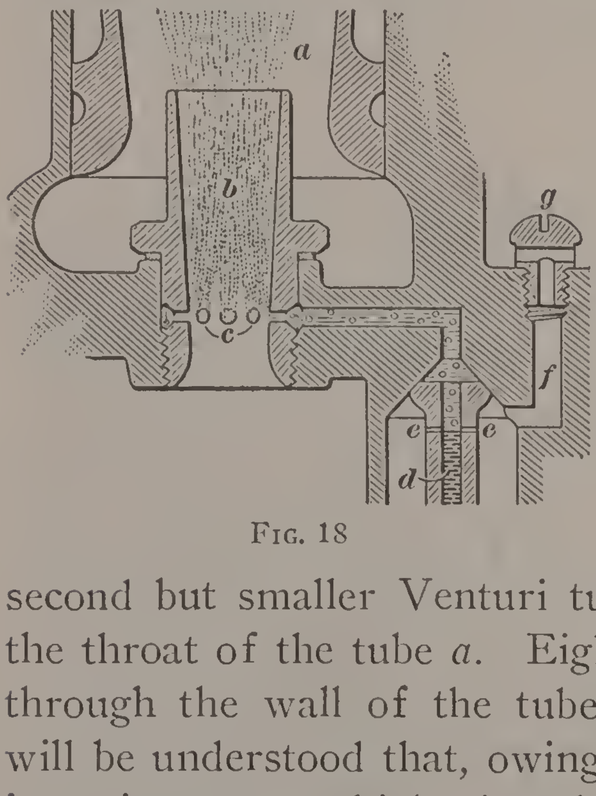


FIG. 18

atmospheric pressure, due to the vacuum in the two Venturi tubes *a* and *b*, up the passage *d* to the holes *c*, where air enters and mixes with the liquid gasoline, changing it to a finely divided emulsion, or froth, which emulsion passes through the jets *c* into the Venturi tube *b*, where it is further atomized and diluted by the air passing through *b* at high velocity. The finely divided mixture of gasoline vapor and air, leaving the mouth of the tube *b* at the throat of the Venturi tube *a*, passes the throttle valve (not shown) and goes to the engine cylinders. As in all carbureters, changing of the liquid gasoline globules into vapor is effected not only by atomization but also by vaporization, which is assisted by preheating the air admitted through the Venturi tubes.

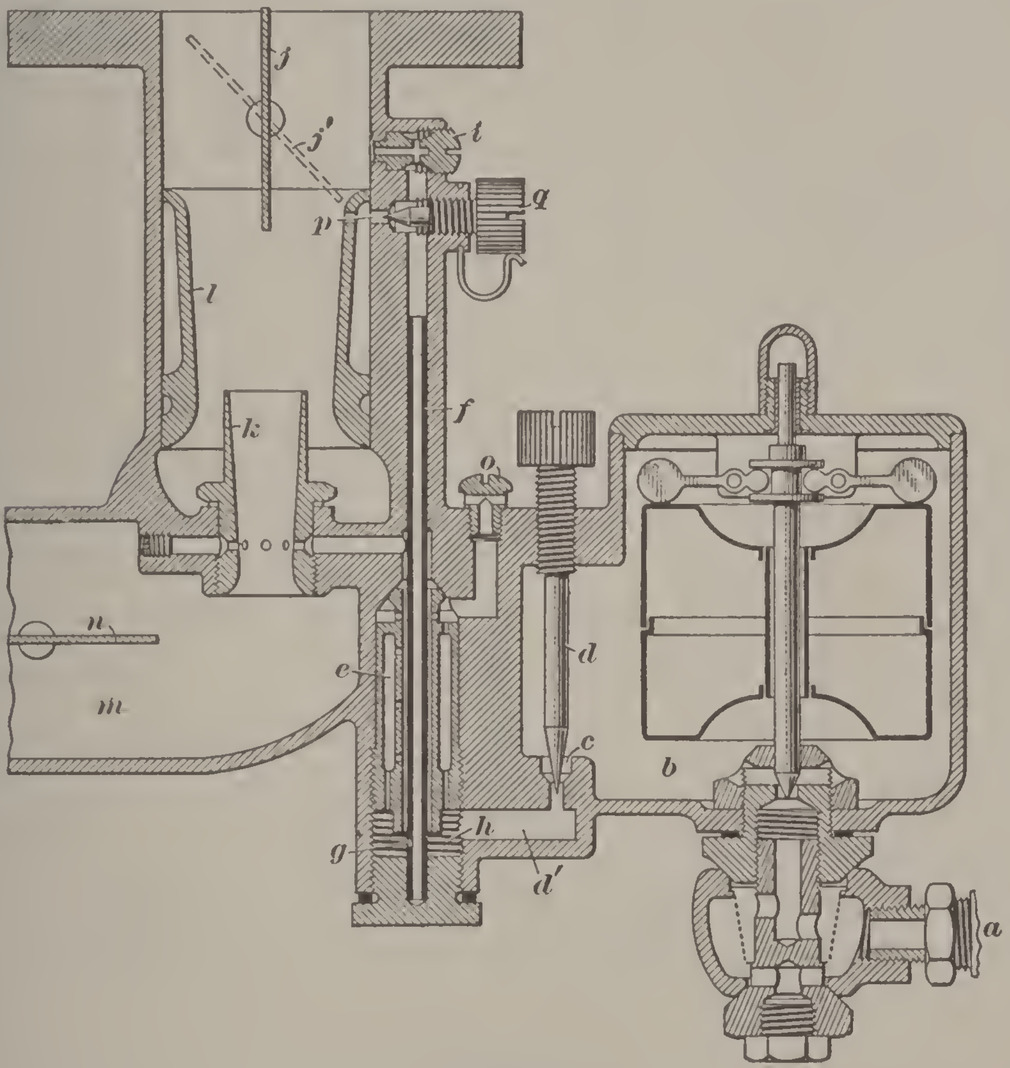


FIG. 19

To sum up, an air-bled jet, instead of passing liquid gasoline into the mixing chamber, supplies an emulsion consisting of very small globules of gasoline suspended in air.

**53.** The general construction of one make of carbureter using an air-bled jet is shown diagrammatically in Fig. 19. The gasoline enters at *a* and passes into the float chamber *b*, whence it passes through an orifice at *c* fitted with an adjustable needle valve *d* into the passage *d′*. At the end of this passage is a plug having a central hole and an annular chamber *e* called the *accelerating well;* the so-called *idling tube f* passes through the central hole of the accelerating well. The idling tube *f* receives gasoline through the small hole *g*. The accelerating well has three small holes drilled through its inner wall, a vent hole drilled through its upper end, and several small holes drilled through its lower end to communicate with the gasoline chamber *h* to which the fuel is supplied by the needle valve at *c*. The passage containing the idling tube *f* terminates at a plug *i* located above the throttle *j* when the throttle is in its closed position. The small Venturi tube is shown at *k*, and the large one at *l*; both Venturi tubes receive preheated air through the air tube *m* provided with a strangling valve *n* for enriching the mixture when starting the engine in cold weather, by throttling the air supply. The liquid gasoline for the emulsion of gasoline and air supplied to the small Venturi tube *k* is drawn from the chamber *h* through the annular opening between the idling tube *f* and the hole in the plug containing the accelerating well *e*. The air-admission plug *o* supplies the air for the air-bled jets in the Venturi tube *k*; an air opening at *p* fitted with a low-speed needle valve *q* supplies air to the gasoline passing out through the idling, or low-speed, plug *i*.

**54.** The operation of the carbureter illustrated diagrammatically by Fig. 19 is as follows: When idling, the throttle *j* is closed. Under this condition, gasoline is drawn from the chamber *h*, through the idling tube *f*, and mixes with air admitted through the passage *p*, the combustible mixture passing through the idling plug *i* into the space above the throttle and thence to the engine. When idling, the two Venturi tubes *k*, *l* and the air-bled jets are out of action, and just enough air passes, at a very low velocity, through the Venturi tubes to supply that required for the idling mixture.

When the engine is speeded up through opening the throttle *j* slightly, the vacuum in the intake manifold of the engine is increased, and therefore the air-bled jets come into action; for very low throttle positions the mixture is fed to the intake by both the idling jet *i* and the air-bled jets. As the throttle is still further opened, the gasoline is drawn faster from the idling tube *f* than it can enter through the hole *g*, and consequently the idling jet automatically goes out of action, all the fuel now being supplied by the air-bled jets in the smaller Venturi tube *k*. It will be plain that the annular opening at *c* should be just large enough to keep the chamber *h* filled with gasoline at all motor speeds; this opening is regulated by trial by screwing the adjusting screw *d* up to strengthen the mixture and down to weaken it. The strength of the mixture for idling is adjusted by trial by means of the low-speed adjusting screw *q*, the throttle being fully closed.

**55.** It is a well-known fact that a carbureter set for a weak mixture, which means an economical mixture, will fail to give good acceleration, that is, will not permit quick throttle opening and consequent quick response of the car. Quick acceleration can be secured in two ways, which are by a permanent setting of the carbureter for a rich and hence very uneconomical mixture, or by temporarily enriching the mixture during acceleration and then returning to the former economical setting. The latter alternative is employed in the carbureter illustrated in Fig. 19, the accelerating well serving the purpose of temporarily enriching the mixture and automatically returning to an economical mixture after acceleration.

**56.** With the engine running at a constant speed corresponding to a car speed of about 20 miles per hour, the accelerating well *c*, Fig. 19, is filled with gasoline to the top. But, if the engine speed is now increased suddenly, the gasoline is drawn faster from the chamber *h* than it can flow into it past the orifice *c*, and there would quickly exist a deficiency of fuel in the chamber *h*, were it not that the accelerating well *e* discharges the fuel it holds, through the holes in its bottom head, into the chamber *h*, thereby temporarily doubling the normal rate of gasoline flow into the chamber *h* and thus supplying the fuel needed for acceleration. By the time the car has speeded up, sufficient fuel flows through the orifice *c* to supply the chamber *h* with all the fuel needed. When the car slows down, the accelerating well gradually fills again with gasoline and is ready for the next sudden acceleration.

**57.** To adjust the carbureter shown in Fig. 19 for idling, the engine is started with the low-speed adjustment screw *q* approximately one-half turn off its seat. When the engine has warmed up, the screw *q* is turned out, that is, counter-clockwise, until the engine idles steadily. As a general rule, the device is properly adjusted when the screw *q* is somewhere between one-half and one and one-half turns off its seat. The adjusting screw *d* adjusts the mixture over the whole driving range. An approximate adjustment is obtained by turning it about three whole turns off its seat, which will probably give a rather rich mixture, and then screwing it in until trial shows a sufficiently weak mixture.

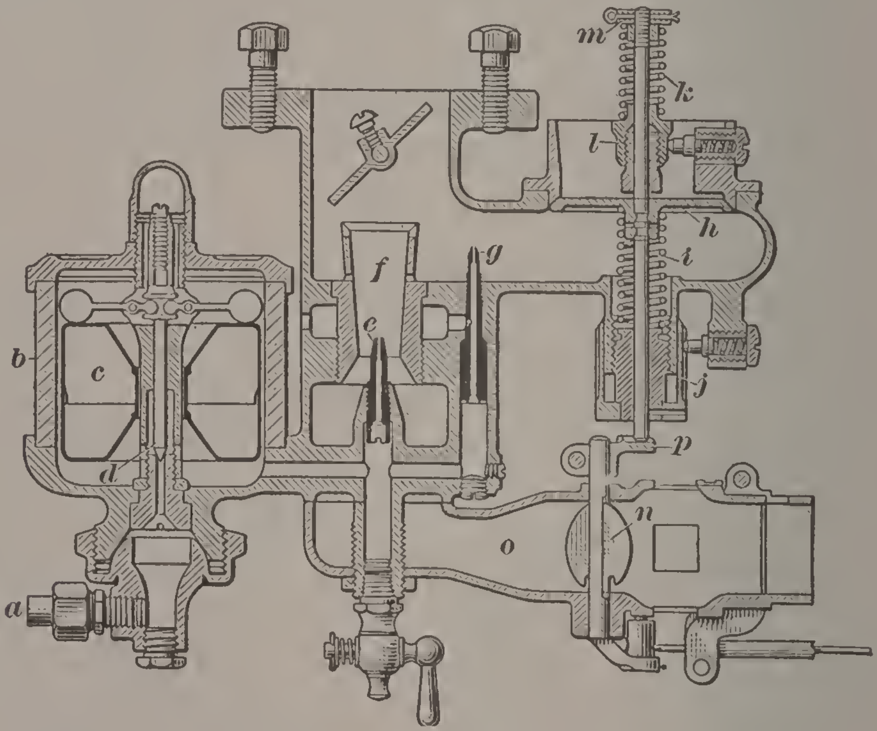
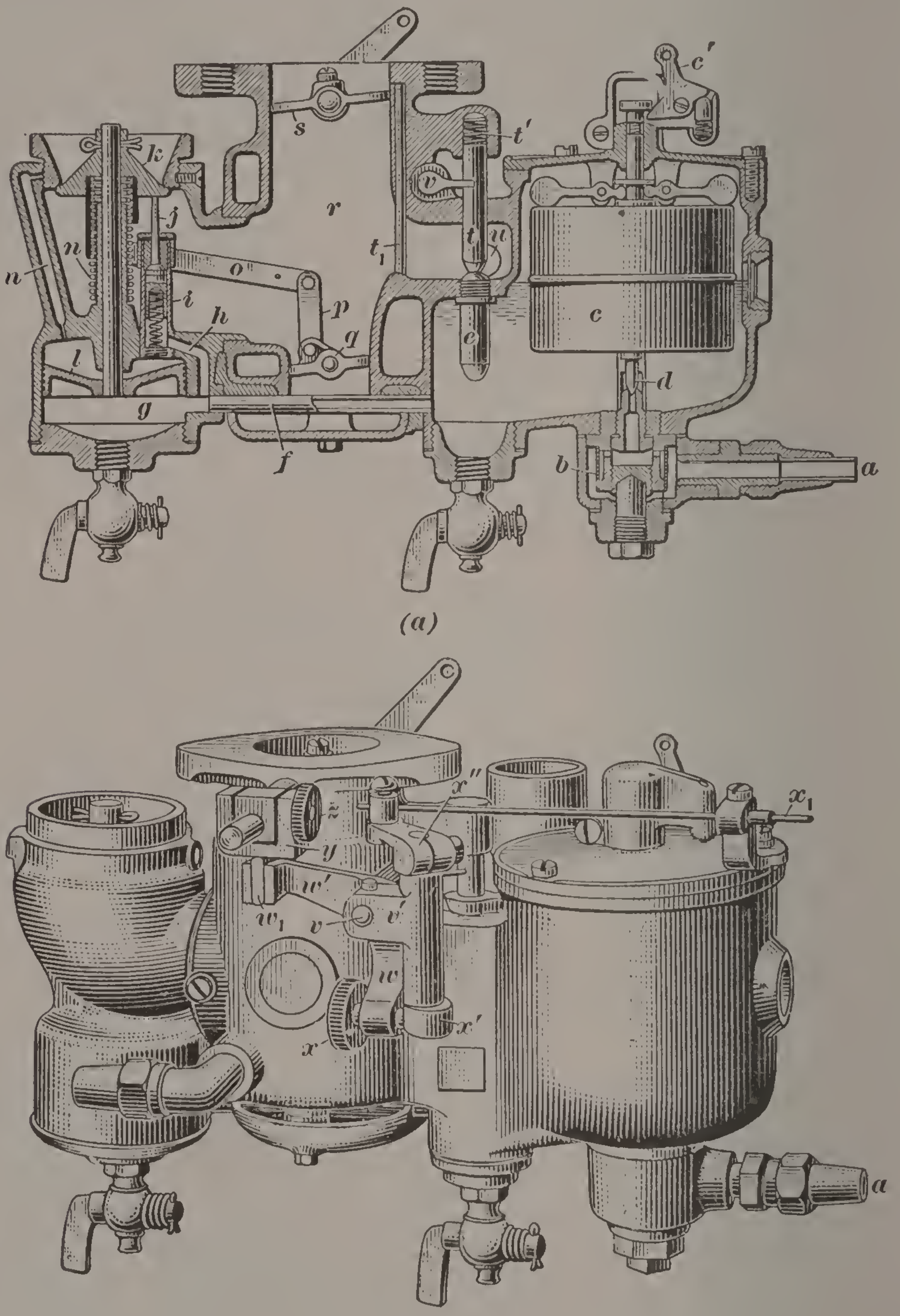


FIG. 20

**58.** A carbureter made with an auxiliary air valve is shown in section in Fig. 20. The gasoline enters at *a* and is maintained at a constant level in the glass float chamber *b* by a metallic float *c* and needle valve *d*. The low-speed spray nozzle *c* terminates at the throat of the Venturi tube *f*; the high-speed nozzle *g* opens into the mixing chamber. The auxiliary air valve *h* has below it the low-speed spring *i*, the tension of which can be adjusted by means of the low-speed adjusting nut *j*. The high-speed spring *k* is placed above the auxiliary air valve *h* and serves to limit the distance this valve can open, the high-speed adjusting nut *l* being used to regulate this distance. With the engine at rest, there is on an average a clearance of $\frac{1}{16}$ inch between the top of the high-speed spring *k* and the bottom of the air-valve cap nut *m*. A strangling valve *n* is placed in the main air intake *o*, which valve carries a cam *p* so adjusted that it will lock the air valve *h* to its seat when the strangling valve is closed. This permits an exceedingly rich mixture to be drawn into the cylinders when starting a cold engine. A flexible metallic tube leading to a heater is usually attached to the main air intake *o*.

**59.** The carbureter shown in Fig. 20 has no gasoline adjustments, the correct size nozzles being fitted at the factory. The method of adjusting the carbureter is as follows: With the engine at rest the low-speed nut *j* is turned until the air valve *h* seats lightly; then the high-speed nut *l* is set until there is about $\frac{1}{16}$ inch clearance between the spring *k* and the cap nut *m*. The engine is now started and run until thoroughly warmed up; then, with the engine idling, the low-speed nut *j* is turned right-handed until the engine slows down and then is turned left-handed about three notches, or until the engine runs strongly again. The throttle is now opened gradually and the spark advanced to the usual running position. If the engine back-fires into the carbureter, the high-speed nut is turned left-handed until all back-firing stops. If the engine fails to respond promptly to the opening of the throttle, it shows the mixture is slightly weak; this can be corrected by turning both adjusting nuts left-handed one or two notches. The idling speed is adjusted by means of the usual throttle stop-screw.

**60.** Another make of carbureter is shown in section in Fig. 21 (*a*) and in perspective in (*b*); the same parts are lettered alike in both views. The fuel enters the carbureter at *a* and passes through a removable wire-gauze screen *b* into the float chamber, in which the float *c* and needle valve *d* maintain a constant gasoline level. The lower end of the fixed primary spray nozzle *e* is submerged in the gasoline. A tube *f*



(a)

(b)

Fig. 21

carries the gasoline to the dashpot chamber *g*, and by way of the passage *h* to the secondary gasoline nozzle *i*, which has a variable annular opening the size of which is governed by the metering pin *j*. This metering pin moves up or down with the auxiliary air valve *k,* the lower end of which carries a piston *l* that is a loose fit in the dashpot chamber *g*. A passage *m* opens the top of the dashpot chamber to the atmosphere, so that the gasoline can flow freely into this chamber and keep it filled.

**61.** The air valve *k,* Fig. 21, is held to its seat by the helical spring *n,* the tension of which is correctly adjusted at the factory. An arm *o* is rigidly fastened to the auxiliary air valve and by means of a link *p* is attached to the butterfly valve *q,* which in the position shown closes the lower air entrance to the mixing chamber *r,* at the top of which the butterfly throttle valve *s* is located. The opening in the primary spray nozzle *e* is varied by means of the needle valve *t,* which is interconnected to the throttle valve in such a manner that opening the throttle raises the needle valve against the resistance of the spring $t'$. A constant air opening into the mixing chamber is drilled through the side of the carbureter, as shown at *u*. The valve *t* is raised or lowered by an arm of the shaft *v,* which arm enters a slot cut into the side of the valve *t*. This shaft *v* passes through a bearing formed on the body of the carbureter, and to its outer end is pinned a bracket $v'$. Mounted loosely on the shaft *v* is a bell-crank whose arms are indicated by *w* and $w'$. The arm *w* carries the low-speed adjusting screw *x* that bears against a cam $x'$ on the lower end of a vertical shaft that may be rotated in the bracket $v'$ by means of the lever $x''$ and dash adjustment wire $x_1$. The arm $w'$ of the bell-crank carries a steel tongue $w_1$ that bears against the curved surface of a steel block *y,* the position of which in reference to the throttle-valve shaft can be slightly changed by means of the high-speed adjustment screw *z*.

**62.** With the engine at rest, the two auxiliary air inlets are closed. To start the engine, the wire $x_1$, Fig. 21, is pulled out, which turns the cam $x'$ and thereby lifts the needle valve *t* from the nozzle *e,* thus setting the carbureter temporarily for a rich mixture suitable for starting. If necessary, the carbureter is primed as well by pulling on the priming lever $c'$, which permits gasoline to overflow from the primary nozzle *e* into the mixing chamber. After the engine fires and as soon as it has warmed up, running idly, the wire $x_1$ is pushed in, thereby dropping the needle valve $t$ and thus setting the carbureter for a leaner mixture. At idling speeds, practically all air for the combustible mixture is drawn through the constant air opening $u$, but at the higher engine speeds the two auxiliary air valves open in proportion to the engine speed. The opening of the throttle lifts the needle valve $t$, thereby increasing the gasoline supply from the nozzle $e$; the opening of the auxiliary air valve $k$ pushes the tapered metering pin $j$ down, thereby opening the secondary gasoline nozzle $i$. The two nozzles and other parts are so proportioned as to maintain a practically constant ratio of gasoline to air at all engine speeds.

The dashpot piston $l$, by offering a fixed resistance to the motion of the air valve $k$ in either direction, prevents any fluttering of the air valve, and thereby promotes a more thorough and uniform mixture of the gasoline and air in the mixing chamber. The small tube $t_1$ assists in getting a rich mixture above the throttle when the engine is idling.

**63.** The carbureter shown in Fig. 21 has only a low-speed and a high-speed gasoline adjustment; in adjusting this carbureter it is well to remember that turning the adjusting screws to the right enriches the mixture and turning them to the left weakens the mixture. Also, the low-speed adjustment must be completed before the high-speed adjustment is attempted; the engine should be properly warmed up, and the dash control set for the weakest mixture.

To make the low-speed adjustment, with the throttle closed and the dash control down, the low-speed adjustment screw $x$ is turned slowly to the left until the steel tongue $w_1$ is just out of contact with the high-speed cam $y$; the screw $x$ is then turned to the right about three complete turns. The throttle is now opened slightly, the carbureter is primed by means of the priming lever $c'$, and the engine is started and allowed to run until thoroughly warmed up. The throttle is then closed until with a slightly retarded spark the engine runs slowly; the low-speed adjusting screw $x$ is then turned slowly to the left until the engine slows down a little, and is then turned to the right, a notch at a time, until the engine idles smoothly. The idling speed is controlled by a throttle-arm stop-screw, which cannot be seen in the illustration, and which is turned to the left to lower the idling speed.

To make the high-speed adjustment, the spark is advanced somewhat and the throttle is quickly opened. If the engine back-fires into the carbureter when speeded up, it shows that the mixture is too weak at high speeds, and must be enriched by turning the high-speed adjusting screw *z* to the right, one notch at a time, until there is no sign of back-firing when the throttle is opened quickly. If the engine chokes when the throttle is opened, it indicates too rich a mixture, and the high-speed adjusting screw should be turned to the left until the engine begins to back-fire, and then to the right again until it runs satisfactorily at high speeds.

**64.** Aeroplane engines nearly always use a carbureter of the compensating-jet type and usually made of aluminum to insure lightness. An outside view of an aeroplane carbureter is shown in Fig. 22 and a view of the same carbureter partly in section is shown in Fig. 23, the reference letters being the same as in Fig. 17, so far as they apply. It has a single float chamber *z*, but is otherwise like two separate carbureters. Each side is complete in every respect, with its own choke tube *v*, throttle *o*, compound nozzle *a b*, compensating jet *c*, and well *e*. Each side has its own idling device and each side supplies its own set of cylinders. The operation of this carbureter is the same as that of the carbureter shown in Fig. 17 and explained in Arts. **47** to **51**, except that this one has no adjusting screw for the idling device, the adjustment of the idling speed being made by

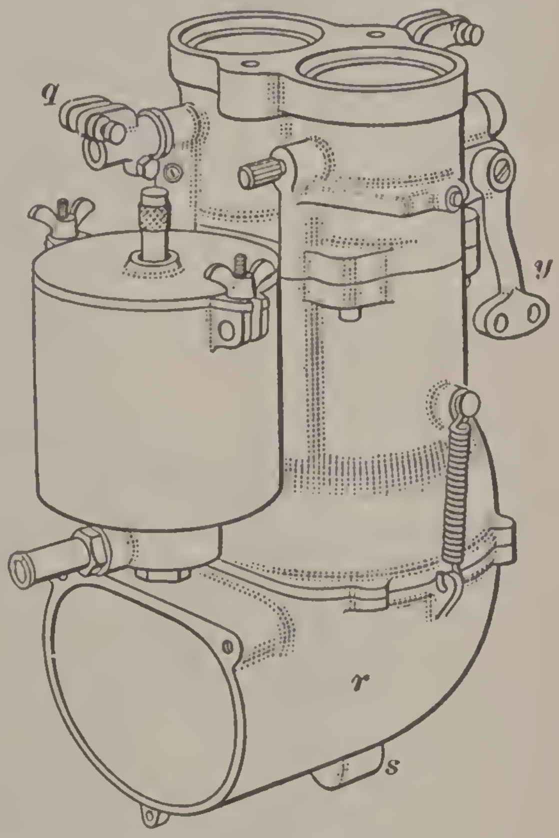


Fig. 22

changing the inner idling well *g* for one with a larger or smaller jet *l* as may be needed, thus eliminating the risk of the adjustment changing while the engine is in the air. In the large twelve- or sixteen-cylinder engines, two double, or duplex, carbureters are generally used, so that each half of each carbureter supplies only three or four cylinders of the engine, the object being to secure a uniform charge in all cylinders and prevent vibration of the engine, and also to secure a higher velocity of air through the Venturi tubes than could be secured with one carbureter having a Venturi tube of very large proportions This high velocity of air past the nozzle helps to vaporize the fuel more fully. The throttles all operate simultaneously. The shafts on which the throttles are mounted

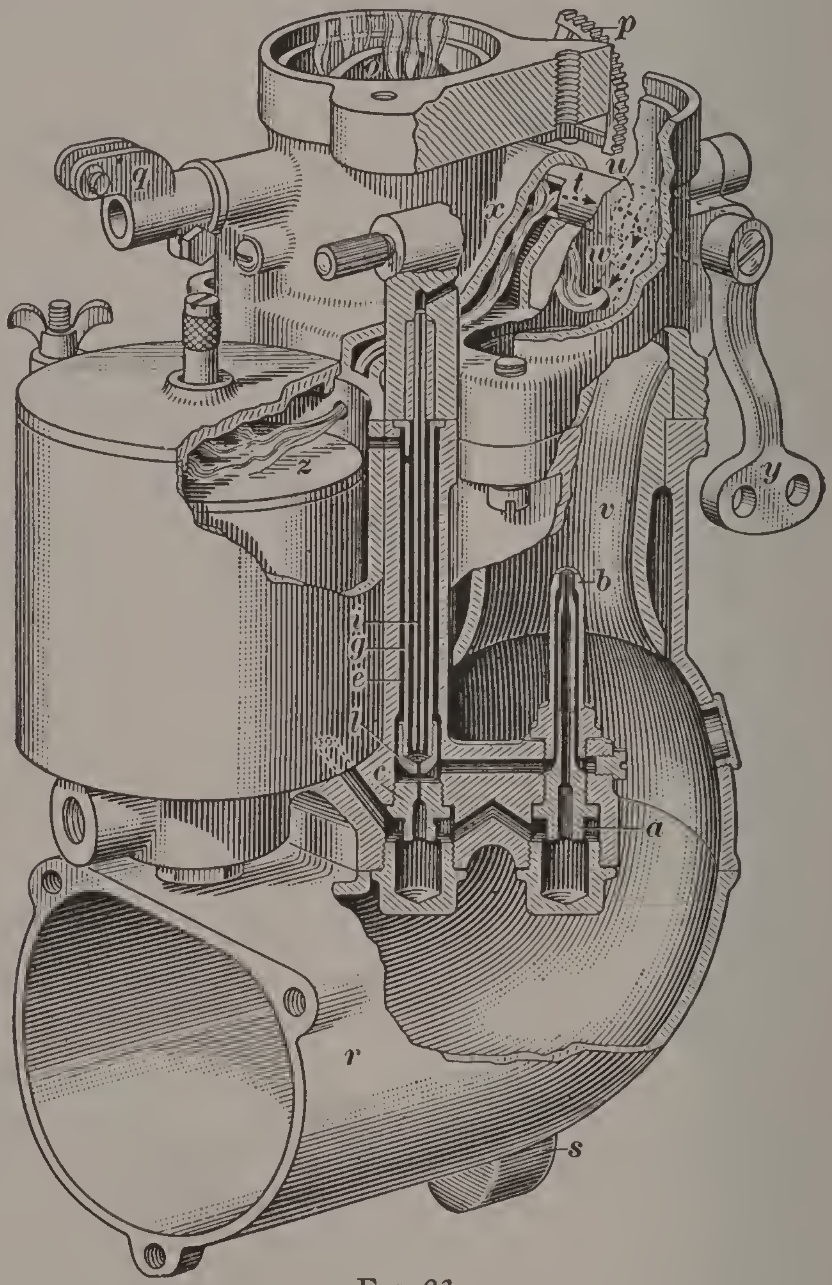


Fig. 23

are parallel to each other and are connected together in each carbureter by segments of a gear, one of which is shown at *p*. The shafts between the carbureters are connected by couplings, one of which is shown at *q*. The detachable bottom or air intake *r* is held in place by two springs, one of which is shown in Fig. 22. A small drain pipe to carry off any accidental overflow of gasoline is connected at *s*.

**65.** In the high altitudes reached by airplanes the air is lighter than it is near the ground and the engine requires less gasoline to keep the fuel mixture of the correct proportions. The ordinary carbureter will supply about the same amount of gasoline in the light air as it does in the heavier air, which makes too rich a mixture in the high altitudes; an additional adjustment is therefore needed. The altitude adjustment device shown in Fig. 23 secures this result by lessening the supply of gasoline. It consists of a hollow shaft *t* in which are ports *u* open to the suction of the engine at a point just above the Venturi tube *v*, where the suction is strongest. Connection is thus made through the passage *w*, port *u*, hollow shaft *t*, and passage *x* to the float chamber *z*. The shaft *t* is fastened to the lever *y*, which is operated by hand by connections placed within reach of the pilot. When this lever *y* is moved, it rotates the hollow shaft *t* and operates in a manner similar to the opening or closing of an ordinary petcock. The pilot opens this a little at an altitude of 2,000 or 3,000 feet, and as he rises he opens it more. When this device is open, a passage for air is made from the float chamber *z* through the passage *x*, hollow shaft *t* in both directions, and through the passages *w* to the Venturi tubes *v*, one of these passages *w* and one of the Venturi tubes being shown in Fig. 23. This allows the suction of the engine to create a partial vacuum in the float chamber *z* because the float chamber is air-tight except for some very small holes that are open to the atmosphere. This partial vacuum in the float chamber has the effect of lowering the pressure on the gasoline in the float chamber and consequently less gasoline will flow from the main jet *a*, thus giving the desired weaker mixture which the lighter air requires.

## CARBURETERS FOR TRACTORS

**66.** The carbureters used on gasoline and kerosene tractors do not differ in principle from those used on stationary and automobile engines; but the conditions of tractor service differ considerably from the conditions that exist in the running of automobile engines. The speed of a tractor is ordinarily between 1½ and 4 miles per hour, and the speed range of the engine is small as compared with that of an automobile engine. The adjustment of a carbureter on a tractor is therefore a simpler matter than the corresponding operation on an automobile. The engine of a tractor runs at a fairly constant speed, this object being accomplished by means of a governor attached to the crank-shaft or the cam-shaft or driven by gearing from some rotating part. The governor is connected by rods and levers to a swinging throttle or butterfly valve in the pipe leading from the carbureter to the intake of the engine. If the speed increases, the governor balls or weights move outwards and their movement is transmitted to the butterfly valve, closing it somewhat and thus decreasing the amount of fuel supplied to the engine. The engine then develops less power and the speed is reduced to the normal. If the speed decreases, the action of the governor opens the butterfly valve farther, increases the fuel supply and the power, and brings the speed back to the normal. A lever from the throttle valve to the driver's platform enables the operator to vary the speed at will.

**67.** The carbureters of many tractors are designed to handle economically the various grades and qualities of liquid fuel, including gasoline, naphtha, kerosene, and distillate. This arrangement is advantageous, in that it permits the use of the class of fuel that is cheapest or most readily available in any particular neighborhood. In other cases, two carbureters are used. These are set side by side and are connected to the intake pipe leading to the engine by means of a three-way cock. One carbureter is adjusted to use gasoline and the other to use kerosene or some other low-grade fuel. The tractor is started on gasoline and brought to normal running condition. Then the three-way cock is thrown over quickly, cutting out the gasoline carbureter and bringing the kerosene carbureter into action. Water spray is injected with the kerosene through a suitable valve, in the manner already described. Many makes of tractors use standard carbureters, such as are commonly used in automobile practice.

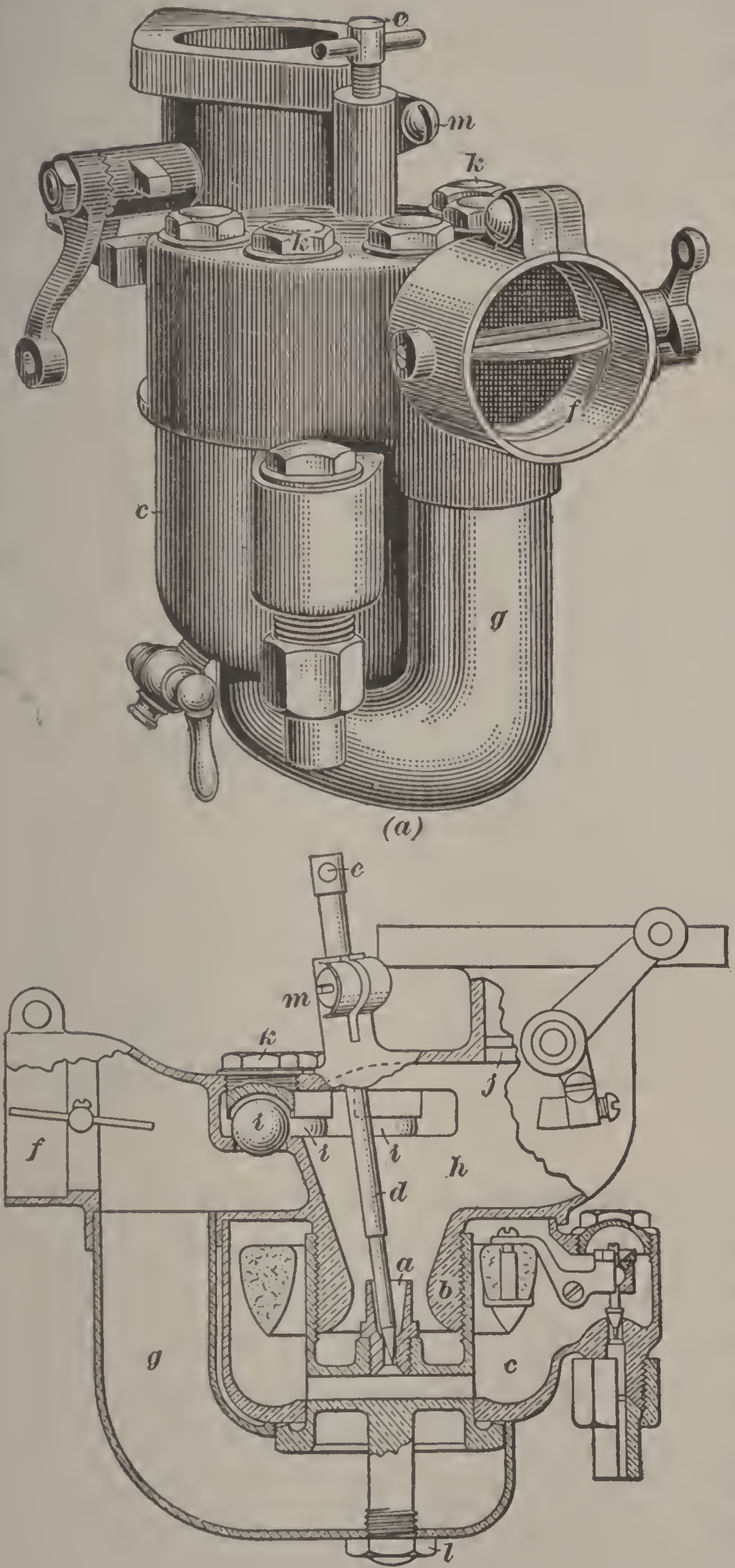


FIG. 24

**68.** An enclosed pattern carbureter used on gas tractors is shown in perspective in Fig. 24 (*a*) and in section in (*b*). The nozzle *a* is in the center of the Venturi tube *b* and is surrounded by the float chamber *c*. The flow of gasoline is regulated by a needle *d* that extends beyond the top of the carbureter and is fitted with a winged head *e*. The main air supply enters at *f*, flows through the passage *g*, and rises around the nozzle *a*, passing thence into the mixing chamber *h*. The auxiliary air enters the mixing chamber by lifting one or more of the balls *i* from their seats. These balls all have the same diameter and hence the same weight. The mixture then passes the throttle valve *j* and enters the inlet manifold. Each ball *i* is of bronze and is held in a cage formed by the cap *k*. The tube forming the passage *g* is held in place on the central stem by means of the nut *l*, and the float chamber *c* may be turned in any desired direction. The screw *m* locks the needle *d* in position after the latter has been adjusted.

**69.** The carbureter shown in Fig. 24 has but one adjustment, namely, that of the needle valve. When the needle *d* has once been set correctly at low speed, the correct explosive mixture at other speeds will be produced by the automatic action of the balls *i*. To adjust this carbureter, the head *e* of the needle *d* is first turned to the right until it will go no farther. The gasoline nozzle *a* will then be completely closed. The screw *m* should be loosened, so that the needle *d* may turn easily. The needle should now have one complete turn to the left, and the engine should be started. With the spark retarded, the throttle slightly open, and with the engine running, the needle *d* should be slowly turned to the right until the engine begins to backfire; then it should be turned slowly to the left until the engine runs at its maximum speed for that throttle opening, after which it should be locked in this position by tightening the screw *m*.

**70. Kerosene Carbureter.**—The form of kerosene carbureter used on the Ford tractor is shown in perspective in Fig. 25 and in section in Fig. 26 (*a*) and (*b*). The intake manifold *a* and the exhaust manifold *b* are cast in one piece, and between the exhaust manifold and the pipe *c* leading to the muffler is formed a chamber *d* that contains the vaporizing coil *e*. This coil, made of light brass tubing, is connected at one end to the carbureter *f* and at the other end to the pipe *g* leading to the main air valve *h*. The float chamber of the carbureter *f* is connected to the kerosene supply pipe at *i*. The suction created by the engine draws the kerosene through the nozzle *j* and sprays it into the air that is drawn in through the pipe *k* from an air washer. The mixture passes into the coil *c*, where it becomes heated by the exhaust gases surrounding the coil. The amount of heat is regulated by raising or lowering the sleeve valve *l*. In the position shown, the exhaust gases do not come in contact with the coil; but if the sleeve *l* is raised, a part of the exhaust will pass through the chamber *d*. By this arrangement, the heating of the vaporizing coil may be varied to suit the atmospheric conditions. The adjusting lever *m* of the valve *l* is provided with a notched sector at *n*.

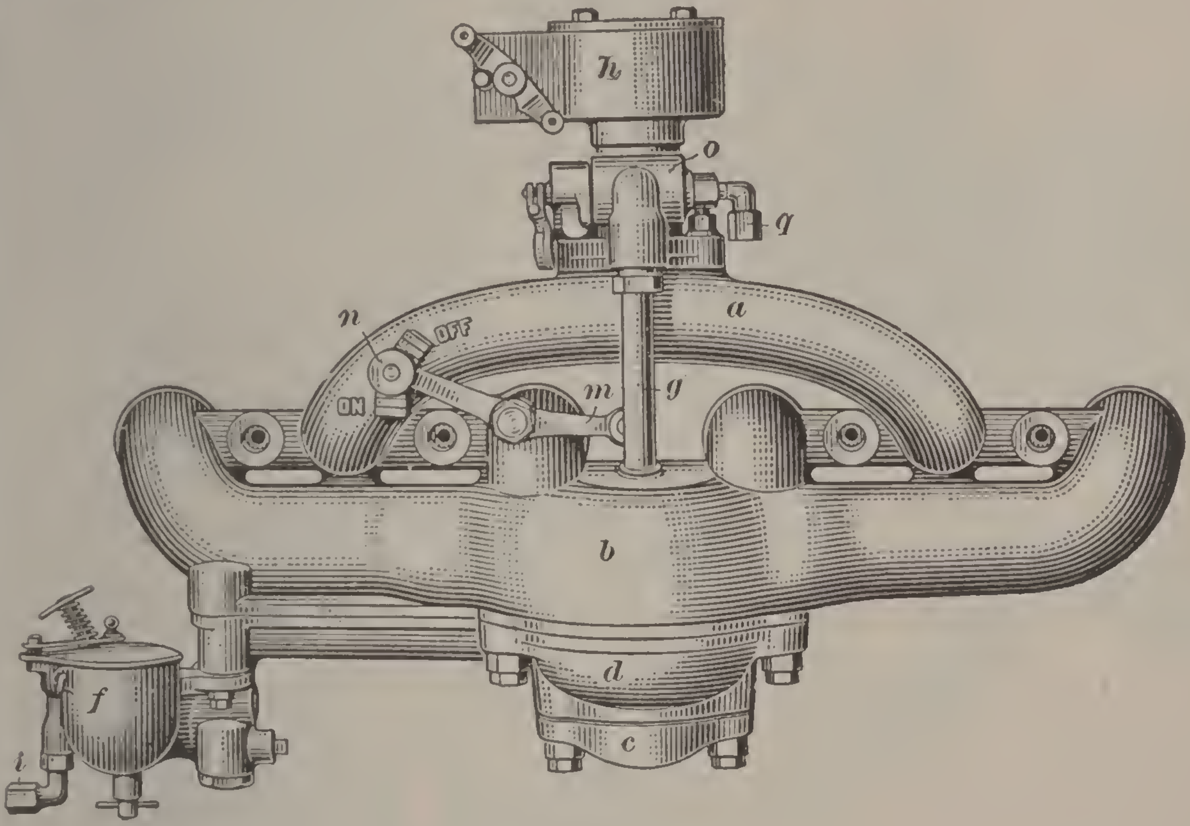


FIG. 25

**71.** The rich mixture of kerosene vapor and air passes up the pipe *g*, Fig. 26, and through the two-way valve *o* into the Venturi tube *p*, where it meets the air supply received through the main air valve *h* from the air washer. The mixture then passes down into the intake manifold *a*. When the engine is to be started, gasoline is used as the fuel. The gasoline pipe is connected at *q*, from which a passage leads into the body of the valve *o*. This passage is approximately at right angles to the one through which the kerosene vapor flows. Consequently, when the engine is to be started, the two-way valve is turned a quarter-turn from the position shown, which shuts off communication with the kerosene vaporizing coil and opens com-

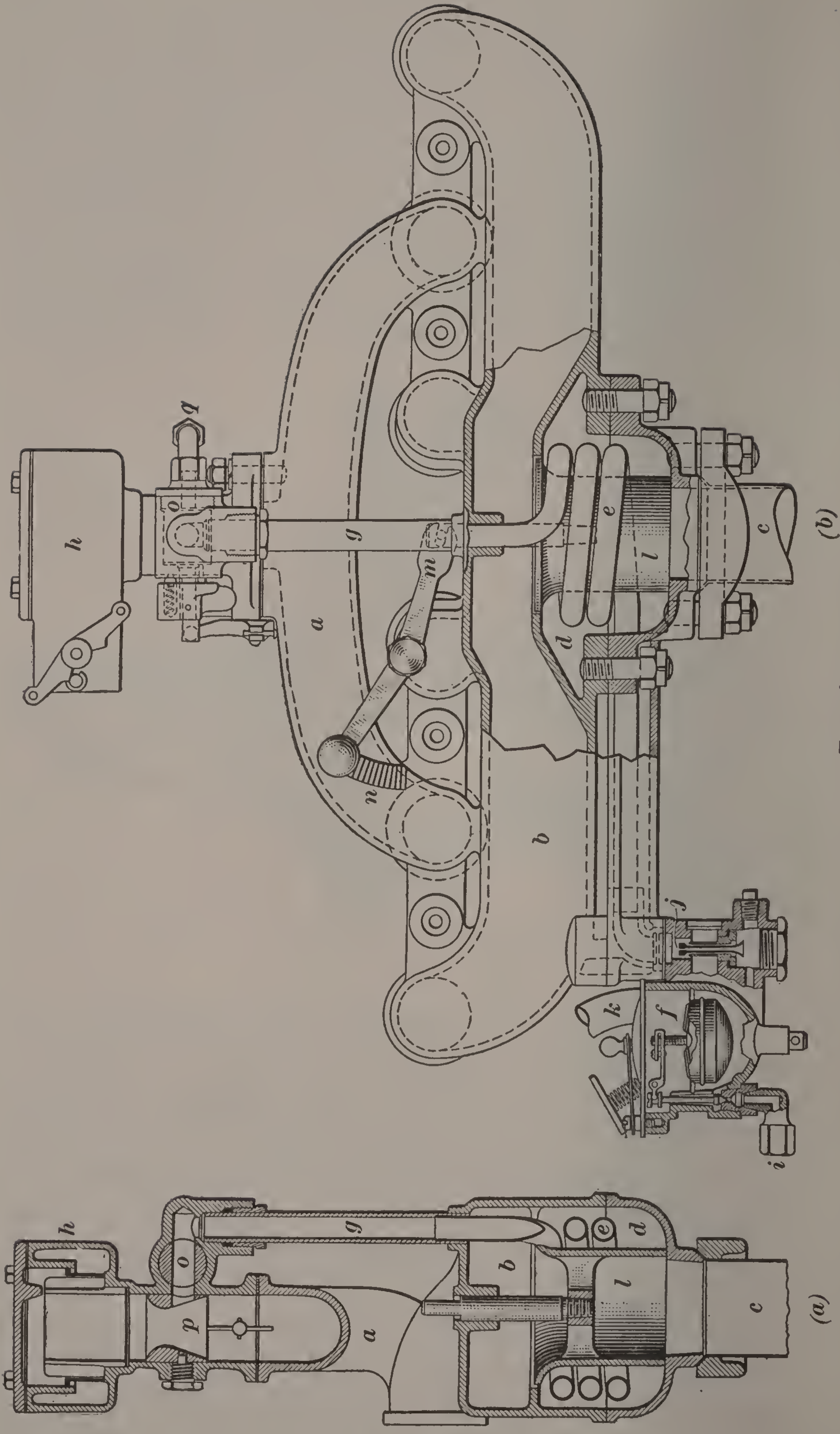


Fig. 26

munication between the gasoline supply *q* and the Venturi tube *p*. When the engine has been started and is running smoothly, the two-way valve is swung back, and the engine takes up its normal operation on kerosene as fuel. Only about one-tenth of the air required is admitted through the pipe *k*, and the remaining nine-tenths is mixed with the rich mixture at the Venturi tube *p*.

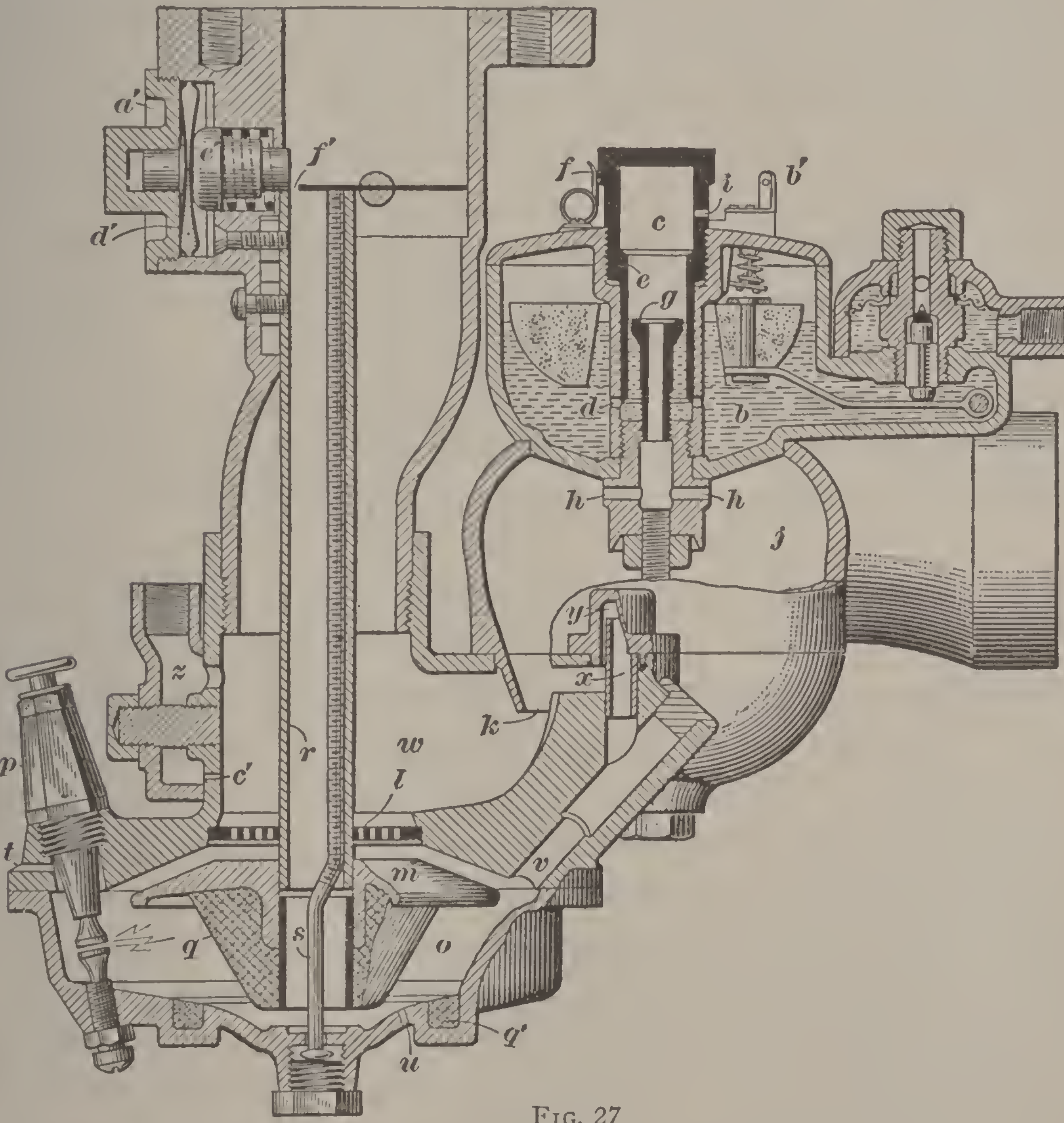


FIG. 27

**72.** When only the lightest and most easily vaporized fuel is used, such as the highest grade of gasoline, little or no heat is needed to vaporize it, except in cold weather, and a simple mixing valve or simple carbureter could then be used, but when heavier fuel like kerosene is used, and especially the heavier grades of kerosene, more heat is required to vaporize it. A form of carbureter is shown in Fig. 27 which is designed to use a fuel which requires a temperature of 600 degrees F. to vaporize it fully. These lower grades of fuel, produced from the mineral oil called petroleum, are separated from the heavier oils by distilling; that is, heating the oil to the desired temperature—in this case 600 degrees—and collecting whatever vapor is driven off. This vapor becomes a liquid as soon as cooled, but will become vapor again when the same amount of heat is applied to it. This is what the carbureter shown in Fig. 27 is designed to do; 600 degrees may therefore be said to be the vaporizing point, or boiling point, of this liquid. But, the petroleum from which it is made has probably been previously distilled at some lower heat, as, for instance, 300 degrees. Then this particular liquid, or distillate, would contain only that part of the petroleum which would vaporize between 300 degrees and 600 degrees, and could be considered as composed of ingredients having boiling points all the way from 300 degrees to 600 degrees, or, as it is sometimes spoken of, a low end point of 300 degrees and a high end point of 600 degrees.

**73.** In the carbureter shown in Fig. 27 the fuel enters at *a* and is maintained at a constant level in the float chamber *b* by the usual means. It enters the well *c* through holes *d* which may be more or less closed by screwing in or out the sleeve *e*, which is held by the spring *f*. A suction tube *g* is placed in the well and adjusted so the top is slightly above the top of the fuel in the float chamber. The fuel is drawn, by the suction of the engine, over the top of the suction tube down through the tube and out through the holes *h*, being partly broken into spray by a limited amount of air admitted through a small hole *i* near the top of the well *c*.

The mixing chamber *j* is of unusual construction, in that the air enters at the side of the bowl, or tangentially, and is discharged at the bottom *k*, which gives the air a violent whirling motion about the suction outlets *h*, thus creating a partial vacuum in the center which causes the fuel to flow through the orifice *h* in exact proportion to the velocity of the air passing through the mixing chamber. This vacuum also helps greatly in breaking up the fuel into the desired fine particles, and, at the same time, the whirling and downward movement of the air and fuel tends to throw the heavier particles of fuel against the sides of the mixing chamber with considerable force. The lighter part of the fuel is in this way vaporized in the mixing chamber and passes on directly to the cylinders of the engine, but the heavier part of the fuel—that is, the part having the higher boiling point—is vaporized by the special heating apparatus contained in the bottom of the carbureter, which heats it to the vaporizing temperature, or boiling point, and the vapor goes to the engine in the form of gas before it has time to cool to the liquid state again.

**74.** That part of the fuel which does not vaporize in the mixing chamber will collect at the bottom of the carbureter and run through the fine screen *l*, where it strikes the hot plate *m* and is converted into vapor. The plate *m* is kept hot by the burning of some of the fuel in the chamber *o*. The fuel is kept on fire by the spark plug *p*. The mixture cannot become explosive, because air is not supplied in sufficient quantity. The cement cone *q*, made of material that stands high heat, protects the lower end of the tube or chimney *r* and also helps to heat the plate *m*. A ring *q′* in the bottom of the combustion chamber is made of the same material as the cone *q* and acts as a wick which helps to keep the fire burning smoothly.

A small wire *s*, placed loosely in the tube *r*, is shaken about by the natural vibration of the engine, and thus removes the soot that would otherwise collect in the tube; also, a small vent *t*, by admitting air, prevents the formation of soot on the spark plug *p*. A drain vent *u* prevents the combustion chamber from flooding, and a vent *v* admits a limited amount of fuel mixture from the mixture passage *w* to the chamber *o*. The fuel mixture passes over the top of the inside tube *x* in the cap *y* and down through the passage *v*. This vent regulates the heat or rate of vaporization at working speeds of the motor in the combustion chamber *o*, and is governed by the condition of the fuel mixture in the mixture passage *w*. When the mixture is rich, more fuel and less air will pass through *v*, which will retard the vaporization in the combustion chamber. If the fuel mixture in *w* is lean, it will cause more air to pass through *v*, which will increase the vaporization in the combustion chamber, thus automatically compensating for different fuel conditions and also different temperature conditions, because in cold weather less of the fuel is vaporized in the mixing chamber *j*, making a leaner mixture in the passage *w*.

**75.** The flow of gasoline when starting, and at idling speed, is taken care of in the carbureter shown in Fig. 27 by means of the independent gasoline priming device *z* and the thermostat *a′*. If the motor has been stopped but a few minutes it can be started on kerosene by flooding the carbureter in the usual way by pressing down on the priming pin *b′*, which depresses the float. If the engine is cold, the start is made on gasoline by opening a hand-operated needle valve at *z*, similar to opening an ordinary petcock, and allowing gasoline to run through the opening *c′* into the chamber *o* where it is set on fire when the the engine is cranked, by the spark plug *p*, because the spark plug is connected in series with an insulated, or *series,* spark plug in one of the cylinders. This furnishes gasoline vapor to run the engine for the first few turns and also heats the combustion chamber so it will vaporize the regular kerosene fuel. The thermostat, or temperature regulator, *a′* operates by expansion of the diaphragm *d′* which, when hot, pushes forward the control plug *e′* which closes more or less the port *f′*. The upward draft of vapor is thus controlled through the tube *r* when the throttle is in the closed position, thus regulating the rate of vaporization in the chamber *o* while the engine is running at idling speed.

## FUEL SUPPLY

### METHODS OF SUPPLYING FUEL TO CARBURETERS

**76.** The tank that carries the fuel for an automobile may be located either at a level considerably higher than the carbureter, so that the liquid will flow freely to the carbureter by gravity, or on the same or a lower level than the carbureter, so that there will be no flow of liquid by gravity even when the tank is full. When the tank is located so that there will be no flow of fuel by gravity, some means must be employed to insure the proper passage of fuel from the tank to the carbureter. The two methods of doing this in use at the present time are the pressure-feed system and the vacuum-feed system. The system in which gravity alone is depended on, is known as the gravity-feed system.

**77. Gravity-Feed System.**—In systems in which the fuel is fed to the carbureter from the tank by gravity, the tank is usually located at the top and at the rear of the dashboard, or under one of the seats. In some one-seated cars, it is directly back of the seat, but in any case it must be high enough so that the bottom of the tank is above the highest gasoline level in the carbureter, even when the car is ascending a steep hill, in which case there is a change in the relative levels of the tank and carbureter.

In the gravity-feed system, there must always be a small opening in the upper part of the tank, so that air can pass into the tank as the fuel flows out. Otherwise, a partial vacuum will be formed in the tank, and the flow of fuel will gradually decrease until the carbureter does not receive enough to keep the engine running. As a general rule, the vent hole is drilled in the center of the filler cap.

**78. Pressure-Feed System.**—In the pressure-feed system, after the fuel has been poured into the tank, air is pumped in by means of a hand-operated pump until a pressure of 1 to 2 pounds is registered on the gasoline gauge on the dash. After the engine begins to run, the pressure is maintained by means of an air pump driven by some moving part of the engine. This pump is usually provided with a relief valve in order to keep the pressure from rising above the desired limit.

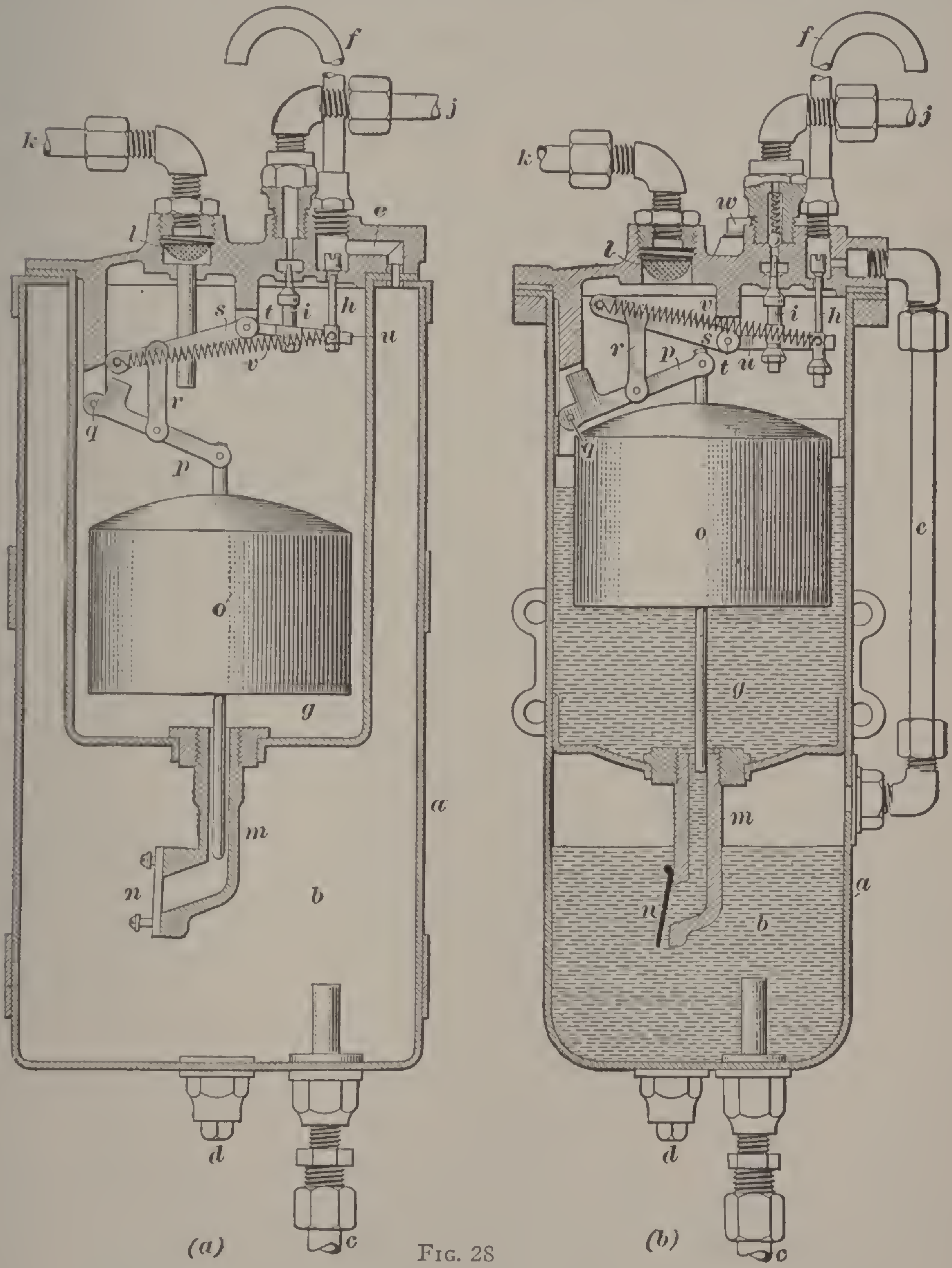
The pressure-feed system was in very popular use at one time, but has gradually been superseded by the vacuum-feed system, which system now forms the regular equipment of the large majority of automobiles.

**79. Vacuum-Feed System.**—The vacuum-feed fuel system consists of means by which fuel from the fuel-supply tank is forced by the pressure of the atmosphere into a small supplementary tank above the carbureter level and near the carbureter, whence the fuel flows to the carbureter by gravity.

The vacuum-feed fuel system is not applicable to gravity fuel tanks in the cowl, but can advantageously be applied to gravity fuel tanks under the front seat in order to permit raising the carbureter so as to bring it as close to the engine cylinders as possible and into a warmer place. Much better vaporization of the fuel, and less condensation in the intake manifold, is secured by raising the carbureter, and consequently the gasoline economy is improved.

**80.** Two different models of the Stewart vacuum tank, which is the main part of the vacuum-feed fuel system, are shown in cross-section in Fig. 28. The operation of both models is identical, their only difference being in constructional details; the same parts are lettered the same, and hence the views of both models can be referred to in reading the description.

The vacuum tank *a* is cylindrical in form and is divided into two chambers. The lower chamber *b* forms a receptacle for gasoline, and is connected by a pipe *c* to the gasoline inlet of the carbureter; this pipe *c* extends some distance above the bottom of the chamber *b*, and consequently the lower part of *b* serves as a settling chamber for water or other impurities in the fuel. By removing a plug *d*, or opening a drain cock screwed in its place, the chamber *b* can be drained, or a small gasoline supply obtained for priming the engine cylinders, etc. The lower chamber *b* at all times is open to the atmosphere by way of the passage *e* and vent pipe *f*. The upper chamber *g*, while the engine is in operation, is alternately open to the atmosphere through the atmospheric valve *h*, and to the intake manifold of the engine by the vacuum valve *i*; in the latter case, a partial vacuum exists in the upper part of the chamber *g*. A pipe connection *j* leads from the vacuum valve *i* to the intake manifold, and another pipe connection *k* leads to the gasoline supply tank; a removable brass-wire gauze strainer *l* is placed at the gasoline inlet to the upper chamber. The lower chamber *b* and upper chamber *g* are connected by an elbow *m* having



(a) (b)

FIG. 28

a flap valve *n* at its lower end. The upper chamber *g* contains the hollow metallic float *o*, which is connected to the lever *p*, having its fulcrum at *q*. The lever *p* is attached by the connecting link *r* to the lever *s* having its fulcrum at *t*; lever *u*, which also has its fulcrum at *t,* has the atmospheric valve *h* and vacuum valve *i* attached to it. The two levers *s* and *u* are free to swing on their common fulcrum *t* independently of each other; their free ends are connected together by the helical tension spring *v,* known from its method of attachment as an *over-center spring,* as in operation it moves from one side of the center of the fulcrum *t* to the other.

**81.** The operation of the Stewart vacuum tank is as follows: With the tank entirely empty, as is the case when the device has just been applied to a car or when all fuel has been drained from the tank, the float *o* has fallen to the position shown in Fig. 28 (*a*), where the atmospheric valve *h* is closed and the vacuum valve *i* is open. If the engine is now cranked, either by means of the self-starter or by hand, and the throttle is closed, a partial vacuum is created in the intake manifold and hence also in the upper chamber *g,* the flap valve *n* being closed. Consequently, the pressure of the atmosphere on the fuel in the main supply tank forces fuel into the upper chamber *g* through the pipe *k.* The float *o* is thereby raised, and also the levers *p* and *s,* the lever *u* being at rest, until the continued rising of the float brings the over-center spring *v* to the upper side of the fulcrum *t,* which position is shown in (*b*), when this spring suddenly pulls up the lever *u,* thereby closing the vacuum valve *i* and opening the atmospheric valve *h.* Air then fills the upper part of the upper chamber and gasoline flows by gravity past the flap valve *n* into the lower chamber and to the carbureter. The float now falls and as soon as it has fallen far enough to bring the over-center spring *v* to the lower side of the fulcrum *t,* this spring suddenly pulls the lever *u* down, thereby closing the atmospheric valve *h* and opening the vacuum valve *i.* Fuel now flows from the main supply tank into the upper chamber again, raises the float, and finally closes the vacuum valve and opens the atmospheric valve again. The upper chamber thus alternately partly empties itself into the lower chamber and is filled again.

**82.** The vacuum-feed tank is usually placed on the engine side of the dashboard; if conditions permit it to be readily placed nearer the carbureter, this should be done. The bottom of the tank should be at least 3 inches above the fuel level of the carbureter, and as much higher as circumstances permit. It is absolutely necessary that the top of the vacuum-feed tank be above the top of the main fuel supply tank, so that there is no danger of gasoline flowing into the vacuum-feed tank by gravity when descending steep hills and overflowing through the vent pipe *f*, Fig. 28. The use of a longer vent pipe is equivalent to raising the vacuum-feed tank.

Should the vacuum-feed tank, when empty, refuse to fill when the engine is cranked, the probability is that some dirt has accumulated on the seat of the flap valve *n*. A pipe plug in the head of the tank, which plug can be seen at *w*, Fig. 28 (*b*), should then be removed and gasoline poured in through a small funnel; this gasoline will usually wash all dirt from the seat of the flap valve and the tank will operate properly again as soon as the pipe plug is replaced. If this treatment fails to effect a cure, the tank must be taken apart and the flap valve cleaned. It is absolutely necessary that the joint between the body and head of the tank be air-tight; a paper gasket shellacked on both sides is used to pack the joint.

If it should be noticed that gasoline is drawn from the tank through the pipe *j* into the intake manifold, which manifests itself through the choking and stopping of the engine, it shows that the float has sprung a leak and consequently cannot operate. The remedy is to remove the gasoline from the float and then repair it.