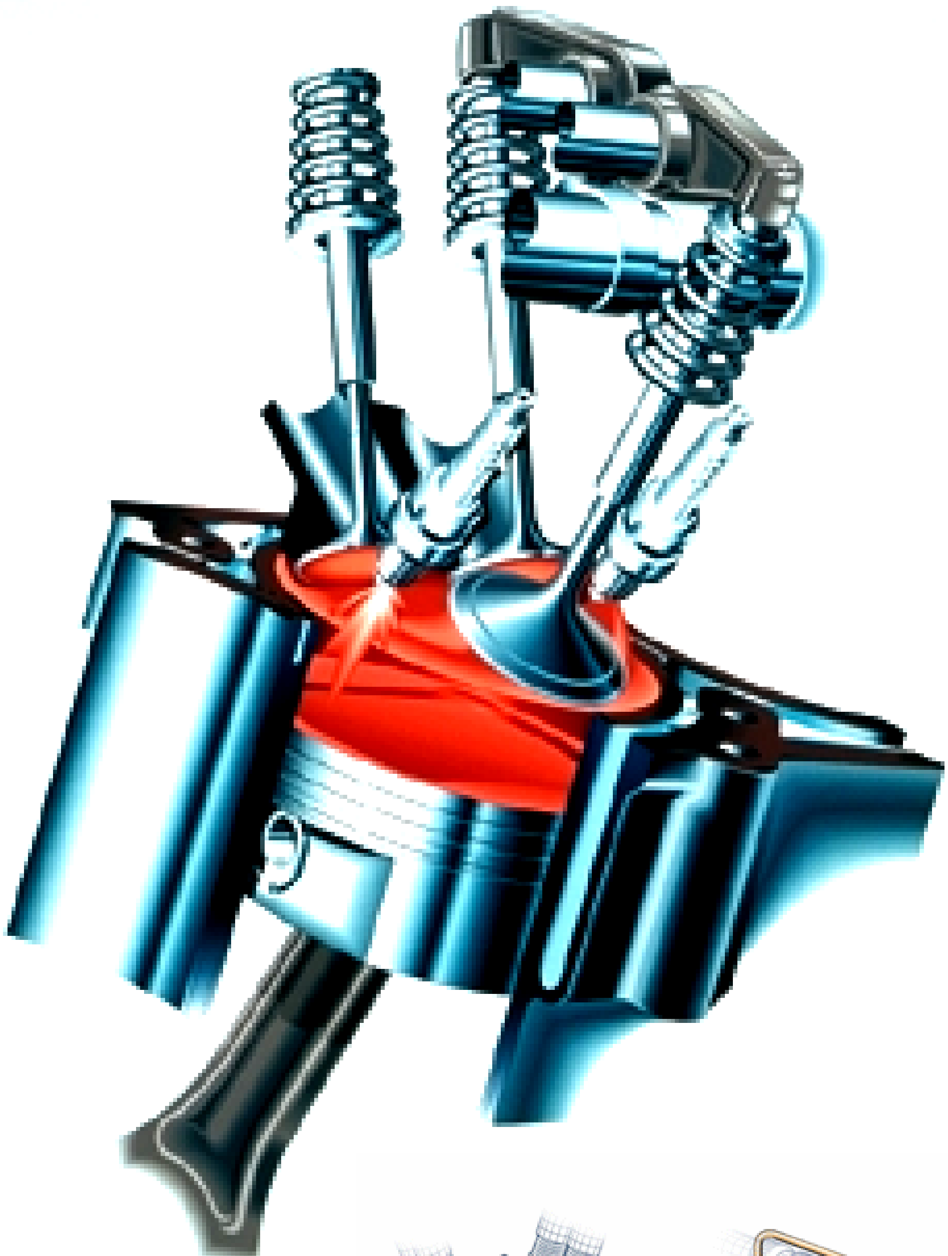
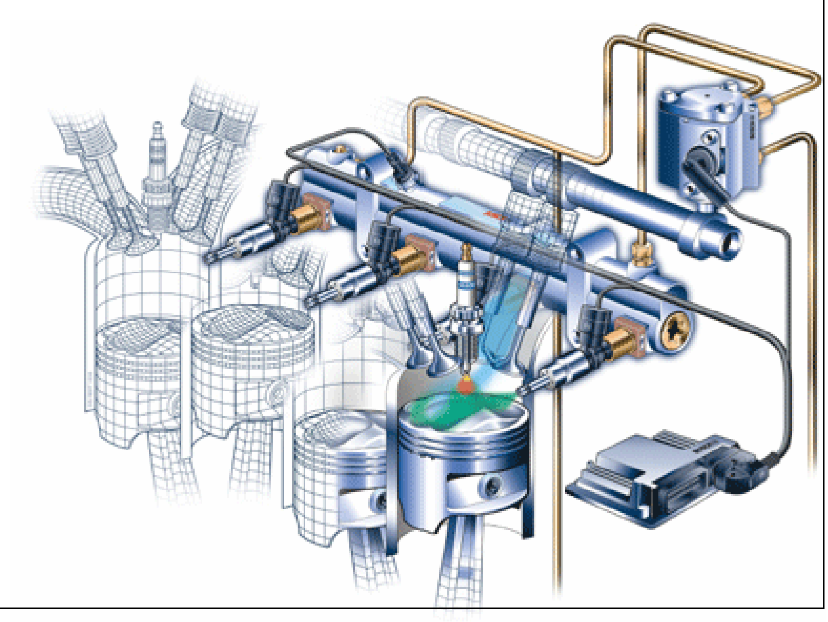
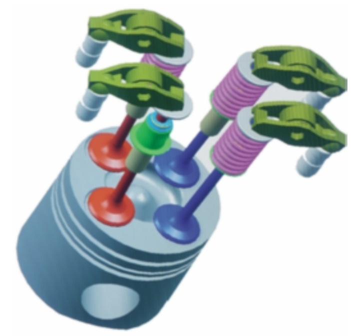
VALVE AND VALVE MECHANISM



Types of valve operating mechanisms, valve springs, guides, push rods, rocker arms, tappets, valve timing diagrams, design



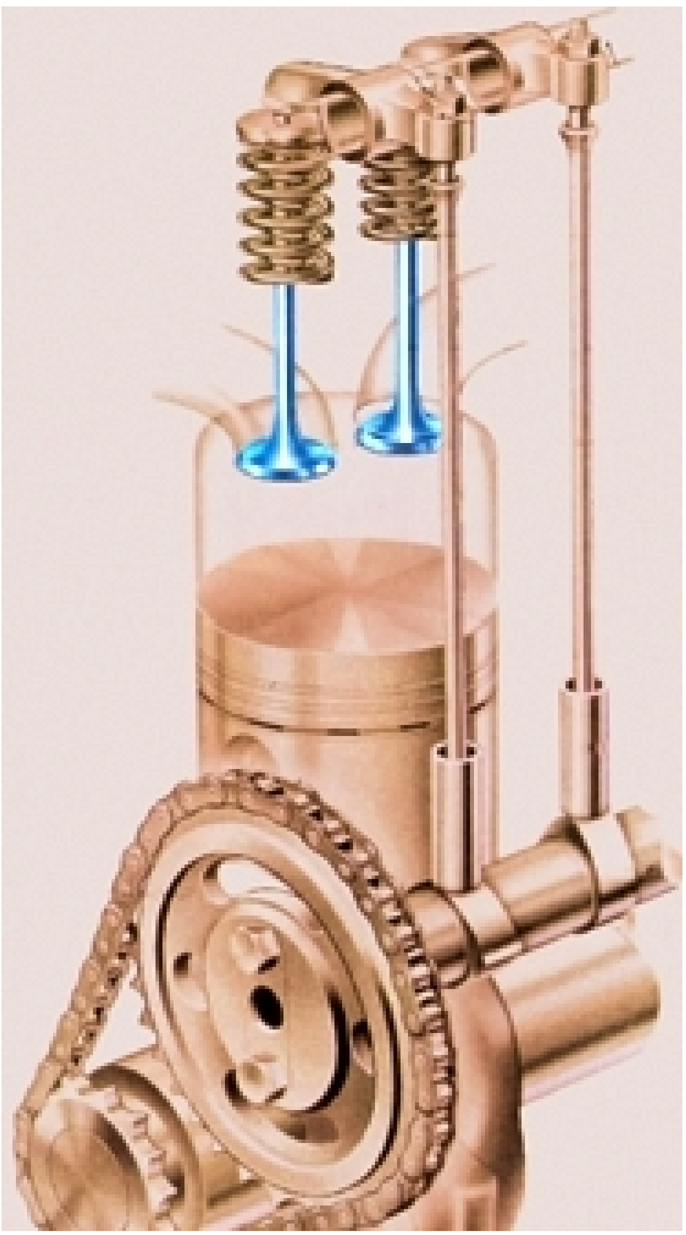
Valve and valve mechanism



To admit the air-fuel mixture in the engine cylinder and to force the exhaust gases out at correct timings, some control system is necessary, which is provided by the valves.

The engine valves may be broadly divided into 3 main categories:
1. Poppet valve
2. Sleeve valve
3. Rotary valve

Out of these three, poppet valve is the one which is being universally used for automobile engines.

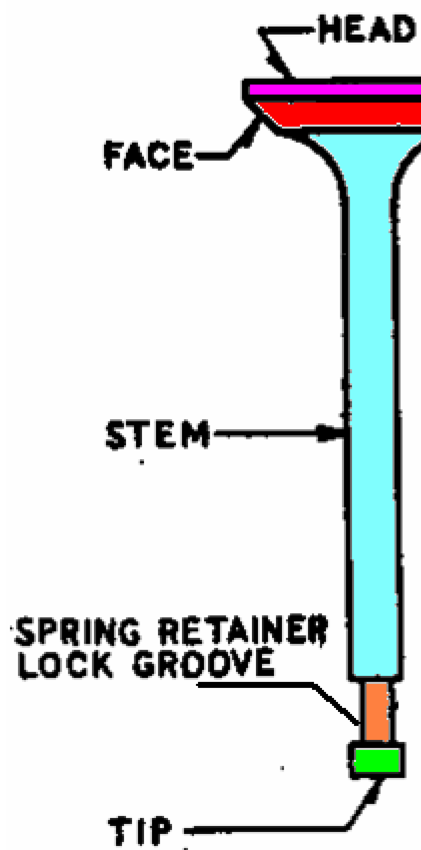


The conventional automotive engine is fitted with mechanically operated poppet valves for both inlet and exhaust. A poppet valve consists of a disc of metal with a coaxial stem on one side which closes a circular opening in a wall separating two chambers, against which wall it is drawn by a spring. To open the valve, a force must be applied to it in, a direction contrary to that of the spring pressure. In the earliest automotive engines, the inlet- valves were opened automatically by the suction in the cylinder during the inlet stroke,. Automatic valves cannot be used in engines that must operate over a wide speed range, as they close too early at low and too late at high speeds to permit of good volumetric efficiency. These valves, moreover, are troublesome in service, because gum in the gasoline may cause them to stick.

Poppet valves are lifted from their seats by means of cams, and are closed by springs. The rate at which the valve is opened and closed depends on the cam outline and on the type and size of cam follower employed. From the standpoint of gas flow it is, of course, desirable that the valve should open and close very quickly, and remain fully open for the greatest possible length of time. However, the valve gear must operate quietly, and in order to do this it must lift and drop the valves more or less gradually. Cams, therefore, usually are so designed that the valve begins to close as soon as it has attained its full lift, and there is no "dwell" in the full-open position

Construction of Poppet Valves

The poppet valve derives its name from its motion of popping up and down. This is also called "mushroom valve" because of its shape which is similar to a mushroom. It consists of a head and a stem as shown in Fig.



It possesses certain advantages over the other valve types because of which it is extensively used in the automotive engines:

1. Simplicity of construction
2. Self-centering.
3. Free to rotate about the stem to new position.
4. Maintenance of sealing efficiency is relatively easier.

Generally inlet valves are larger than the exhaust valves, because speed of incoming air-fuel mixture is less than the velocity of exhaust gases which leave under pressure. Further, because of pressure, the density of exhaust gases is also comparatively high. Moreover, smaller exhaust valve is also preferred because of shorter path of heat flow in this case and consequent reduced thermal loading.

Generally inlet valves and exhaust valves are 45% and 38% of the cylinder bore respectively. Further, to improve heat transfer to the cylinder head, the stem diameter of the exhaust valve is generally 10 to 15% greater than that of the inlet valve. Moreover, the valve lift in both inlet and exhaust valves should be at least equal to 25% of the valve head diameter which would provide the annular valve-opening area equal to the port throat area. If the valve lift is less, the volumetric efficiency of the engine will be decreased. On the other hand if it is excessive, the inertia of the valve actuating mechanism would be unduly large resulting in excessive noise and wear.

The valve face angle (with the plane of the valve head) is generally kept 45° or 30°. A smaller face angle provides greater valve opening for a given lift, but poor sealing because of the reduced seating pressure for a given valve spring load. Due to this reason in some engines, the inlet valve face angle may be kept 30° or 45° whereas the exhaust valve face angle is only 45°, as this increases its heat dissipation. In some cases, a further differential angle of about 1/2 deg to 1 deg is provided between the valve and its seating (Fig.), which results in better sealing conditions.

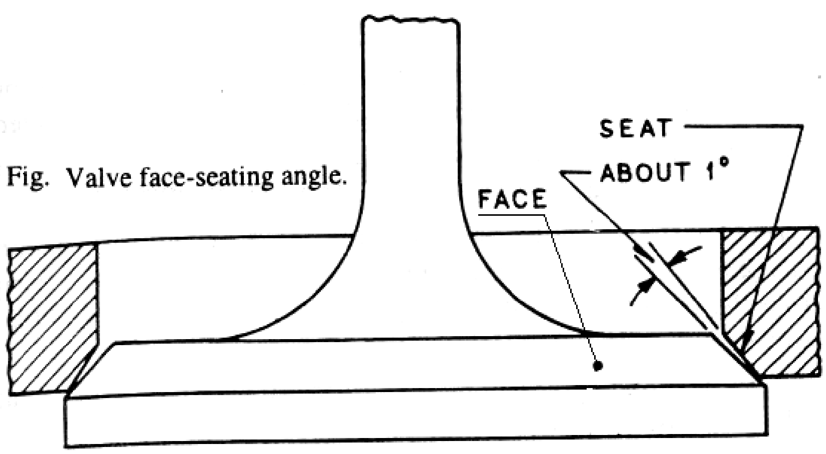


Fig. Valve face-seating angle.

The machined surface of the block or the cylinder head on which the valve rests when closed is known as the valve seat. This surface usually forms a truncated cone whose generatrices make an angle of either 45° or 30° with the plane of the valve head. During the early years of the industry flat-seated poppet valves were used to a certain extent, which have the advantage that for a given port diameter and lift, the flow area is considerably greater than with conical valves. A disadvantage of flat-seated valves, which led to their abandonment-is that they are not self centering, and therefore are more likely to leak, especially after the guides have become worn.

In the analysis it has been assumed that the flow through the valve is parallel to the seat elements. This is substantially correct at small lifts, when the distance between valve and seat is only a fraction of the width of the seat, but with increase in the lift the direction of flow changes. The gases naturally seek the path of least resistance, and in turning a corner they approach the inner boundary of the flow path.

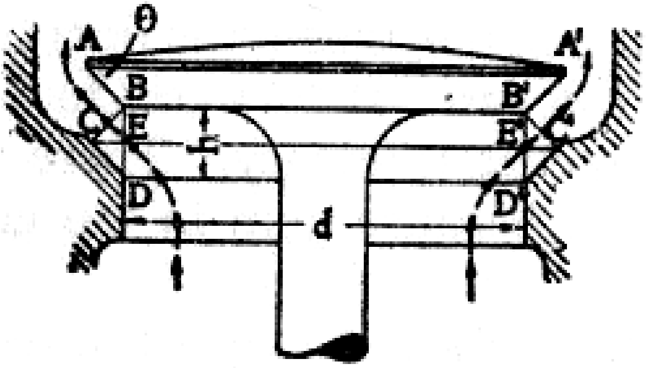


Fig. Conical valve.

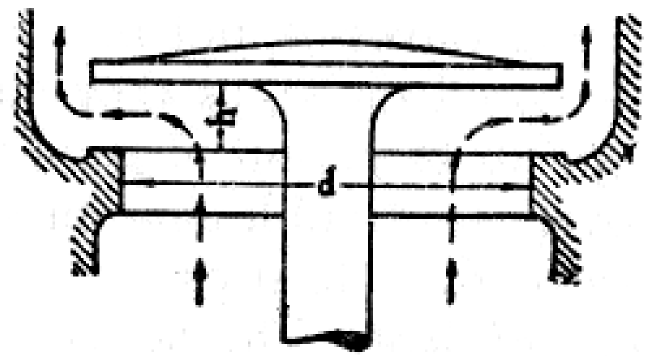


Fig. Flat-seated valve.

In an L-head engine the direction of flow on the side of the valve toward the cylinder, where the gases can flow off freely, is somewhat different from that on the opposite side, where there is only a moderate clearance between valve and valve-chamber wall. There the gases must describe nearly a semi-circle, and in seeking the path of least resistance, they approach the edge of the valve head. The best measure of valve capacity evidently is the minimum sectional area normal to the direction of flow.

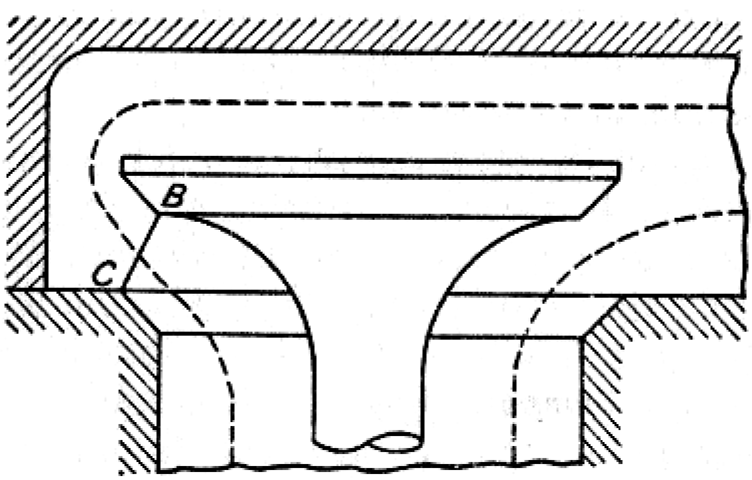


Fig.Center lines of flow paths around valve head.

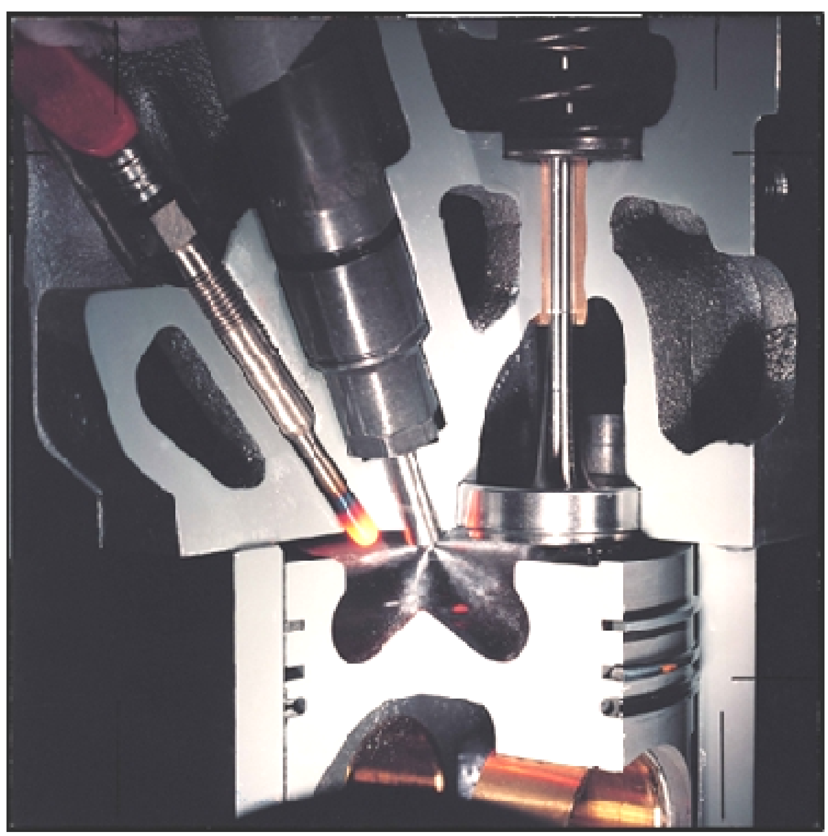
From Fig., where the dashed lines are meant to represent the center lines of the flow paths, it can be seen that the direction of flow relative to the seat elements varies around the circumference of the valve. In modern engines the valve seats are made comparatively narrow, and in Fig., which closely represents actual proportions, the line BC connecting the inner edge of the valve seat at full lift with the outer edge of the seat on the block, makes an obtuse angle with the elements of the seats, instead of a right angle as in flat-seated valve Fig.. It has been suggested that the area of the conical frustrum of which BC, is an element be taken as a measure of the valve capacity, but in view of the fact that the direction of flow is not normal to that line this plan is of doubtful value.

The valve lift generally is slightly more than one-fourth the port diameter in the case of 45-deg, and slightly less in the case of 30-deg valves. Valve-stem diameters are made equal to one-fourth the valve diameter. The outside diameter of the valve head will be about 1.175 times the port diameter.

Valve-Operating Conditions

The heads of the valves are subjected to the high temperature of the burning gases, and it is essential that they should not warp under the influence of the heat, and that their seats should not scale or corrode, as in either case they would become leaky. Occasionally small particles of scale will get onto the valve seats, and the valve heads must be of sufficient hardness at the high temperature at which they operate so they will not pit under this condition.

Lubrication of the valve stems is hard to effect, and the stems must not wear too rapidly in their guides, even though poorly lubricated or not lubricated at all. That portion of the stem immediately below the head is subject also to the heat of the burning gases which, when the exhaust opens rush by it at a velocity of up to 300 fps; and to the corrosive action of unconsumed, hot oxygen and intermediate products of combustion.



Trouble of a rather serious nature is sometimes caused by valves breaking a short distance below the head, at the point where their working temperature is the maximum. This is probably due to corrosion fatigue; in other words, it results from repetitive applications of mechanical stress combined with corrosive action by the exhaust gases or certain constituents thereof. Air-hardening properties of the valve steel sometimes have been blamed for such breakages, but these latter occur also with valves made of a steel having no such properties. High resistance to corrosion fatigue is therefore desirable in valve steels.

Finally, the tip of the stem receives a quick succession of blows from the tappet as the clearance is being taken up, and it must be sufficiently hard to withstand these blows without undue wear. Hardening of the tips is sometimes effected by the so-called cyaniding process (dipping in a bath of molten potassium ferro-cyanide).

Valve-Operating Temperatures

Tests have .shown that under continued full-load conditions, exhaust valves may reach a temperature of 1475 F- a cherry red. Valves of large diameter run hotter than smaller ones, and the valve temperature increases with engine speed. An increase in the compression ratio, as a rule, lowers the valve temperature, but if the compression is carried too high and detonation sets in, the effect is reversed. It is usually assumed that exhaust valve temperatures are highest with retarded ignition and weak mixtures, probably because the exhaust pipe is hottest under these conditions, but a large number of tests carried out on a particular engine showed that the reverse holds true, the exhaust-valve temperature being lower with a weak mixture and retarded ignition. The explanation is that the temperature of the valve depends not only on that of the exhaust gases, but also on the temperature of combustion, which latter is lowered by weakening the mixture and retarding the spark.

It was found that the exhaust valve ran cooler when a long valve guide (Fig.) was used; that is, when the valve guide was carried closer to the valve head. The guide then has the effect of protecting the valve stem from the hot gases passing through the valve immediately after opening. One objection to such a long valve guide is that it is difficult to lubricate, and as a result wear on both the valve stem and guide is rapid. The experiment was therefore tried of enlarging the bore of the guide 0.016 in., by counter boring from the valve-head end as far as the wall of the valve pocket, and this was found to result in decreasing the valve temperature (27 deg at 1500 rpm and 72 deg at 4500 rpm). An increase in the valve-stem diameter from 0.343 to 0.405 in. lowered the temperature of the valve about 40 deg throughout the speed range.

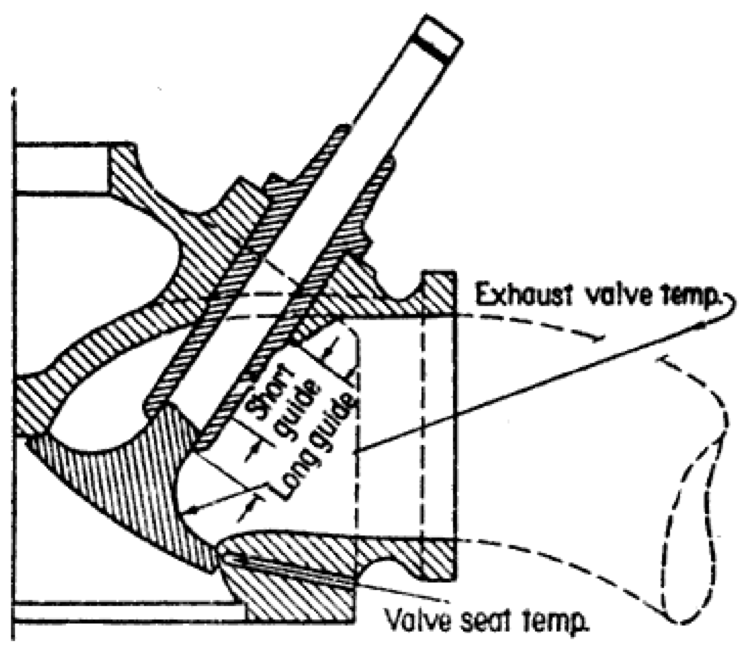


Fig. Drawing showing long and short valve guides used in measurements of valve temperature.

If an exhaust valve becomes leaky, as, for instance, through "dishing" of its head by reason of loss of strength at high temperature, through improper adjustment, or through excessive warping, the head will be destroyed very quickly, as the burning gases will then blow by it.

Exhaust valves operate under relatively more severe conditions on account of higher temperatures involved. An exhaust valve is subjected to:

1. Longitudinal cyclic stresses due to the return spring load and the inertia response of the valve assembly.
2. Thermal stresses in the circumferential and longitudinal directions due to the large temperature gradient from the centre of the head to its periphery and from the crown to the stem. A typical variation of temperature in an exhaust valve is given in Fig.
3. Creep conditions due to operation at very high temperatures, particularly in case of valve head.
4. Corrosion conditions.

Exhaust Valve Material Requirements

On account of operating conditions described above the material for exhaust valve should have the following requirements.

1. High strength and hardness to resist tensile loads and stem wear.
2. High hot strength and hardness to combat head cupping and wear of seats.
3. High fatigue and creep resistance.
4. Adequate corrosion resistance.
5. Least coefficient of thermal expansion to avoid excessive thermal stresses in the head.
6. High thermal conductivity for better heat dissipation.

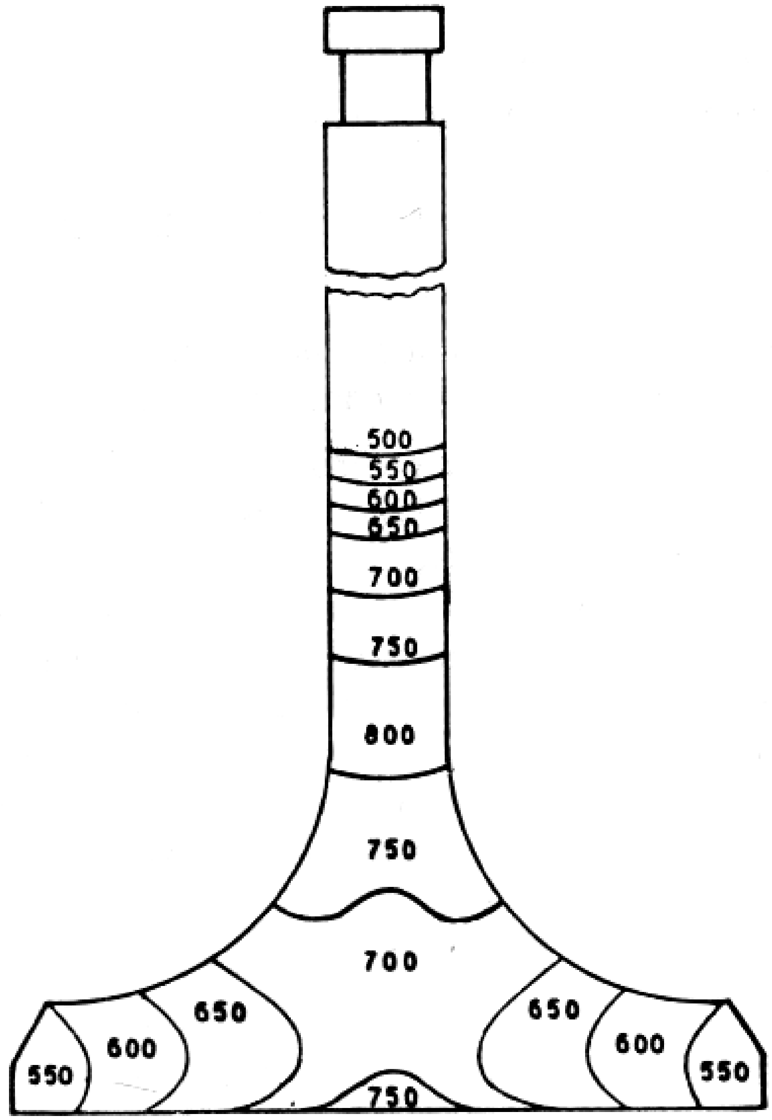


Fig. Temperature distribution in degree celsius in an exhaust valve.

Materials for Valves

Owing to the expensive character of the material necessary for the exhaust valves, the inlets are now generally made of more common and cheaper material. This practice is encouraged also by the fact that the inlet valves now are generally made of somewhat larger diameter, so they would not be interchangeable with the exhaust valves even if they were made of the same material.

Both the mechanical and the thermal stresses on engine valves increase with the speed of operation, and as engine speeds have increased continuously, there has been a constant search for better materials, especially for the exhaust valves. Silicon-chromium (Silcrome) steel containing 3-3.5 per cent silicon and 8-9 per cent chromium came into use during the early twenties, and was considered an excellent exhaust-valve material at the time. This steel possessed good workability and good machining qualities, but it left something to be desired with respect to hot strength. While at normal temperature it showed a tensile strength in excess of 200,000 psi, at 1200 F this dropped to 42,000 psi, and at 1600 F it was only 4600 psi. The steel began to scale at 1800 F. Its resistance to warpage and corrosion at high temperatures was poor.

In the middle thirties specific outputs had increased so much that a better material was needed for heavy-duty bus and truck engines. What was called for particularly was higher hot strength and a higher scaling temperature. These properties could be obtained by a more liberal use of alloying elements, particularly chromium, and a new type of valve steel was then introduced of which Silcrome XB, developed by Thompson Products, Inc., is representative. This has a higher carbon content than the original Silcrome steel, viz., 0.60-0.86 per cent; less silicon, 1.25-2.75; but more than twice as much chromium, 19.00-23.00, and in addition from 1.00 to 2.00 per cent nickel. This steel resists warping much better, and it also has greater resistance to heat corrosion. At 1600 F its tensile strength is 7625 psi, and its scaling temperature is 2150 F.

***Austenitic Valve* Steels**

More recently so-called austenitic, non hardening steels have been introduced as a material; for exhaust valves. They excel silicon-chromium steel with respect to hot strength, impact value, hot hardness, and resistance to oxidation and corrosion. These steels, which contain high percentages of chromium and nickel-the combined contents of these two elements usually ranging between 25.00 and 30.00 per cent-in addition to being non-responsive to heat treatment, are non-magnetic.

An austenitic valve steel contains 0.30-0.45 carbon, 0.80-1.30 manganese, 2.50-3.25 silicon, 17.50-20.50 chromium, 7.00-9.00 nickel and not over 0.03 phosphorus and sulphur each.

It has a hot strength of 17,500 psi at 1600 F and a scaling temperature of 2200 F. But while these austenitic valve steels possess many advantages, they also have some undesirable qualities. One thing against them is that their coefficient of heat expansion is materially greater than that of silicon-chromium steel (0.000011 as compared with 0.0000078). This calls for a slightly greater clearance between the valve stem and its guide and between the valve and its tappet. For heavy-duty engines a valve-stem clearance of 0.010 to 0.015 in. per inch of stem diameter is recommended. The hardness of austenitic steel is rather low (about 45 Rockwell C, as compared with 55 for the original Silcrome steel) ,and it does not resist the hammering action on the tip very well, especially where there is line or point contact, as with rocker arms contacting the tip. To meet this condition, valves of heavy-duty engines sometimes have tips of Stellite or tool steel applied by either electric or acetylene welding. The wear of austenitic valve stems' in the guides also is somewhat more rapid than that of other steels. This difficulty may be overcome by nitriding the stems, but the injurious effect of tetraethyllead on nitrided surfaces would seem to discourage this practice. Cold-working (rolling) of the stems to increase their hardness also has been suggested. The various processes by which nonmetallic coatings are formed on wearing surfaces to keep them from scoring may be applied also to valve stems. Carbon-steel stems may be. welded to heads of austenitic steel, which has the further advantage that the carbon steel is much lower in cost. This process of building up valves by welding has been carried to its logical conclusion by welding heads of a material resistant to scaling and pitting, to a stem of a material having good bearing qualities in cast iron under conditions of poor lubrication, and to the latter a tip of a material which is capable tappet action well of withstanding the

***Precipitation-Hardening* Steel**

The latest addition to the list of exhaust-valve materials is a steel intermediate between the ferritic and the austenitic types; it shares the property of harden ability with the ferritic steels, and high hot strength with the austenitic. This steel, Silcrome XCR, contains 0.40-0.50 carbon, not more than 1.00 manganese, 23.25-24.25 chromium, 4.50-5.00 nickel, 2.50-3.00 molybdenum, and not more than 0.035 phosphorus and sulphur each. At 1600 F it shows a tensile strength of 20,000 psi, which is a tremendous improvement over the 4600 psi of the original Silcrome. With respect to heat expansion it is intermediate between the ferritic Silcromes and the austenitic type. Its oxidation and corrosion resistances are excellent, but its workability is only fair, and its machinability definitely poor. Valves of Silcrome XCR are hardened to 48-58 Scleroscope all over, and owing to the relatively great hardness, both the seat and the stem wear well. This steel must be forged within a narrow temperature range; if overheated it loses its hardenability; while if forged at too lower temperature, it is likely to shatter, its impact value being quite low. In spite of these drawbacks and its rather high cost, this steel is being used extensively for the exhaust valves of heavy-duty engines.

Materials for Inlet Valves

The inlet valve does not present nearly so difficult a materials problem as the exhaust valve, as the temperature attained by it in service is always considerably lower. Two types of low alloysteel are used extensively for inlet valves. Nos. 3140 and 8645. The former is a chrome-nickel steel- containing 1.0 to 1.5 percent of nickel and 0.50-0.80 percent chromium (besides 0.37-0.45 per cent carbon and 0.60-0.95 per cent manganese); the latter a chromium-nickel-molybdenum steel containing 0.35-0.75 percent nickel, 0.35-0.65 per cent chromium, and 0.12- 0.25 per cent molybdenum, besides normal amounts of carbon and manganese. Some-use has been made of a medium-alloy chromenickel- silicon steel-with(8 to 9 per cent nickel, 12 to 13 per cent chromium, and 2.5 to3 per cent silicon. This CNS steel, which has low carbon and manganese contents, is said to be immune to the corrosive influences of tetra-ethyl lead.

Miscellaneous Considerations

1. An adequately designed valve with proper material can also fail due to local stress concentrations if there is any unevenness around the valve-seat interface on account of distortion of valve heads or seats, bending of valve stem or trapping of carbon particles between the valve and the seat.
2. Excessive surface finish of the valve stem will result in loss of lubricating oil film, while excessive roughness of the stem would increase the guide wear. A thin layer of chromium giving the surface finish of about 0.5 μm would provide the optimum condition.
3. As engine thermal efficiency is increased with increase of compression ratio, lower valve temperatures would result in case of higher compression ratio.
4. Arranging the inlet and the exhaust ports in the cylinder head alternately would increase the transfer of heat from the exhaust to the inlet valves, compared to the case when the like valves are placed together. This would result in decreased exhaust valve temperatures. However, this would also complicate the design of the inlet and the exhaust manifolds in case both are to be on the same side of the engine.

Form and Dimensions of Head

The valve head should be made of the minimum thickness consistent with strength requirements. In American practice, the top of the head is usually made spherical and the bottom surface conical. This gives a head which is much thicker at the center (where the bending moment is the maximum) than at the edge. Poppet valves have been standardized by the.S.A.E.

The seat on the valve head must project slightly beyond the seat in the cylinder casting at both top and bottom, in order that no shoulder will be formed on the-casting when the valve is ground in. A fairly wide seat is an advantage, as it helps to keep down the temperature of the head. The heat absorbed from the burning gases by the valve head has only two paths through which to flow off-down the valve stem to the valve guide and thence into the cylinder block and jacket, and through the valve seat directly into the block-and with the- conventional design by far the greater portion passes off through the seat.

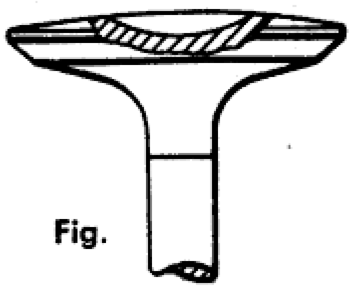


Fig.

S.A.E. Standard valve.

In Fig. is shown the form of head generally used for steel valves in American practice, as fixed by the S.A.E. standard.

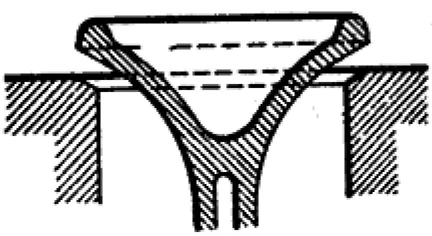


Fig. Tulip-type valve.

Fig. is the so-called tulip valve, used to a considerable extent in aircraft and racing engines, which is thought to facilitate How through the valve port.

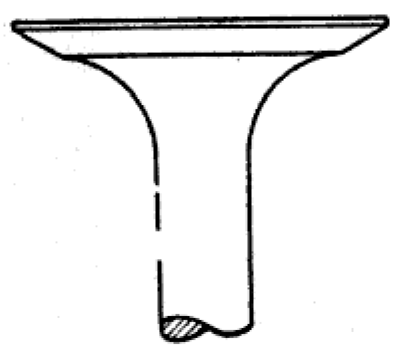


Fig. Flat-top valve.

Fig. shows a form of valve that is intermediate between the S.A.E. standard and the tulip type, which has come into use in recent years. It has a Hat-top head and a rather large fillet between head and stem, which latter tends to improve How conditions and to add to the strength of the stem near its junction with the head. Sometimes that part of the stem which does not enter the guide is made to taper slightly from the fillet down.

To ensure good seating of the valve, -it should be made with an interference angle of 1 deg. That is to say, the included angle of the valve face should be made 1 deg greater than that of the seat face, so that initially the valve seats only on the outer edge.

Sodium-Cooled Valves

The exhaust valve temperatures in modern engines reach very high values of the order of 750°C. In heavy duty engines, it may be still higher. Therefore, cooling of exhaust valves becomes very important. To do this cooling water jackets are arranged as near the valve as possible. In many cases, nozzles are directed towards the hot spot caused by the exhaust valve.

Large valves of heavy-duty engines can be kept at a reasonably low temperature by sodium-cooling, which is now employed extensively for aircraft-engine valves, and occasionally for bus- and truck-engine valves.

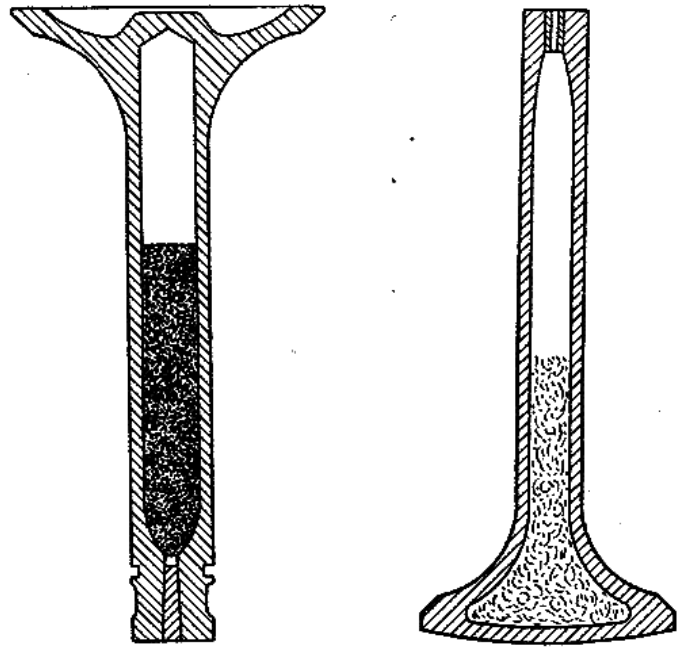


Fig. (Left). Valve with sodium-cooled stem.

Fig. (Right). Valve with sodium-cooled head and stem.

Originally a mixture of potassium nitrate and lithium nitrate was used, which melts at about 260 F, but later metallic sodium -was substituted for these salts.

The advantages of sodium are a low specific gravity (0.97), a high specific heat, a low melting point (207 F), and a high boiling point (1616 F). Fig. shows a section of a sodium-cooled valve designed for use in aircraft engines. The stem is of somewhat larger diameter than usual, and is drilled out from the end & the chamber thus formed, after being nearly closed at the end by swaging process, is filled about half full with metallic sodium. Assuming the valve to be positioned as in an L-head vertical engine, the sodium will be at the bottom (tip end) of the chamber when the valve is closed. it may be seen that in normal operation the valve is alternately accelerated and decelerated at rates many times that due to gravity, with the result that the sodium is thrown violently from one end of the chamber to the other. When at the top end, it absorbs heat from the hot wall, which it gives up to the cooler, lower end of the stem when next it drops to the bottom of the chamber, whence the heat passes to the valve guide and into the cylinder block. These sodium-cooled valves are sometimes furnished with an inner lining of copper, which latter has four times the heat conductivity of valve steels. The end of the stem is sealed with a steel plug, over which is welded a cap of hard steel.

In the sodium-cooled valve shown in Fig., which is of an earlier design, only the stem is hollow and partly filled with sodium. Later it was found possible to make both the head and the stem hollow, as in Fig., which shows a valve designed for installation in the cylinder head. In operation the highest temperatures are reached by the center portion of the top surface of the valve and a point on the stem some distance below the head. In comparative tests under similar conditions with a conventional "solid" valve, a sodium cooled valve with hollow stem, and a sodium-cooled valve with hollow stem and head, the maximum temperatures reached by the center portions of the heads were approximately 1380 F, 1240 F, and 1170 F, respectively. At the seat the temperatures of the valves in these cases ranged between 1000 F and 1100 F. In solid valves the higher temperature of the center portion of the head sometimes results in the formation of cracks at the seat.

There can be no doubt as to the great operating advantages of sodium-cooled valves, and the only reason they are not widely used in automotive engines is that they are rather expensive to produce. Considerable effort has been devoted in recent years to the development of improved processes of production. In one process a piece of steel tubing of slightly more than the diameter of the finished stem, after being cut off to the right length, is upset at one end and then spun to what may be called "tulip shape." A disc of steel is then welded on to close the opening in the head, while the end of the stem is closed in the same way as in the case of a valve in which only the stem is hollow.

Valve Seats

The valve seats must be faced very accurately, so that there is complete contact between the valve and the valve seat when the former closes. Valve seat face is thus ground to the same angle to which the valve face is ground. This may have any value from 30° to 45°. For cylinder blocks or heads made of grey iron, the inlet valve seats are directly machined on the cylinder blocks or heads as the case may be because working conditions are not severe. These are called *integral seats.* However, where aluminium blocks or heads are used, separate valve seat inserts are employed even for inlet valves. For the exhaust valves, always the separate valves seat inserts are used, the operating conditions being very severe. Insert seats are also used as salvage procedure when badly damaged integral seats are reconditioned. Valve seat inserts are simply rings made of alloy steel consisting of chromium, silicon, tungsten or cobalt with a conical seat on one of the inside edges. These are force-fitted in the recesses machined in the cylinder head. When worn, these inserts can be easily replaced.

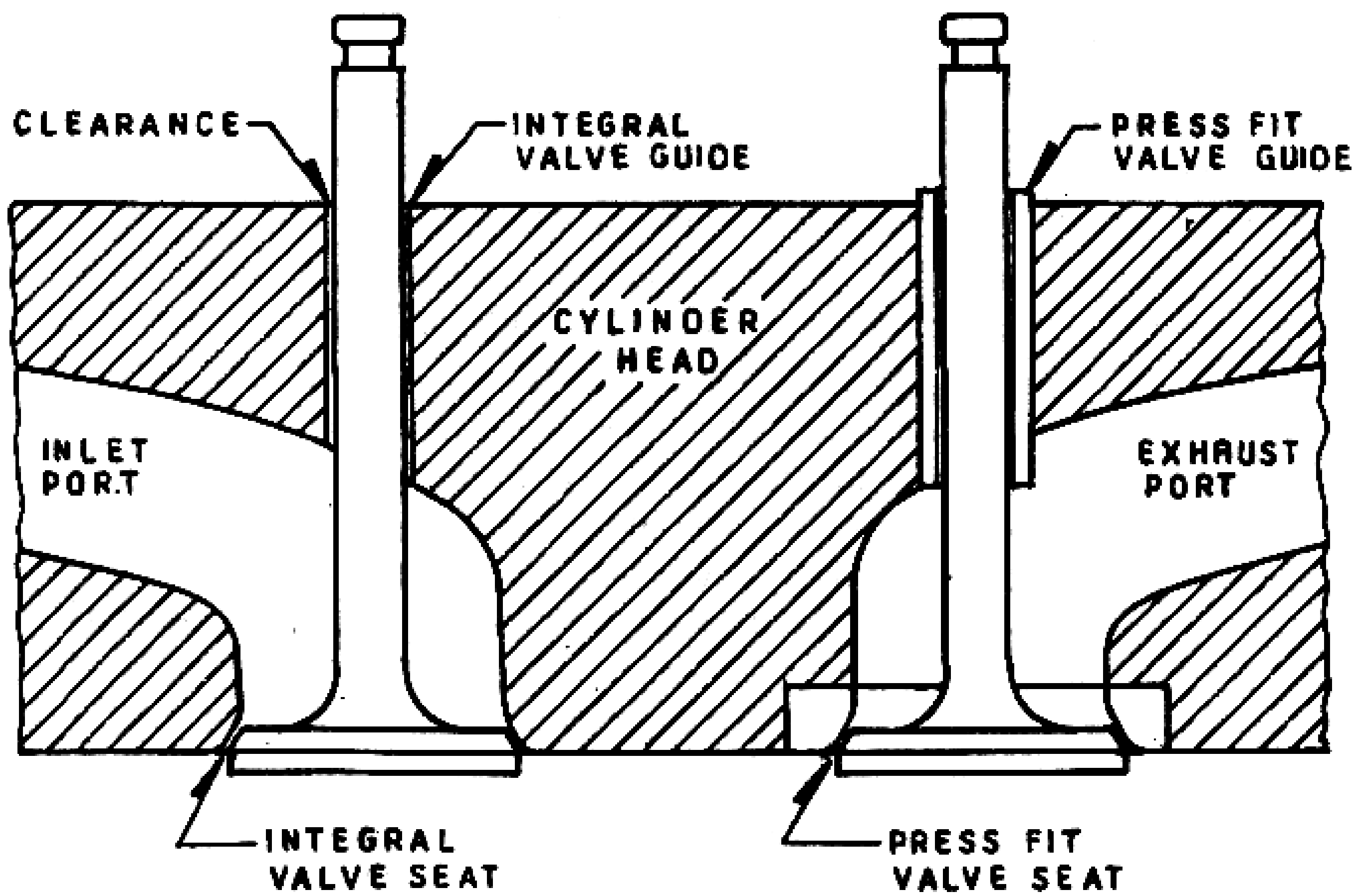


Fig. Types of valve seats and guides.

Valve Springs

Helical springs are used to keep the valve in constant contact with the tappet and the tappet with the cam. Since the spring is subject to compressive loads, it is ground flat at each end to ensure even distribution of pressure. The coil ends are also placed diametrically opposed to avoid the bending tendency of the spring under compression. The arrangement for the retention of the springs is simple. A ring split into two halves with internal projection to fit into the valve spring retaining groove and the outer surface tapered is employed. Over the split ring another ring is inverted which supports the spring. The valve springs are subject to heavy service. These are, therefore, made from high grade spring steel wire, the materials being generally hard-drawn carbon steel or chrome-vanadium steel. Valve springs are often shot peened to make them fatigue resistant.

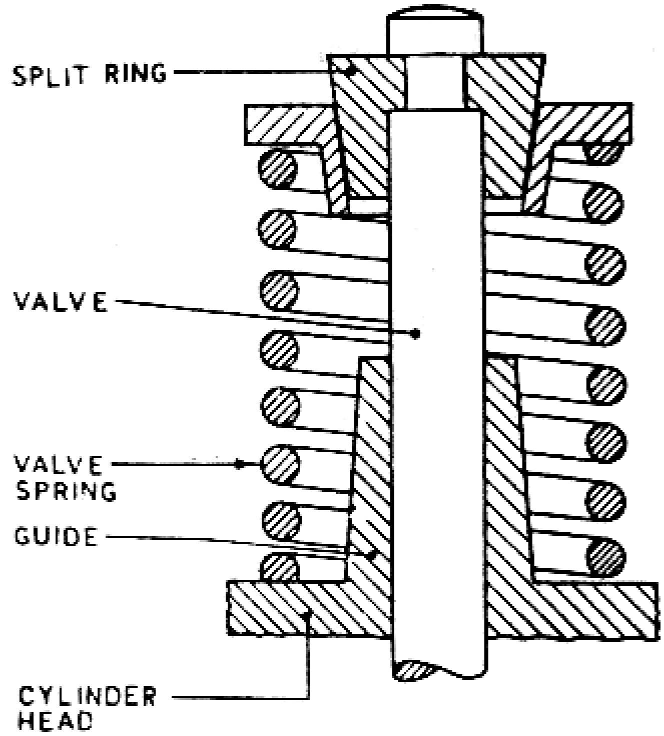
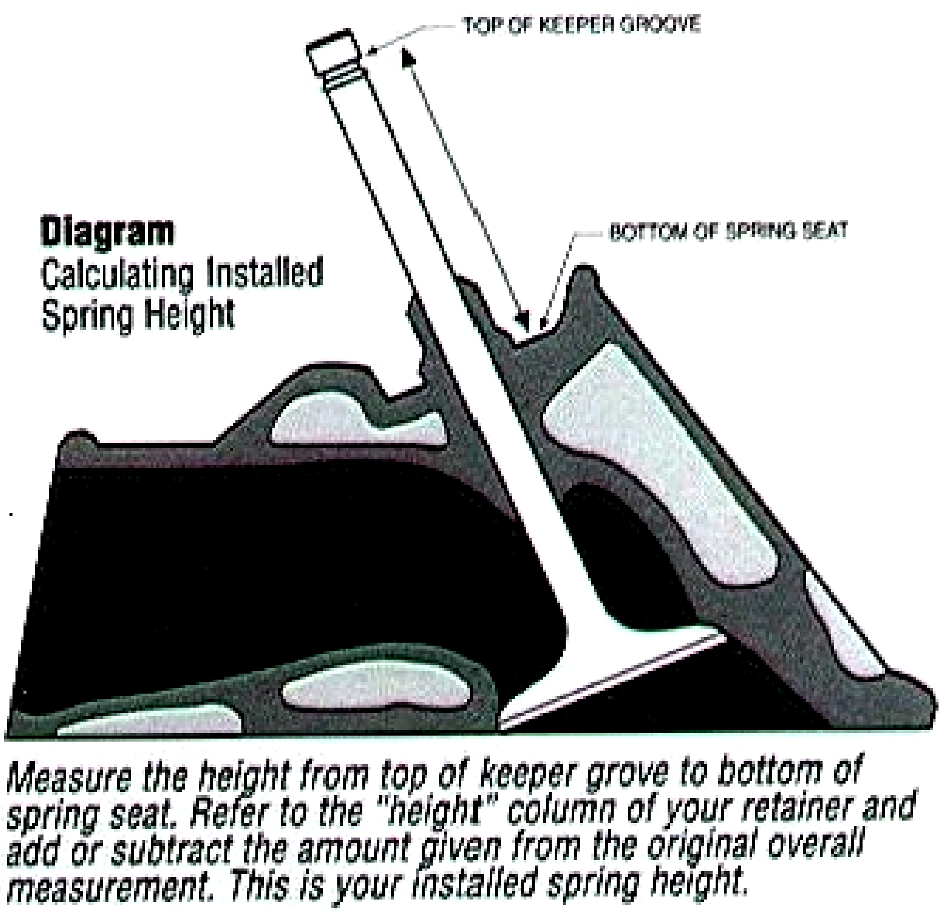


Fig. Conventional method of valve spring retaining.



Valve Rotators

Ordinarily the temperature is not uniform around the circumference of a valve head, being highest where the greatest mass of hot gases passes over it, as on the side nearest the cylinder in an L-head engine. By actual test it was found that in an engine of this type, under certain operating conditions, the exhaust valve- seat insert reached a temperature about 280 F higher on the "near" than on the "far" side, and there can be little doubt that even greater temperature differences exist between opposite sides of the valve head. Such temperature differences cause distortion and leakage. If while in operation the valve could be made to rotate on its seat, that would tend to equalize temperatures and keep down their maximum value. It would tend to keep the seat clean and if leakage should start at any point of the circumference, the resulting damage to the valve would be reduced. A number of so-called valve rotators have been brought out, but so far they have not come into extensive use, probably because they have not always been reliable. Some merely "free" the valve of the restraining effect of the friction due to the spring pressure, while others, in addition, convert some of the axial force producing the opening or the closing motion into a tangential force. The problem of a simple mechanism that will positively rotate the valve on its seat evidently is not an easy one, and complicated and delicate mechanisms can hardly be tolerated in the valve gear. However, according to one valve specialist, positive rotation is more effective in prolonging valve life than any other known means.

Fig. shows a valve-rotating mechanism. The valve spring rests on a seating collar which transmits the spring pressure to the retainer cap through a conical spring washer. When the valve is closed (left view) the pressure of the valve spring is relatively light, hence the spring washer is distended and bears with its inner edge on the retainer cap at 2. As the valve is being lifted (right view) the pressure of the spring increases, the spring washer flattens out, and its point of support is transferred from 2 on the retainer cap to 3 on the steel balls, which latter rest on inclined surfaces on the retainer cap. The effect of the incline is to create a horizontal force component tending to produce relative angular motion between spring washer and retainer cap. Both parts are subject to friction, but the restraining moment on the spring washer is much greater than that on the valve, and as a result an angular motion is imparted to the assembly consisting of valve, retainer cap and retainer lock. During each valve lift each ball moves down the incline, and in between lifts it is returned to the top of the incline by a light spring.

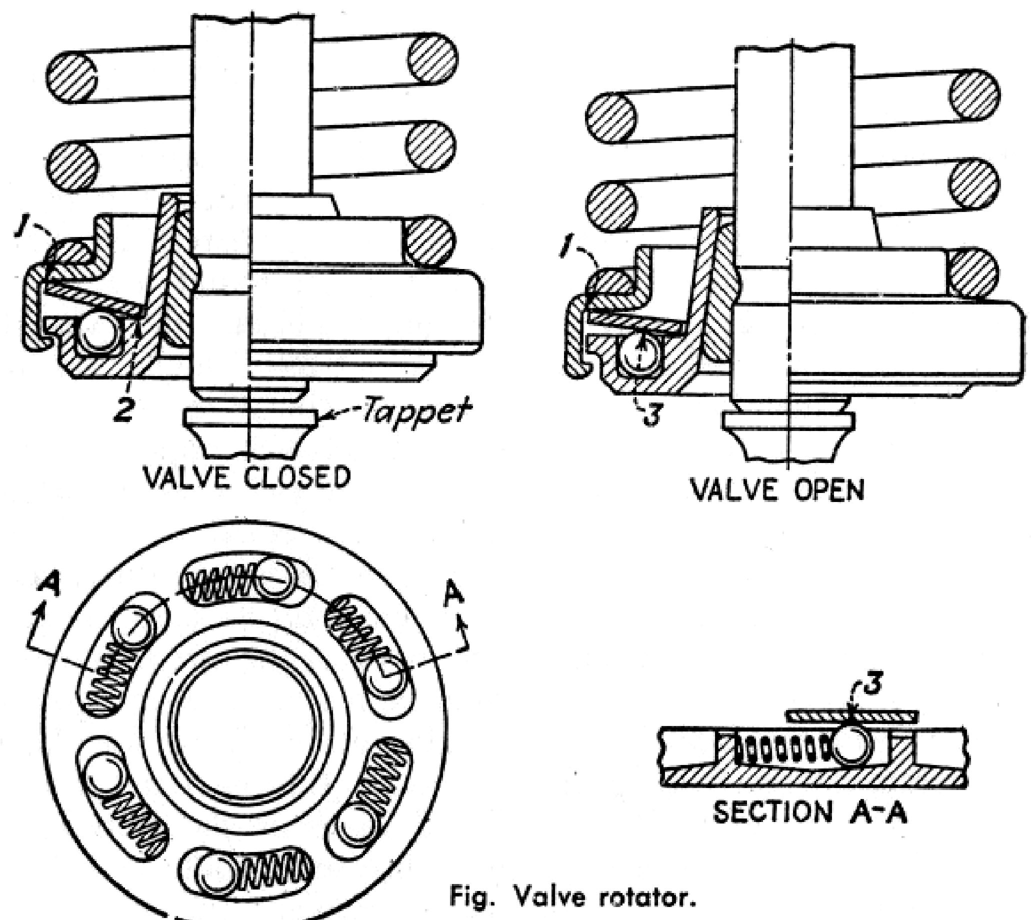


Fig. Valve rotator.

Valve Guides

In low-cost engines the valve guides are sometimes cast integral with the cylinder block or head, but the more general practice is to make them in the form of a bushing which is pressed into a hole drilled in the cylinder or head casting. Separate guides have the advantage that they can be renewed when worn. A fairly close fit for the valve stem in the guide is necessary, particularly in the case of inlet valves, because if there is excessive clearance between the stem and guide of these valves, air will be drawn into the cylinder through this clearance during the inlet stroke and dilute the charge received by the cylinder. If the clearances of the valve stems of an engine differ, the charges received by the different cylinders will be unequally diluted, a condition that cannot be corrected by carburetor adjustment. In passenger-car engines the clearance between inlet-valve stem and guide ranges between 0.002 and 0.003 in. It is very difficult to lubricate the exhaust valve guides effectively, owing to the high temperatures reached by them, and these, therefore, are subject to comparatively rapid wear. Exhaust-valve stems should have a clearance of between 0.002 and 0.004 in. in their guides.

Separate guides are usually made of cast iron, of 1/8 to 3/16-in. wall thickness, and are made a force fit in the hole in the cylinder or head casting. Sometimes the guide is provided with a flange or shoulder which abuts against a finished surface on the cylinder or head casting as the guide is pressed into position, but more generally this is omitted.

The exhaust-valve guide is preferably made to extend substantially up to the point of the stem where the fillet under the head begins, as it has been found that this keeps the valve head cooler than a design which leaves more of the stem exposed to the action of the hot gases during the exhaust period. A slight further reduction of the valve-head temperature can be achieved by counter boring the upper part of the valve guide, or, alternatively, undercutting the upper part of the valve stem, so that there is no contact between stem and guide over this portion of the length of the latter, which then serves merely as a shield for the valve stem, protecting it from the hot gases rushing by during the exhaust period. The guides of inlet valves are preferably made shorter, so that they project into the valve pocket only very slightly, as this reduces the resistance to flow. As indicated in Fig., in the case of the exhaust valve it is advantageous to water-jacket the whole length of the boss for the valve guide, as this keeps down the valve temperature. Lengths of valve guides are usually between 2 and 3 times the valve-port diameter.

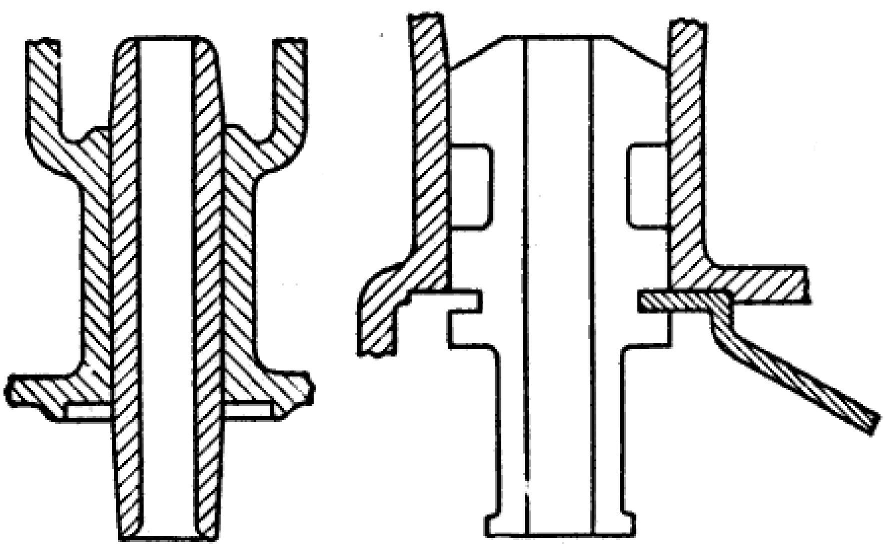
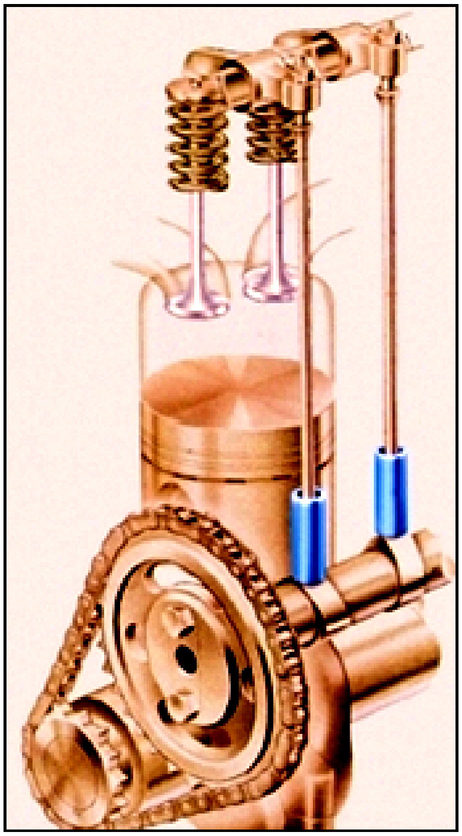


Fig. (*Left*). Standard type of valve-stem guide.

Fig. (*Right*). Ford axially-split valve-stem guide.

An unusual type of valve guide (Fig.) was used in early Ford engines. The valves of this engine were formed with an enlargement on the end of their stem, which supported a horseshoe-shaped spring retainer. Owing to this enlargement, it was impossible to insert the valve into a one-piece guide. The guide therefore was split through its axis, and valve and guide were inserted and with drawn together. The guide was held in position in the bore in the cylinder block by a horseshoe-shaped stamping which entered a groove turned in the guide and rested against a machined surface on the block.

Design of Valve Tappets



In L-head engines the valves are operated from the cams through the intermediary of tappets, which latter usually consist of a cylindrical steel part moving in a cast-iron guide formed on or secured to the crankcase. The tappet carries the cam follower at its lower end and is provided with clearance adjusting means at its upper end.

In the design of these members, lightness is an important consideration, since the strength of the valve spring required and the shock and noise produced by the lifting action are directly proportional to the weight of the parts moved by the cam, which include the tappet. In Fig. is shown a section of a roller-type tappet. Its body *A* is drilled out from the top for the sake of lightness, and its lower end is slotted to receive the roller B carried on roller pin C. A roller-type cam follower must be held in alignment with the cam, and to this end the guide is extended downwardly and slotted to receive the roller. At its upper end the tappet is threaded internally to receive the adjusting screw E, which latter also is drilled out. After a clearance adjustment has been made by means of screw *E,* the latter is locked by check nut F.

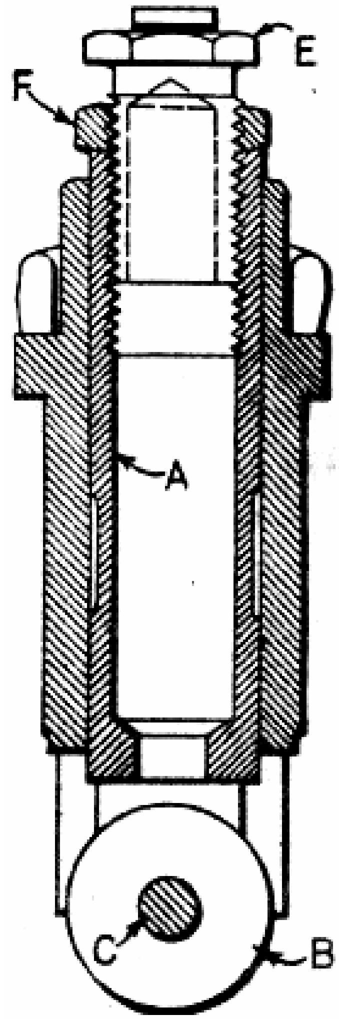


Fig. Roller-type valve tappet.

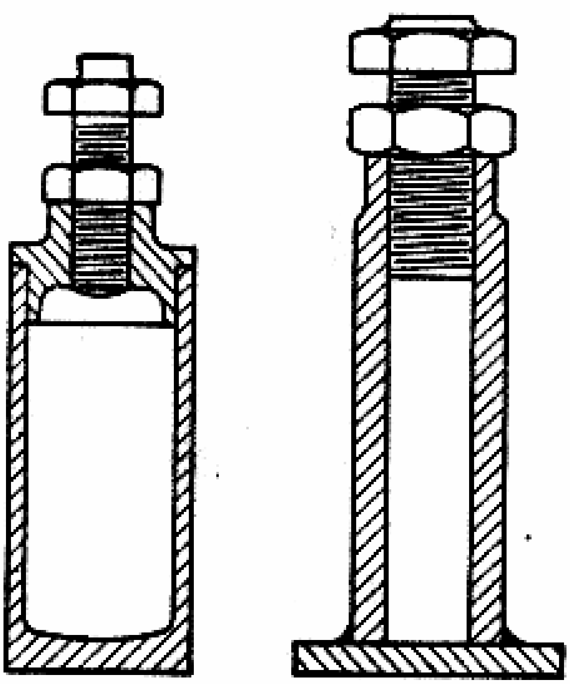


Fig. Mushroom tappets for L-head engines.

Two tappets for use with mushroom-type cams are shown in Fig.. The one on the left is a very light design which provides ample bearing surface. The other one is of tubular stock and has the foot welded to it. A foot of cast iron sometimes is welded to a tubular shank and is hardened by chilling. In other cases the entire tappet is made of cast iron. Tappets have been made also in which the wearing surface of the foot was provided with a veneer of Stellite or some other hard alloy.

Tappets are used also in valve-in-head engines, but in that case the clearance-adjusting means are located on the top of the engine, where they are more accessible. Two designs of tappets for this type of engine are shown in Fig.. The one on the left is thimble shaped and formed on the inside with a spherical seat for the ball end of the side rod. Solid side rods are used where the distance between the tappet and the rocker lever is comparatively short, as where the camshaft is located on the side of the cylinder block; with the camshaft in the crankcase, tubular side rods are preferable, because of their greater resistance to buckling. It will be seen that the side rod is shown to make a small angle with the axis of the tappet. This has the advantage that its reaction on the tappet has a small horizontal component which can be made to counteract the friction between cam and tappet, thus reducing the friction encountered by the latter. In the design shown at the right the spherical seat for the tubular side rod is at the top

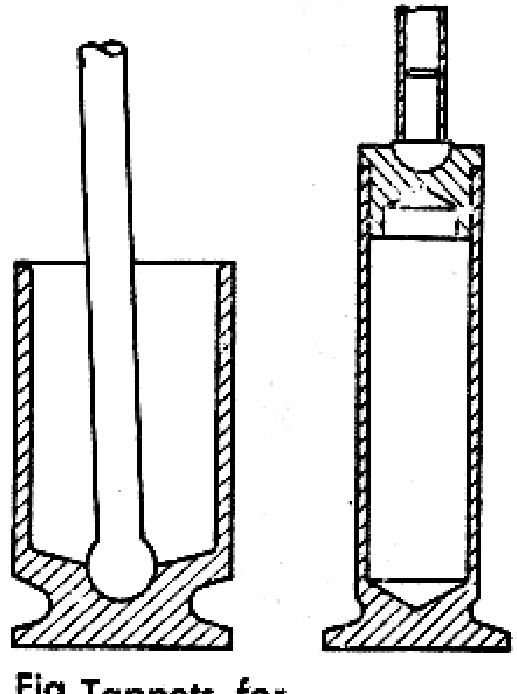
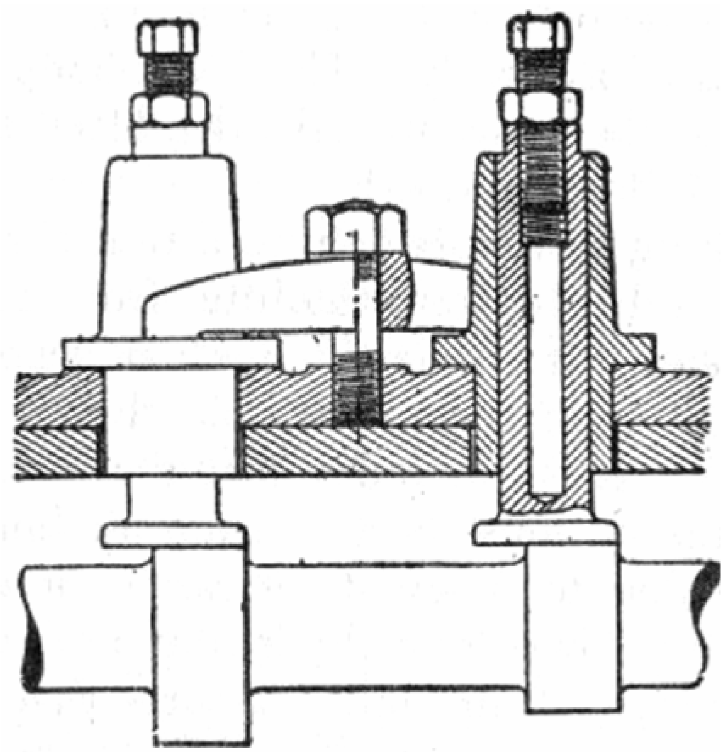


Fig. Tappets for valve-in-head engines.



Offset cam followers.

The tappet bearing surface must be brought down as close to the cam as feasible, because the load on it is an overhanging load, and if the overhang were great the pressure near the lower end of the bearing would be quite intense. With mushroom type cam followers it is a good plan to offset the follower lengthwise from the middle of the cam, so it will rotate in. its bearing, and no groove will wear in its foot. Such an arrangement is shown in Fig..

In the past it has been customary to make the contact surface of the tappet foot flat. However, the cam usually is located closer to one supporting bearing than to the other, and when the camshaft flexes under the lifting impact, its contact element or surface will be inclined toward the flat tappet surface, which results in stress concentration at one side of the cam. To prevent such stress concentration, tappet-foot surfaces now are sometimes made spherical, with a radius of 30 in. or more. To cause tappets with spherical contact surface to rotate, the cams are made to taper slightly in the axial direction.

Clearance Required

The amount of valve clearance required has increased in the course of time, because modern engines, on account of their much higher speeds, operate at higher temperatures. In passenger-car engines of the L-head type the average clearance between pushrod and valve stem with the engine cold is about 0.010 in. for the inlet, and 0.012 in. for the exhaust valves. For service purposes the "hot" clearances usually are specified, and are somewhat smaller than the figures given. Valve-in-head engines require greater clearances, especially where the cam motion is amplified by the tappet levers.

Automatic "Zero-Clearance" Tappets

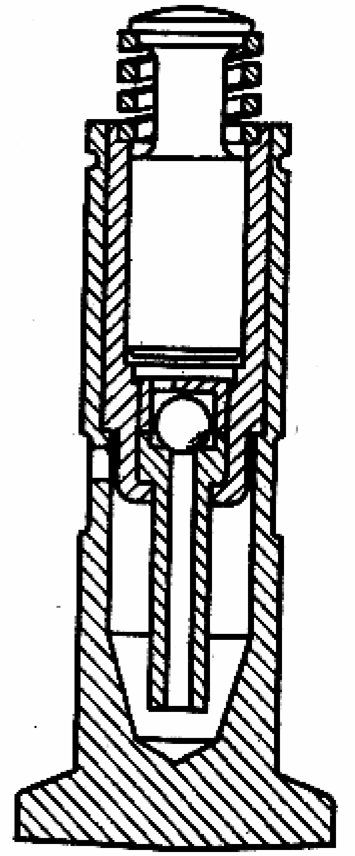
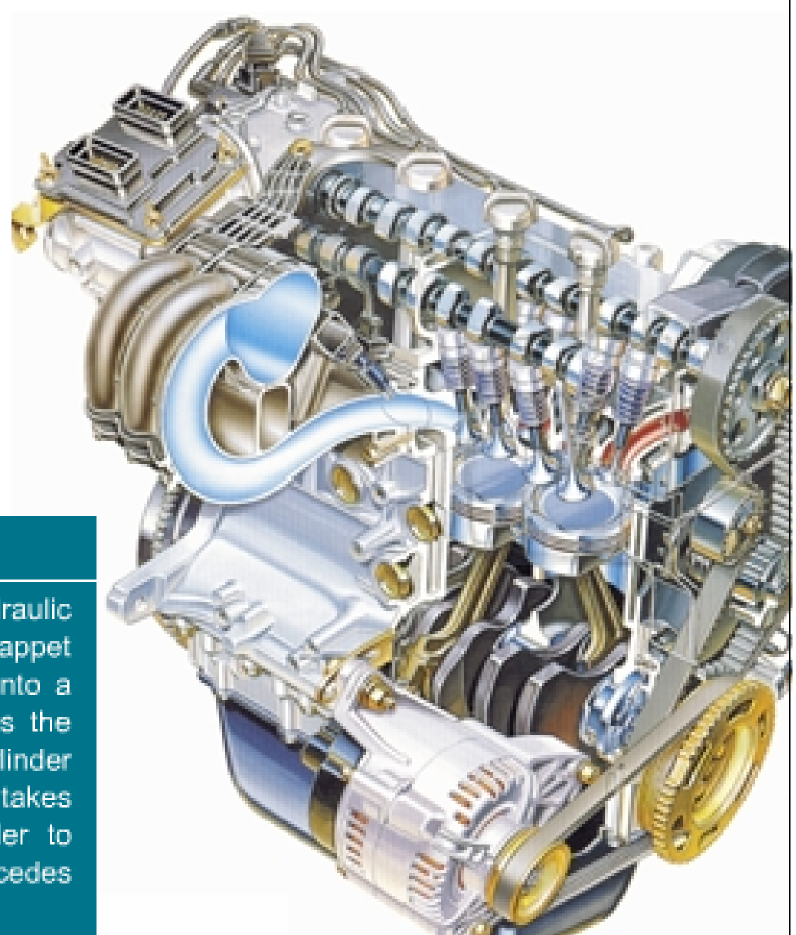


Fig. Zero-lash hydraulic tappet.

By means of a hydraulic device supplied with oil from the engine lubricating system (or from a separate source), it is possible to take up clearance between the tappet and valve automatically as soon as it develops. **A hydraulic tappet** is used extensively by engine manufacturers. A sectional view of this tappet is shown in Fig.. The adjusting means is a separate hydraulic unit which is set into the valve lifter body during the process of assembly. The lifter body is of substantially the same design as the conventional valve lifter, hence only the hydraulic unit needs to be described.

Oil from the engine lubricating system is delivered to a chamber adjacent to the tappet guide, and is fed into the lifter from a point near the bottom of the chamber. It enters the annular groove in the tappet body and passes through the radial hole therein, into the cavity below the hydraulic unit. In order that the hydraulic unit may function properly, the oil must be free from air bubbles, and suitable means are provided to de-aerate it before it enters the tappet. The tube extending down from the hydraulic unit also assists somewhat in the separation of air, and it assures that practically all of the oil in the cavity forms a reserve supply for starting. Oil from the cavity passes through the ball-type check valve into the adjusting chamber below the plunger. A light spring holds the plunger against the valve stem, and the face of the lifter in constant contact with the cam. The bottom of the plunger clears the bottom of the bore by about 1/I6 in. In this manner the air is worked out at the time of installation, the lifter is always filled with oil, and the clearance is entirely taken up by the oil column below the plunger. Hydraulic tappets of this type assure silent operation, eliminate the need for valve adjustment, and increase valve life. They obviate the need for a quieting ramp on the cam.



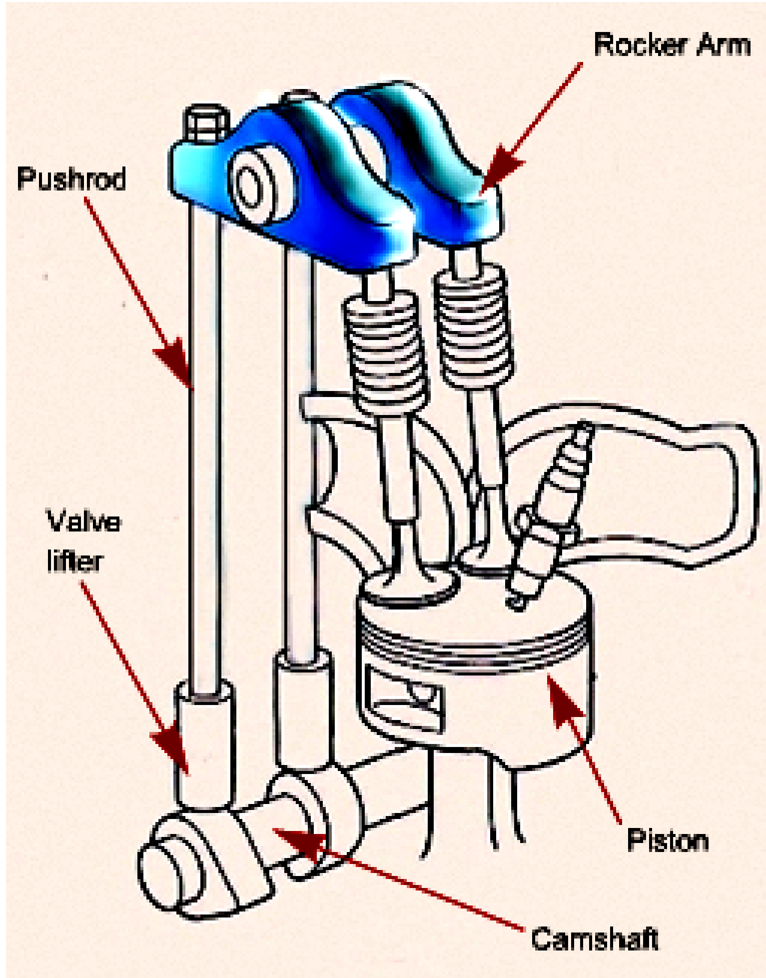
Hydraulic tappet

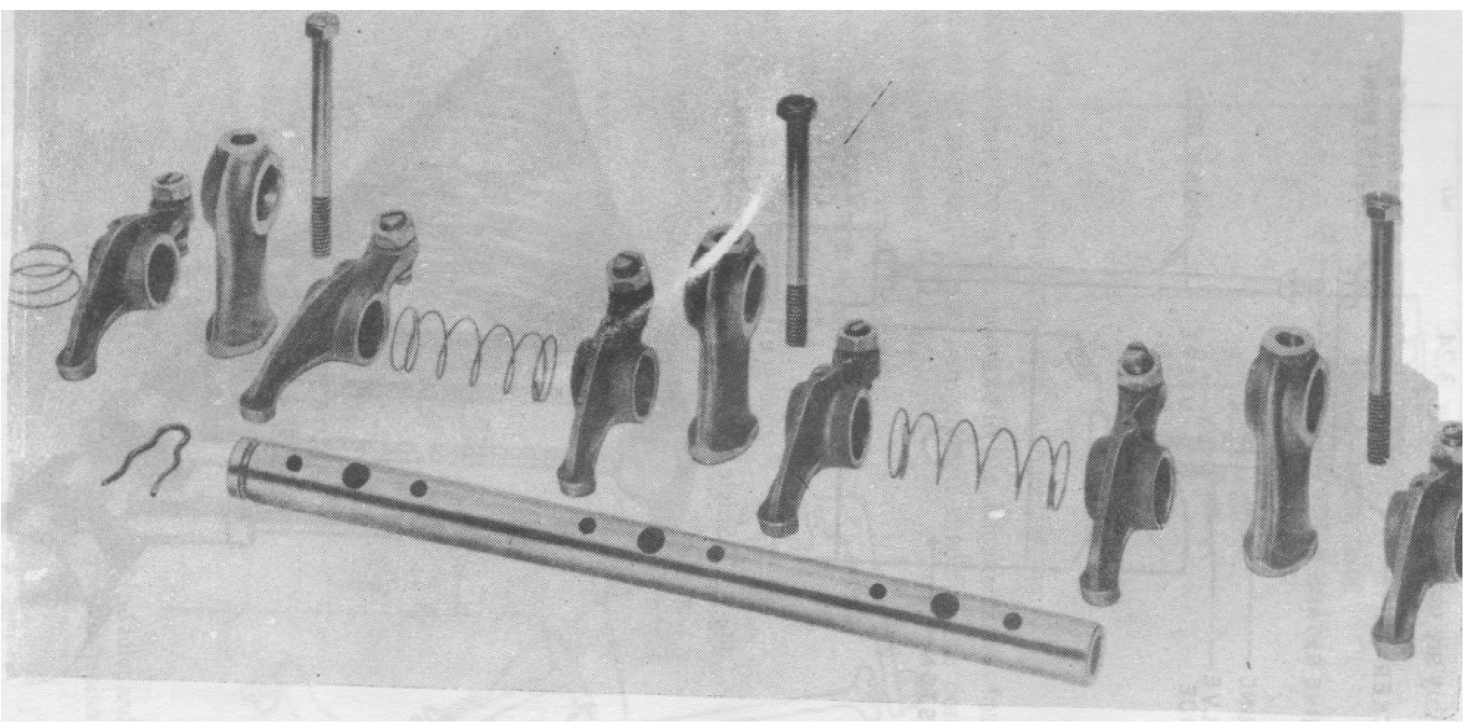
A form of self-adjusting tappet which uses hydraulic pressure to take up any adjustment. With the tappet at rest at the bottom of its stroke, oil flows into a cylinder via the ports and as the tappet rises the ports are shut off to trap the oil inside the cylinder and transmit the load to the cup. As wear takes place, more oil is trapped within the cylinder to compensate. The Fiat Uno, Siena and the Mercedes use this system.

Rocker Arm and Rocker Shaft

The function of the rocker arm is to reverse the upward motion of the push rod to downward motion of the valve and vice versa. The rocker arm may be either solid or hollow.

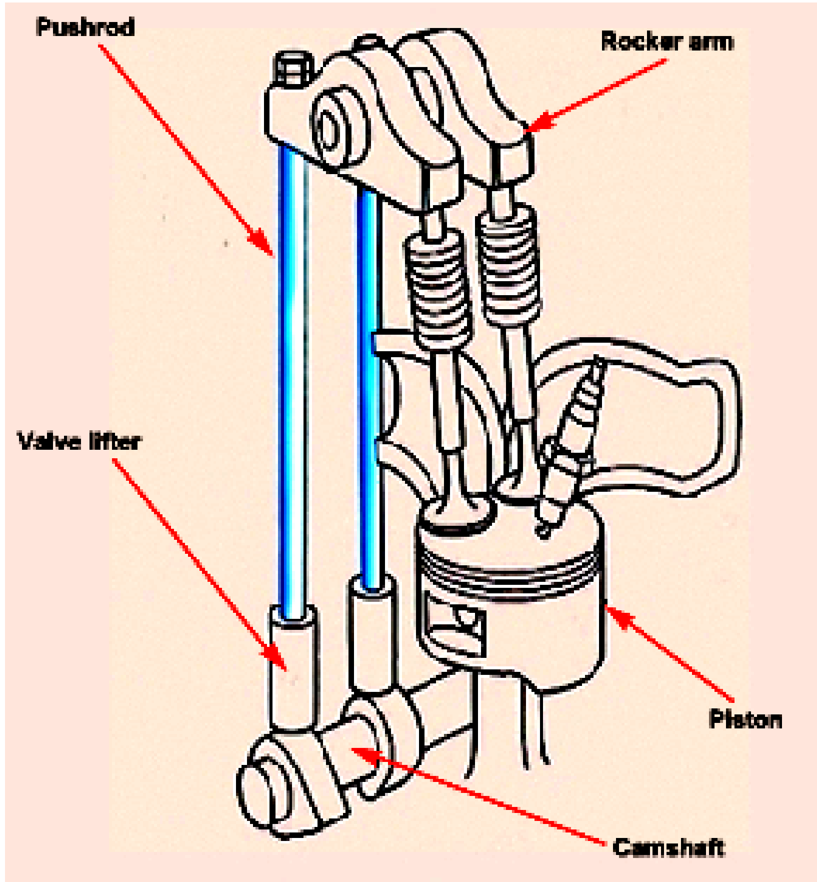
A stationary hollow rocker shaft serves as a pivot to the rocker arms and provides passage for lubricating oil simultaneously. Rocker arm is made of steel (forged or stamped) or iron (cast). Cast rocker arms are comparatively cheaper but are not as strong as forged or stamped ones. However, these give satisfactory service in cars. Stamped rocker arms have been found to be light, very strong, yet cheapest of all the types. Rocker shafts are made from hollow steel tubing. A typical material for these would consist of 0.55% carbon, 0.2% silicon, 0.65% manganese and the remainder iron. After machining the shaft is case-hardened. It is mounted on cast iron or aluminium pedestals placed between each pair of rocker arms.





Push Rod

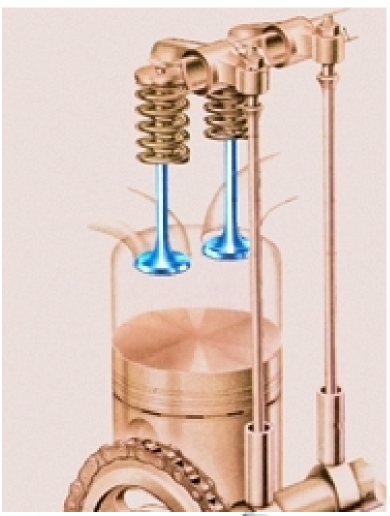
It serves to transmit the reciprocating motion of the valve lifter to the rocker arm. Since the valve lifter moves in a straight line whereas the rocker arm end moves in an arc about its pivot, to provide compatibility of the two, the push rod forms part of ball and socket joints on both ends. Push rods are made of carbon-manganese steel. A typical push rod steel contains 0.35% carbon, 0.2% silicon and 1.5% manganese. After hardening and tempering, a hardness of about 250 B.H.N. is obtained. The push rod may be either solid or hollow. A hollow push rod is lighter, resulting in decrease of inertia forces. Further, it may also serve as a passage for oil for lubrication of the valve actuating mechanism.

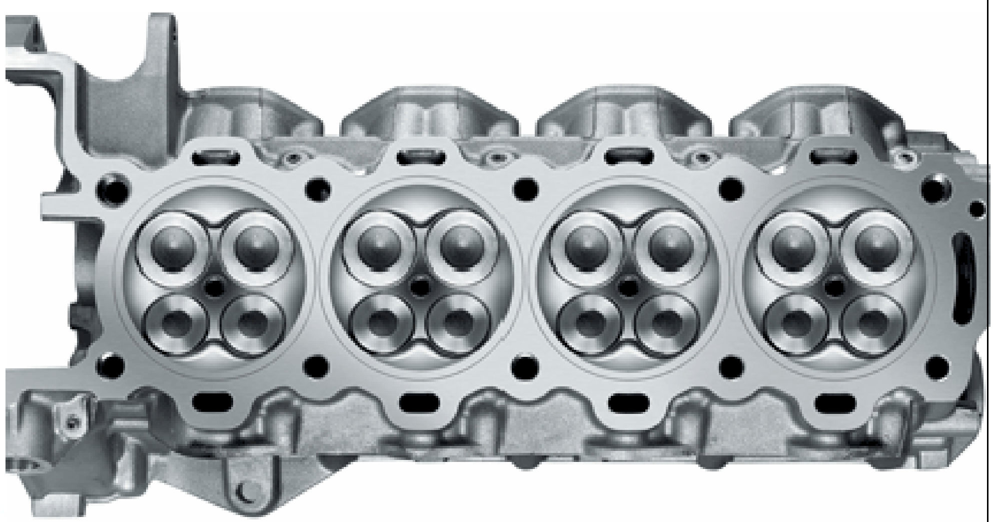


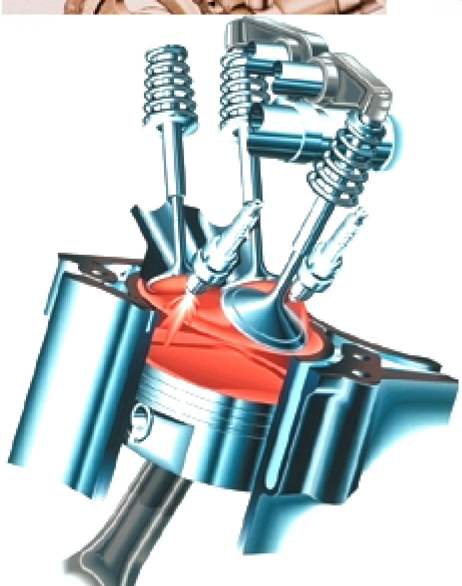
Dual Valves

Large valves are more troublesome than small ones, because a large disc will be warped more by the heat, and, besides, the weight of the valve increases rapidly with the linear dimensions, hence the stress on the valve and its mechanism due to rapid opening and closing becomes very great for large diameters. For this reason it has become customary in high-speed engines with large cylinder bores to use two inlet and two exhaust valves per cylinder.

An experimental investigation of the relative capacities of large and small valves was made in connection with the development of the Liberty aircraft engine, and the conclusions reached were that at the same pressure drop, one valve of diameter D and lift *h* is equal in capacity to, first, a pair of valves of diameter O.707D (equal port area) and lift 0.70*h* and, second, a pair of valves of diameter 0.6D and lift h, for values of *h* not exceeding about O.25D. Engines with two, three, four & five valves are shown in the following Figures.







Valve Timing

The valves are operated by cams on a shaft which turns at one-half the speed of the crankshaft, so that each valve is opened and closed once during two revolutions of the crankshaft. In order that an engine may operate satisfactorily at high speeds, it is necessary that the exhaust valve open before the end of the power stroke and close after the completion of the exhaust stroke; and that the inlet open before the end of the exhaust stroke and close after the completion of the inlet stroke. This involves an overlapping of the exhaust and inlet periods, which is made necessary in part by the very slow opening and closing motions now employed for the sake of quiet operation. If the inlet began to open only after the exhaust had closed, the effective valve opening during a considerable part of the inlet stroke would be so small that the incoming charge would be seriously throttled. For an engine which is intended to "peak" at 3000-4000 rpm the valve timing shown in Fig. should prove satisfactory. That there is considerable latitude with respect to the different valve functions may be seen from the following table which applies to 1953 passenger-car engines:

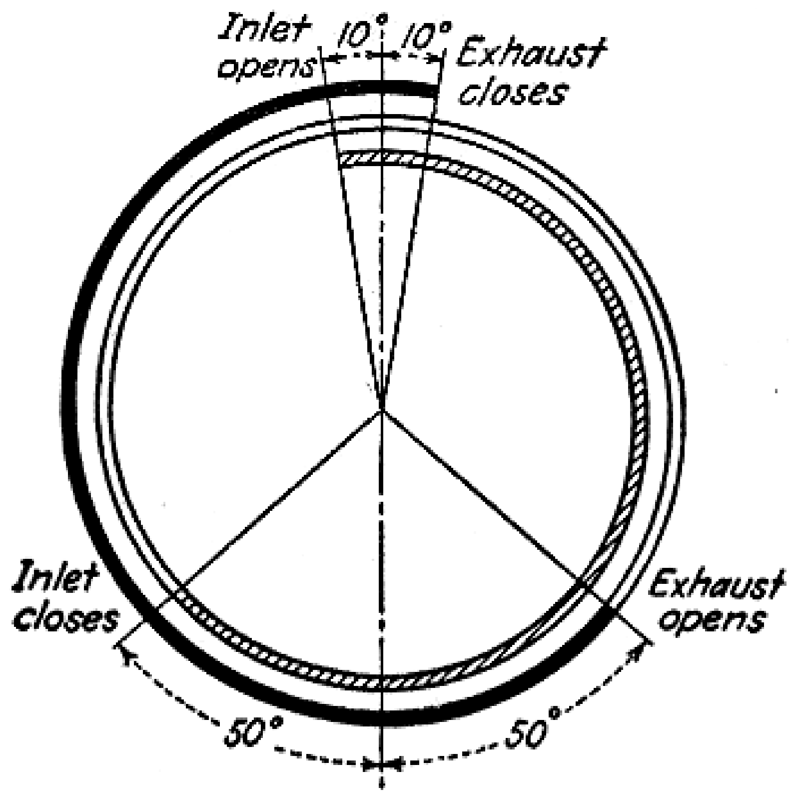
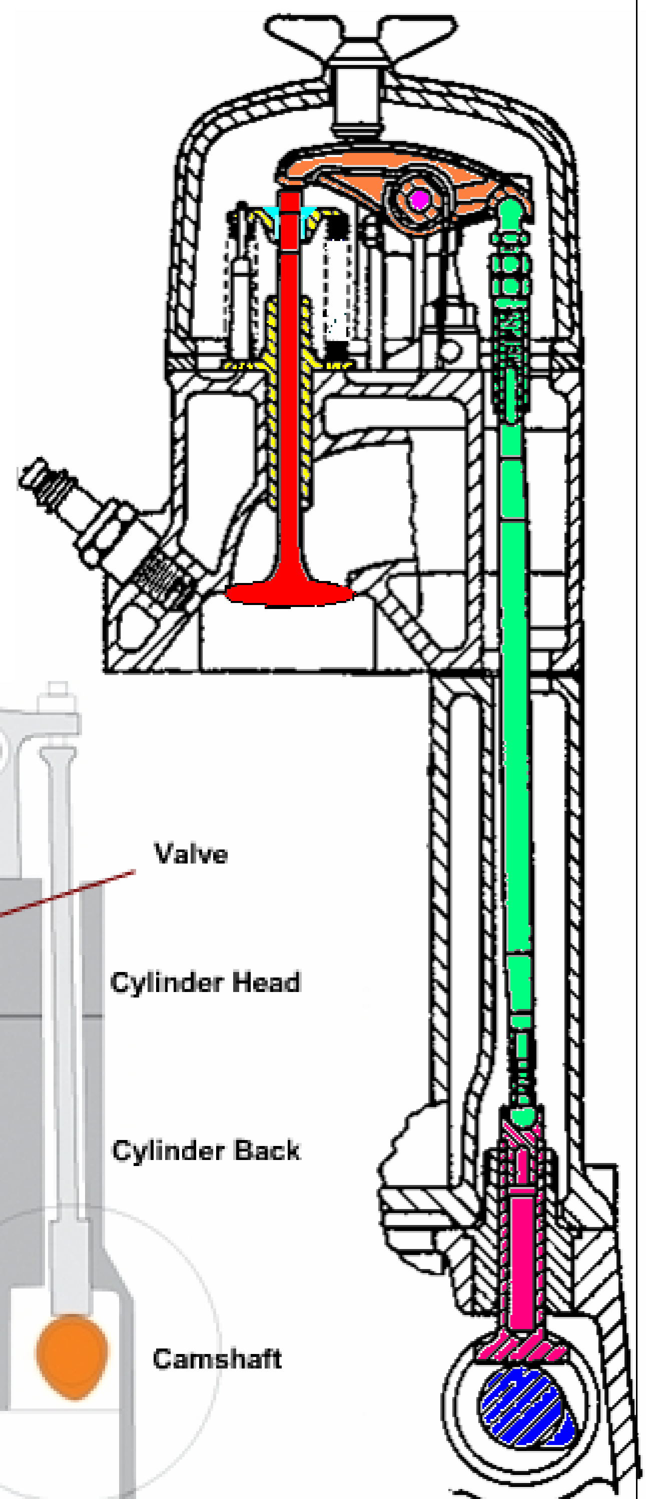


Fig. Typical valve-timing diagram.

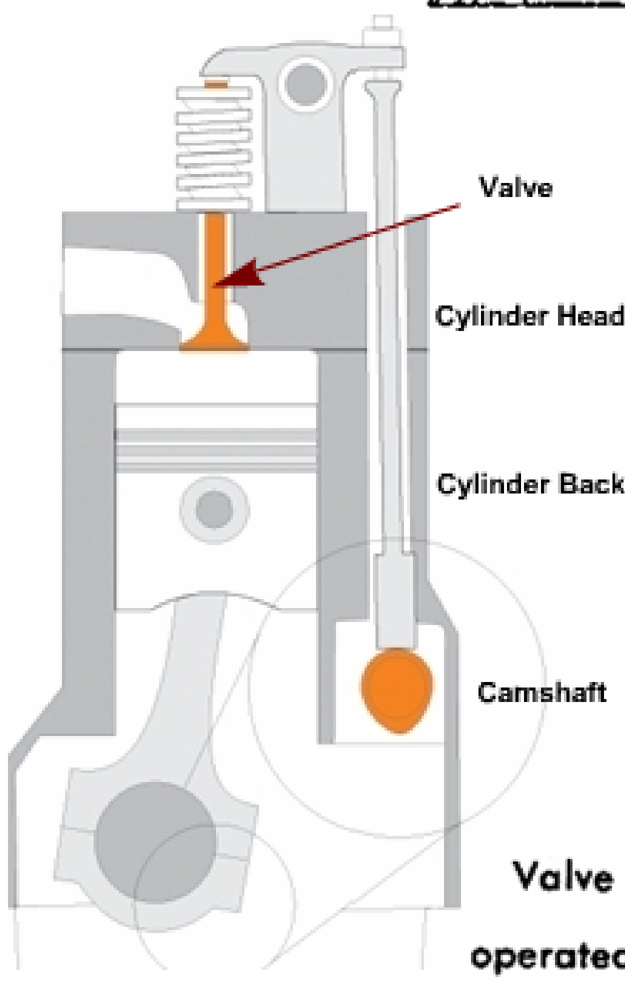
Valve Function	Early	Late	Mean
Inlet opens........	25° BTC	1° ATC	12° BTC
Inlet closes........	36° ABC	92° ABC	52° ABC
Exhaust opens.....	70° BBC	37° BBC	50° BBC
Exhaust closes.....	3° ATC	42° ATC	13° ATC

Overhead Valves

Valves in the head are operated either by tappet rods extending up the side of the cylinders, or by means of an overhead camshaft. When tappet rods are used, they extend up through an enclosed space and the rocker arms, etc., at the top of the engine are enclosed by a valve cover, which is usually of pressed steel. When the whole valve mechanism is thus enclosed, not only are any noises produced by it muffled, but the joints can all be effectively lubricated and all bearings are protected against dust. In multi-cylinder overhead-valve engines the rocker arms are mounted on a hollow shaft, to which is connected a lead from the pressure lubricating system. At the center of each rocker arm bearing an oil hole is drilled through the wall-of the hollow shaft, so that oil will feed to the bearing surface, and sometimes a hole is drilled lengthwise of the rocker arm from the rocker bearing surface to the point of contact with the valve stem. By placing the breather pipe on the valve cover and establishing communication with the crankcase by means of the tappet-rod passages, an oil-misty atmosphere is created in the valve chamber, and the lubrication of all bearings is provided for.

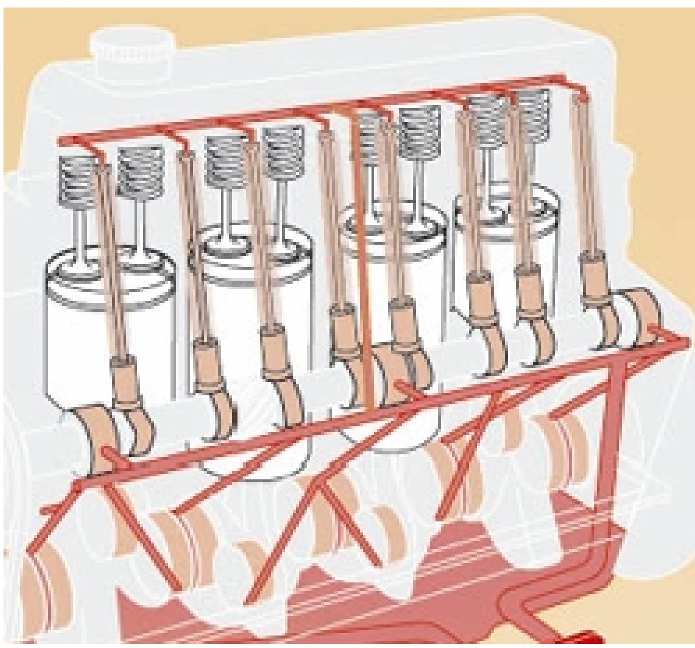


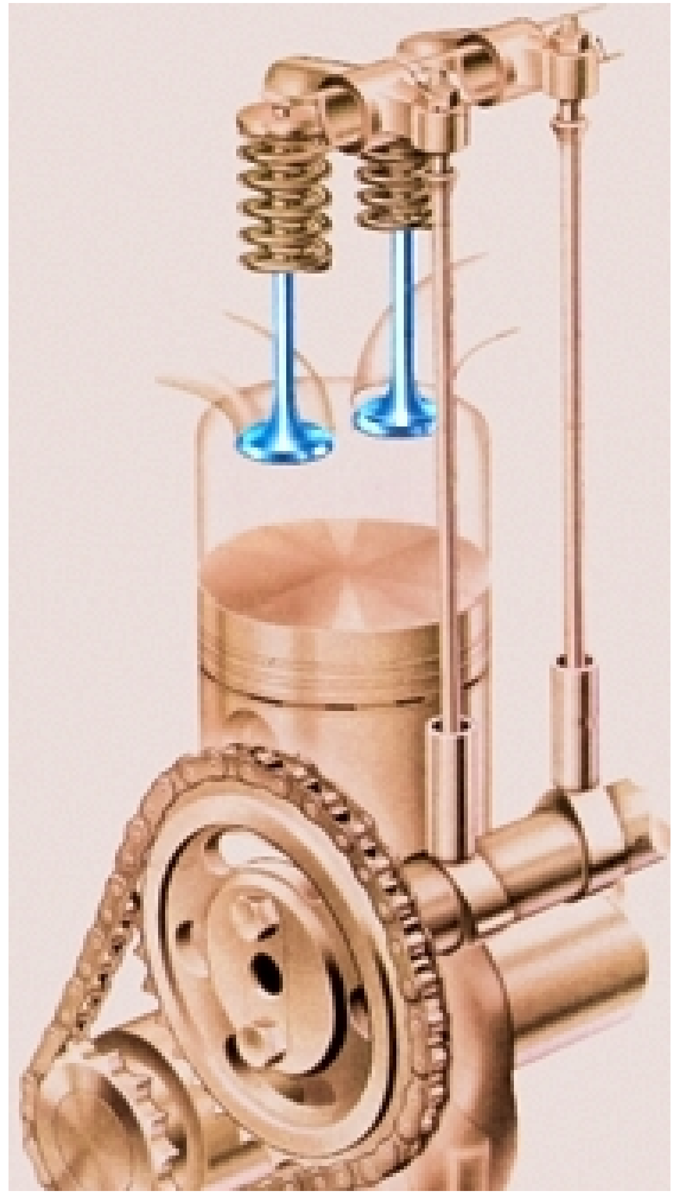
Valve in cylinder head operated through side rod



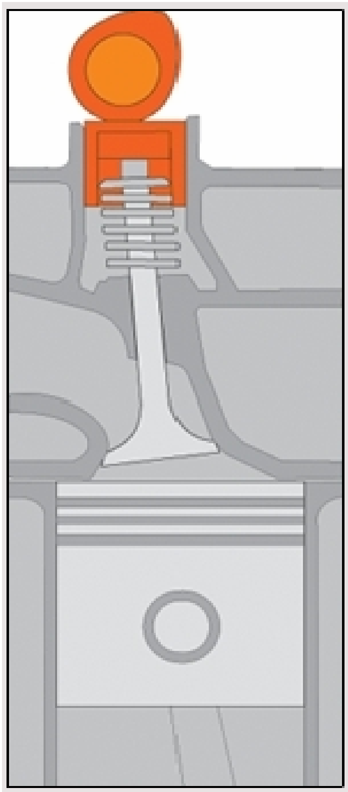
With tappet rods extending up the side of the cylinder block, as shown in Fig., the weight of the moving parts naturally is greater than in L head engines, and every effort should be made to lighten these parts. The tappet rods preferably are made of steel tubing of an outside diameter of about 3/8 in. for the size of cylinder used in passenger-car engines. Into the lower end of the tube can be fitted a thrust pin with a half-round head which has a bearing in a socket formed on a thrust block set into the hollow tappet. At the top an internally threaded sleeve with a hexagon on it is fitted over the tube, and receives the clearance-adjusting screw, which latter has a spherical head nested in a socket formed on the end of the rocker-lever arm. Owing to the fact that all contact surfaces are very liberal in size, and of such shape that they naturally retain any oil getting onto them, there is usually very little wear on these surfaces. The rocker levers usually are drop forgings, though one manufacturer has made them of steel pressings.

In determining the weight of the valve-reciprocating parts where rocker levers are used, it is necessary to first find the radius of gyration of the rocker lever, which can be done either by calculation or experimentally by the pendulum method. The actual weight of the rocker is then reduced in the proportion of the radius of gyration to the length of the rocker arm bearing on the side rod, and the value thus obtained is added to the weight of the tappet and side rod. The weight of the valve and parts moving with it is reduced in the proportion of valve motion to tappet motion, and then added to the other weights.





Overhead Camshahs



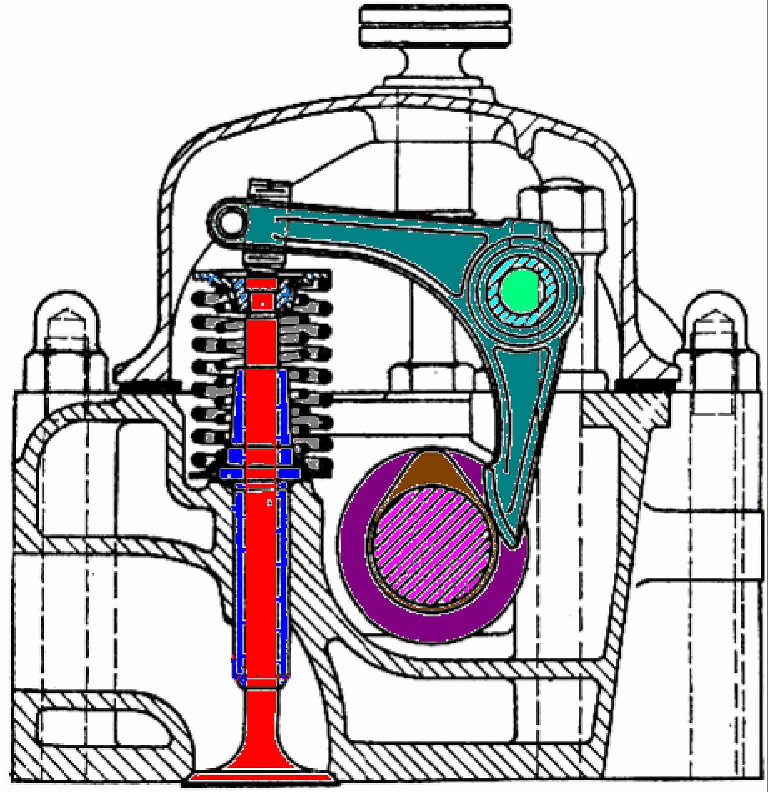
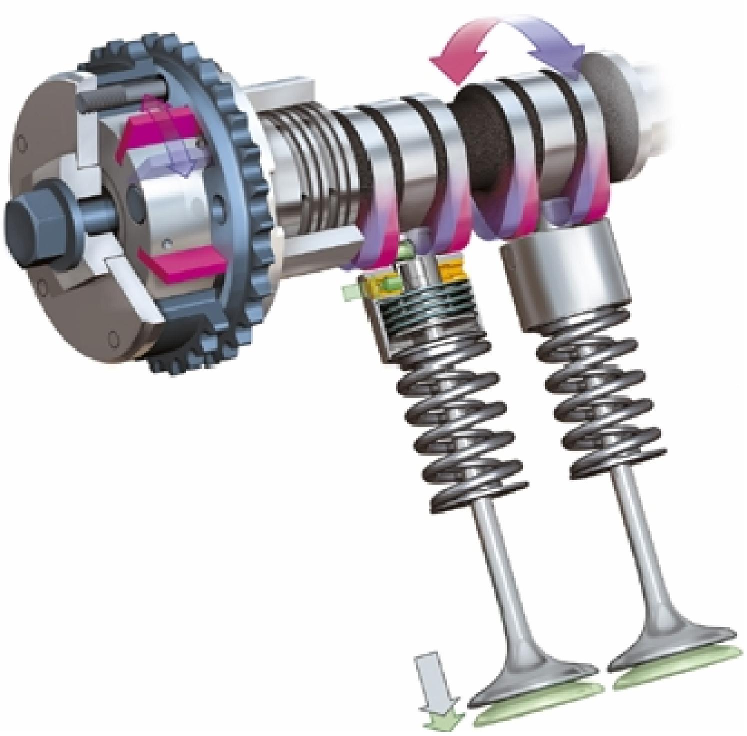
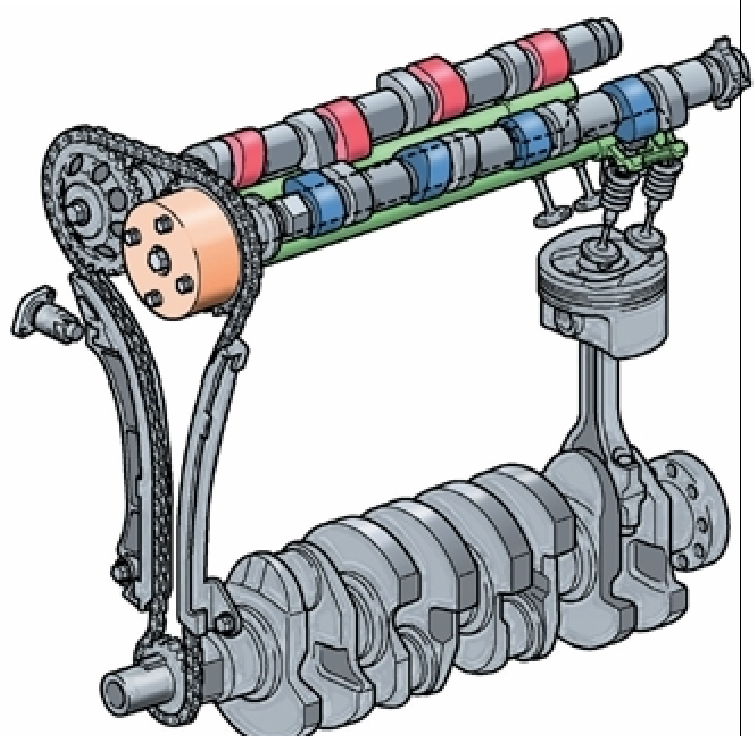


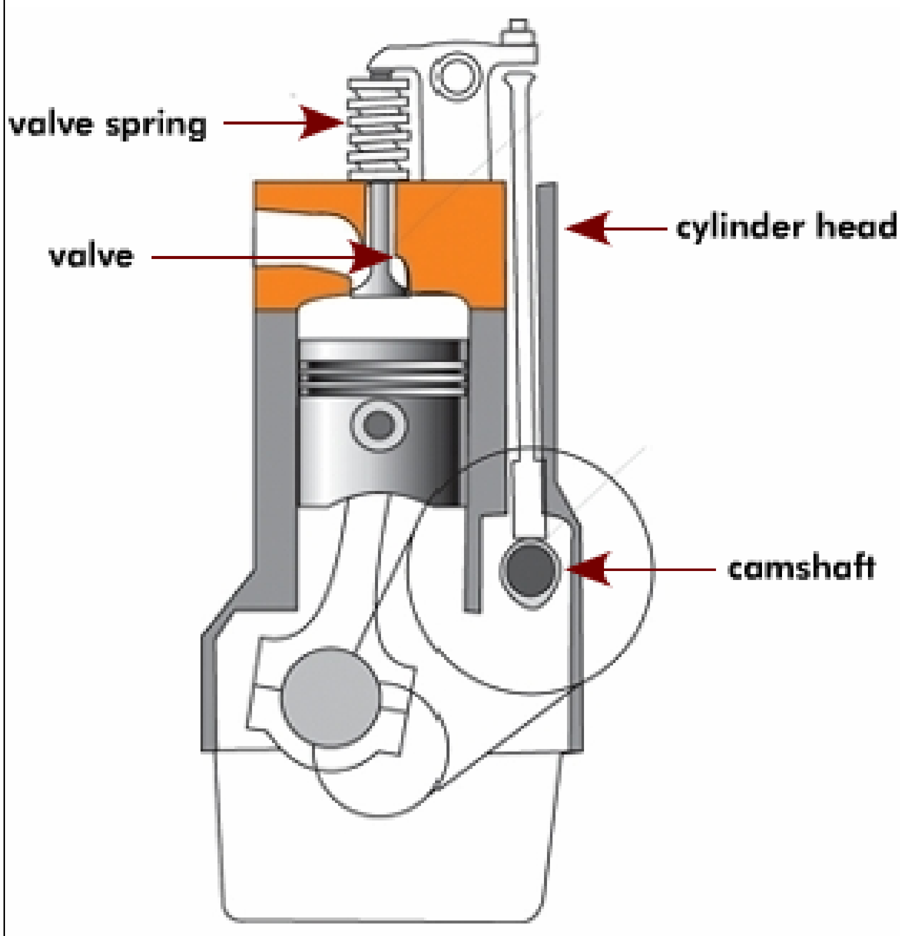
Fig. Valve operated from overhead camshaft.

The simplest and most direct method of actuating valves in the cylinder head is by means of an overhead camshaft, Fig.. It reduces the necessary weight of valve reciprocating parts, thus making it possible to get along with lighter springs and to increase the maximum speed.
It appears that one reason for the less quiet operation of the engine is that the source of the noise (the cam gear) is directly underneath the hood, and the noise is therefore more readily transmitted to the passengers ears than when it originates down in the crankcase. It has been found that a contributing factor to noise in the valve gear is the discontinuity of the torque; that is, when the nose of a cam has passed a cam follower, the pressure of the valve spring causes the cam and its shaft to snap forward, thereby taking up the clearance between gear teeth. Trouble from this source may be guarded against by "burdening" the camshaft with additional load, such as the fan, water pump, or generator.





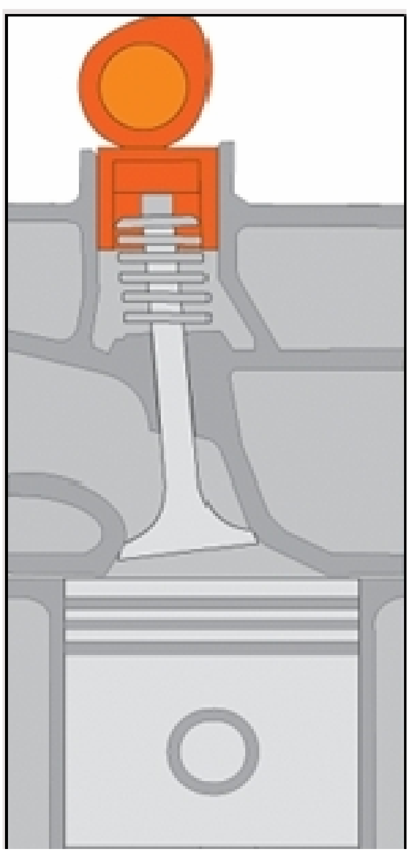
Valve Actuating Mechanisms

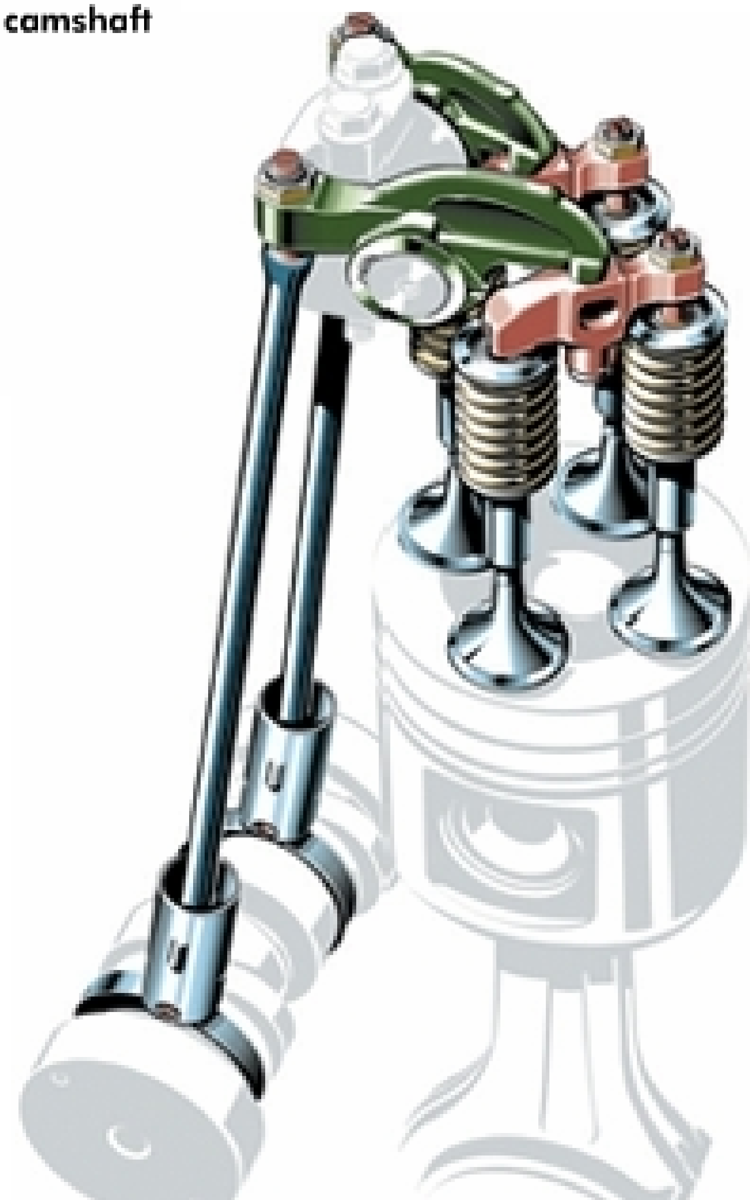


In all the valve actuating mechanisms a cam driven at half the crankshaft speed is used to operate each valve inlet or exhaust. However, there are different methods of operating the valves from the cam.

These may be broadly divided into two types viz.,

1. Mechanisms with side camshaft and
2. The mechanisms with overhead camshaft.





1. Mechanisms with side camshaft

In these the camshaft is on the side of the engine and the valves are operated either directly by the cams or through the push rods and rocker arms.

These may be further classified as:

(a)Double row side valve mechanism (T-head)

This is the oldest type of valve actuating mechanism and is shown in Fig. In this the inlet and the exhaust valves are operated by separate camshafts which makes the mechanism complicated. Moreover the shape of the combustion chamber provides poor combustion and low engine performance due to which this type of mechanism is obsolete.

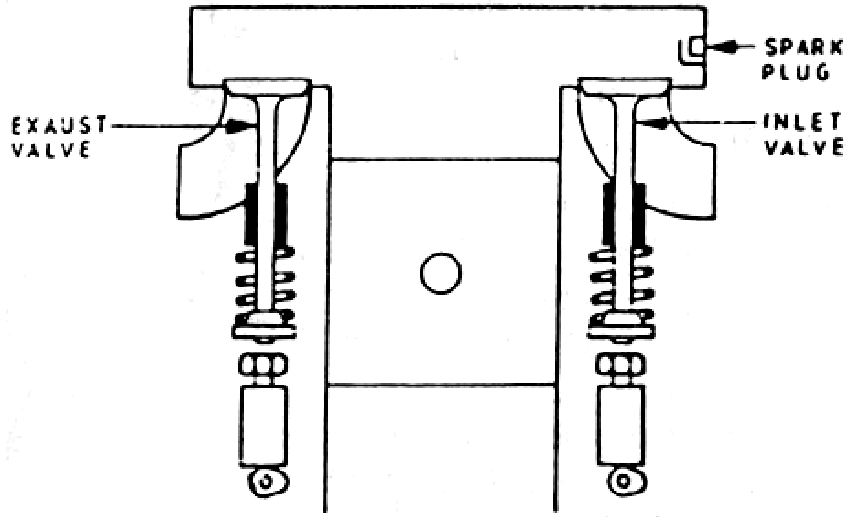


Fig. Double row side valve mechanism.

(b) Single row side valve mechanism (L-head)

In this the inlet and the exhaust valves are all arranged in a single row and operated from the same camshaft (Fig.). This method was once quite popular on account of the following advantages:

(i) Low engine height.
(ii) Low production cost.
(iii) Quiet operation.
(iv) Ease of lubrication

This mechanism is, however, no more in use, because it was found to be very inefficient on account of the complicated shape of the combustion chamber which is more prone to detonation. There were also restrictions of space on the size of inlet valves that would be used. Moreover, difficulties were experienced in cooling the exhaust valves.

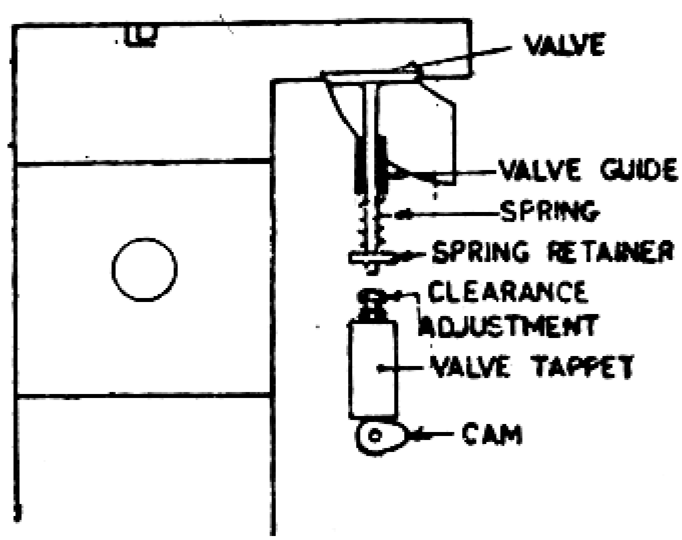


Fig. Single row side valve mechanism.

(c) Overhead inlet and side exhaust valve mechanism (F-head)

This is a combination of the two systems described above. Overhead valve mechanism is used for the inlet valve operation and the side valve mechanism for the exhaust valve. It is used in F-head engines. This mechanism is simpler than the overhead camshaft operated types and allows the use of larger inlet valves, but larger valves being heavier, there is also a limitation on the maximum speed of the engine that could be allowed. F-head engines were found to be less efficient and were also more expensive due to which these have also become obsolete.

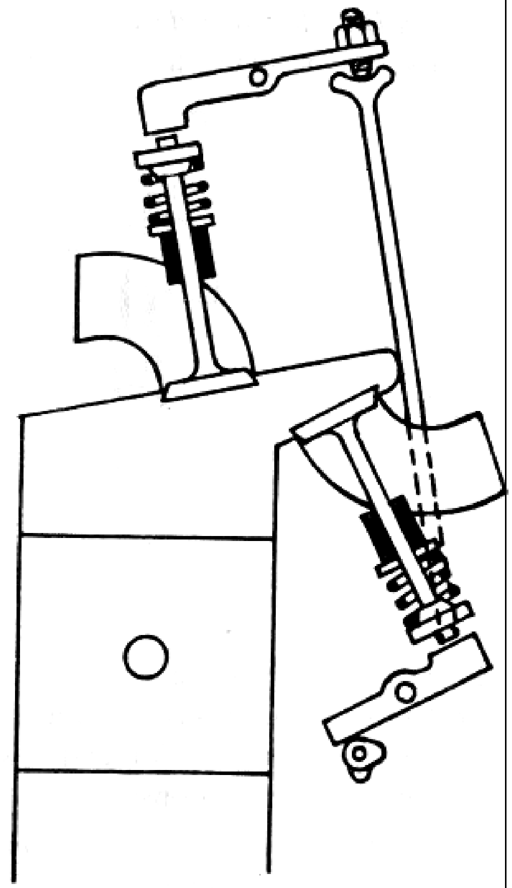


Fig. Overhead inlet and side exhaust valve mechanism.

(d) *Single row overhead valve mechanism (I-head)*

This type is used quite extensively these days and is shown in Fig.. The cam operates the valve lifter which in turn actuates the push rod. The push rod further operates the rocker arm, which actuates the valve.

This type of mechanism is having the following advantages:

(i) Higher volumetric efficiency than the side valve design.

(ii) Higher compression ratios can be used.

(iii) Leaner air-fuel mixtures can be burnt.

(iv) The rocker-arm leverage makes it possible to impart desired cam profile lift multiplication to the system and hence use smaller cam lobes compared to the side valve mechanism.

The above advantages are, however, accompanied by some drawbacks of the mechanism.

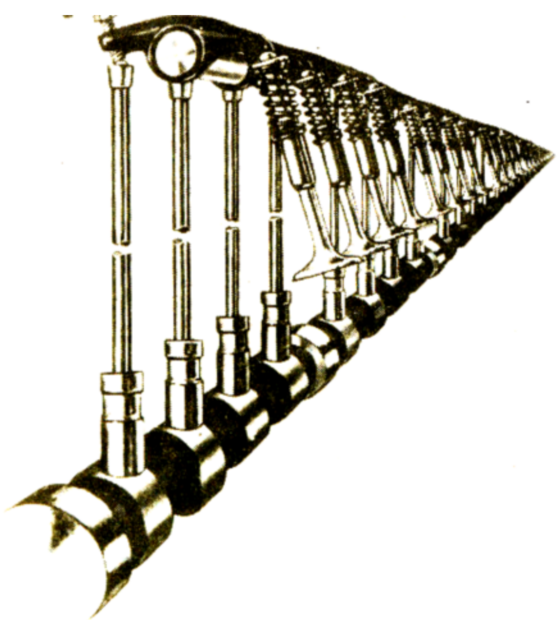
These are,

(i) The valve operation, on account of the elasticity of the system and the resulting vibrations, is not very precise while accelerating or operating at high engine speeds.

(ii) Larger valve lifter clearances are required.

(iii) Noisy operation.

(iv) Greater maintenance required due to more wear at more joints.



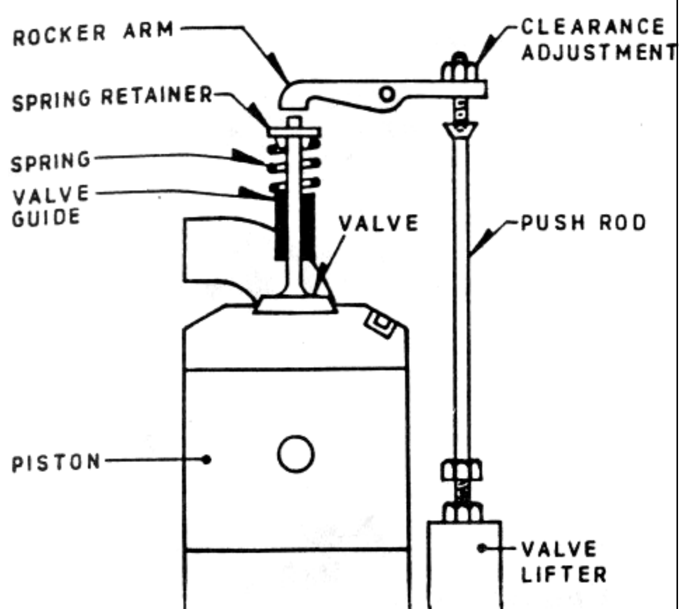


Fig. Single row overhead valve mechanism.

2. Mechanisms with overhead camshaft

The valve operating mechanisms with overhead single or double camshafts are highly efficient. However, with these considerably more lubricating oil is needed to flood the cam profiles as compared to the overhead valves operated by side camshafts. Moreover, they have the disadvantage of higher initial costs.

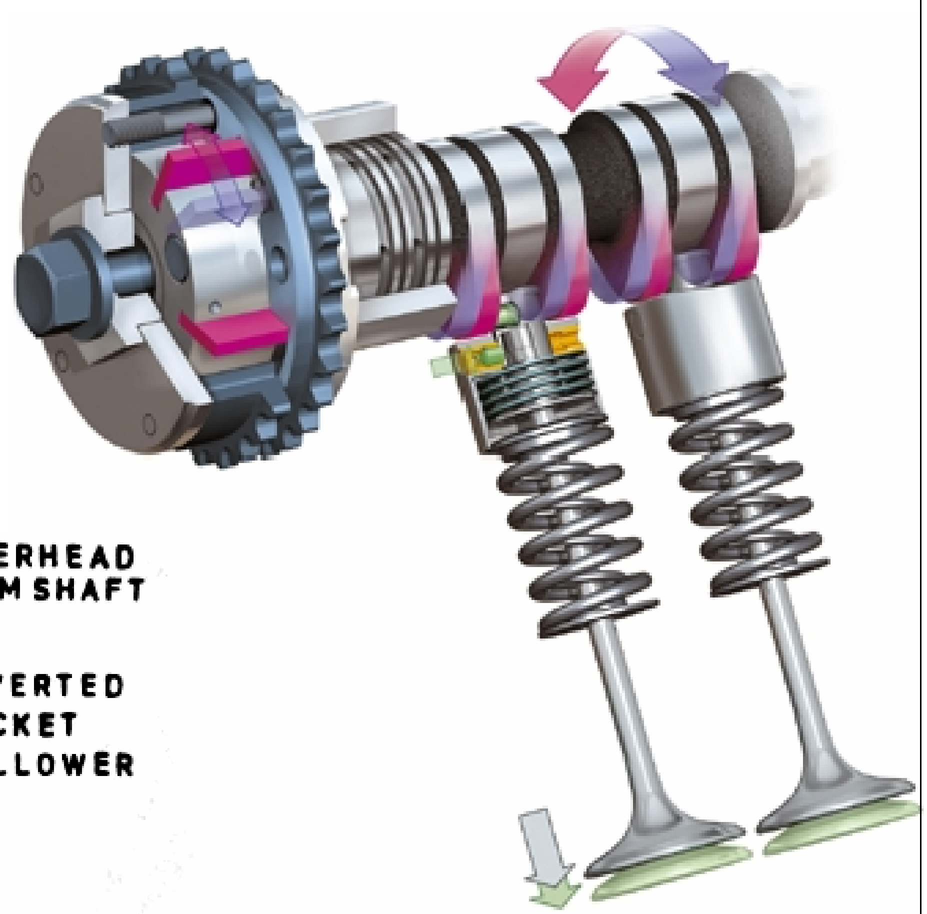


Figure. shows single row valves operated by a single overhead camshaft and an inverted bucket type follower. With this type of follower, the camshaft is arranged directly over the valve stems. This type of mechanism is direct and very rigid so that valve movement follows precisely the designed cam-profile lift. Moreover, valve stems are not subjected to side-thrust which means less wear. Tappet clearances are also quite small and do not require adjustment very often. However, drive to the camshaft is quite complicated, positive lubrication is required and adjustment of valve lifter clearance is relatively more difficult.

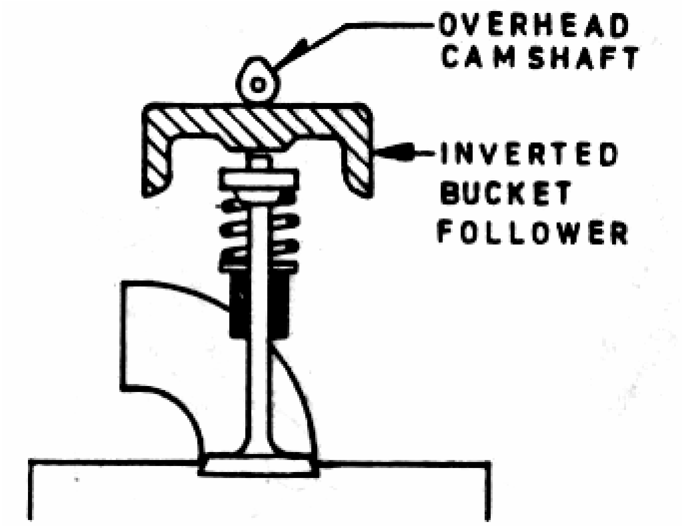


Fig. Overhead camshaft-operated mechanism with inverted bucket type follower (Single row valves)

A similar valve-operating mechanism with end-pivoted rocker arm is shown in Fig.. The rocker arm provides leverage ratio, which enables the designer to provide smaller cam profile. Moreover, the inertia of rocker arm follower is less compared to the sliding bucket type described earlier and adjustment of tappets is easy. However, due to the elastic bending of the rocker arm, the stiffness of the system and hence precision of valve operation is decreased, a side-thrust is produced to the valve stem and guide and more wear and noise occur.

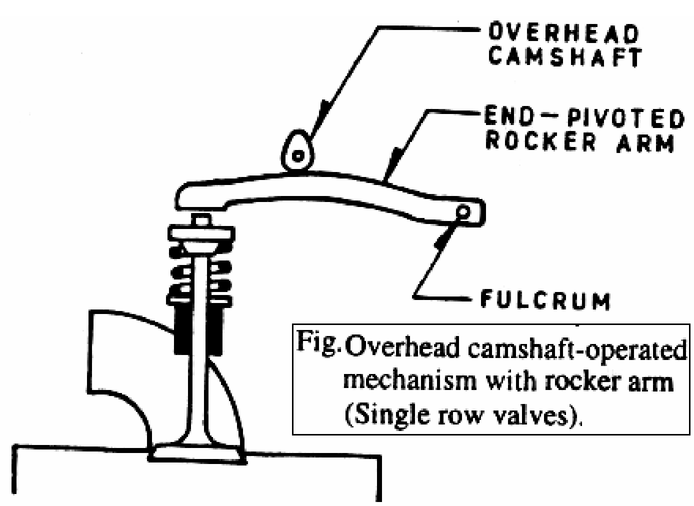


Fig. Overhead camshaft-operated mechanism with rocker arm (Single row valves).

Valve & valve mechanism

In Fig. is depicted a mechanism for inlet and exhaust valves in separate rows, but operated by a single overhead camshaft with inverted bucket type follower and the pivoted rocker arm.

However, quite often the double-row valves are operated by two separate overhead camshafts as shown in Figures.

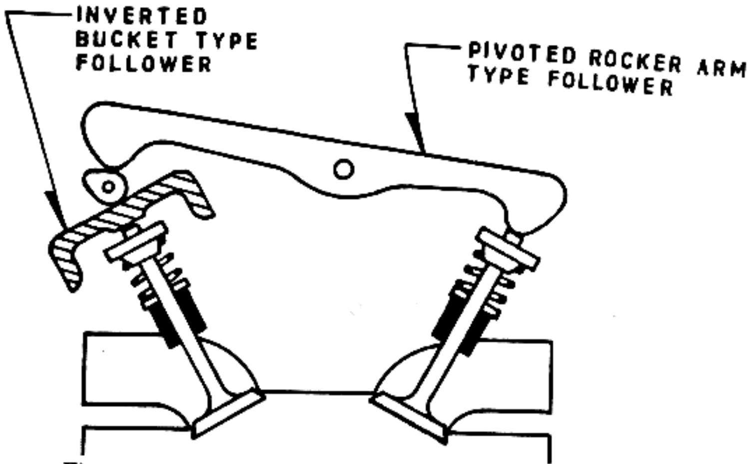


Fig. Overhead camshaft-operated mechanism (double row valves), inlet valve operated by inverted bucket type follower and exhaust valve by pivoted rocker arm.

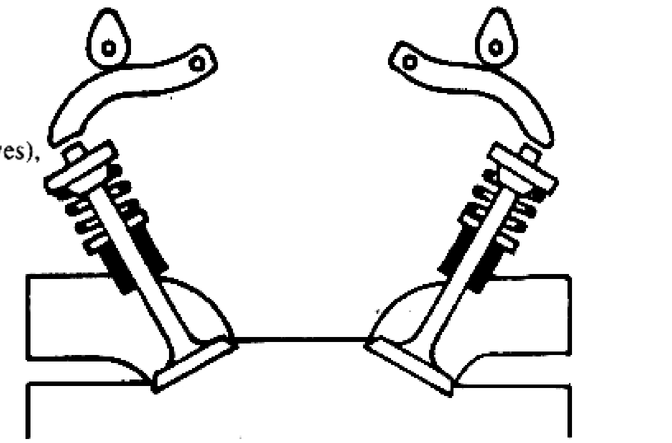


Fig. Double overhead camshaft-operated mechanism with separate rocker arms.

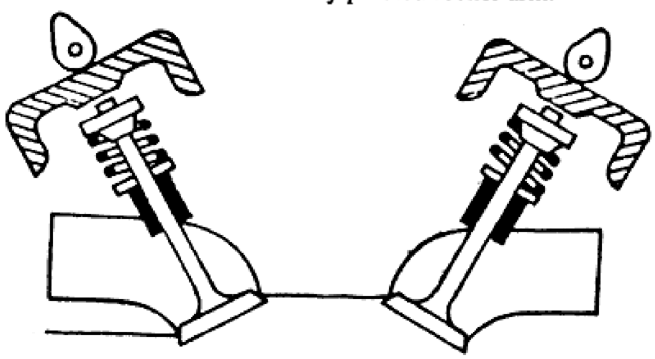
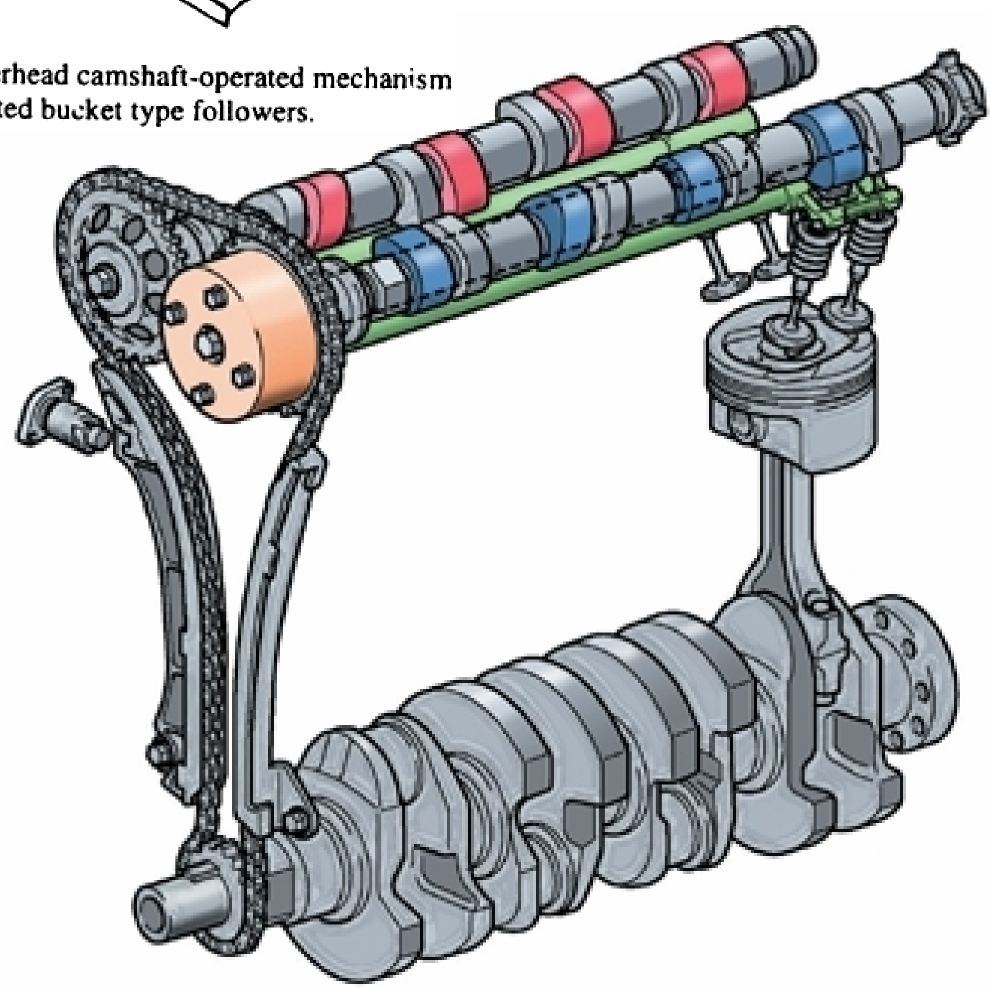
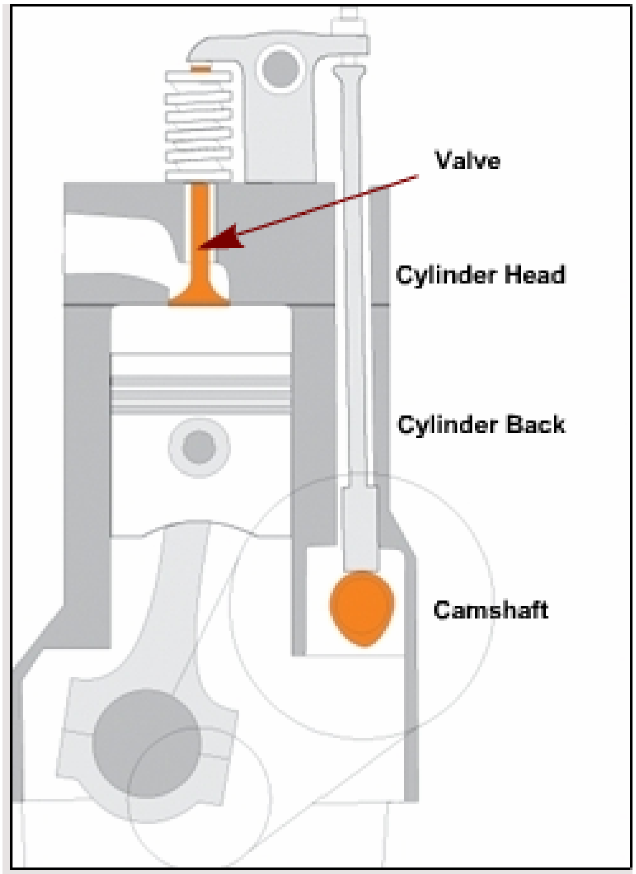


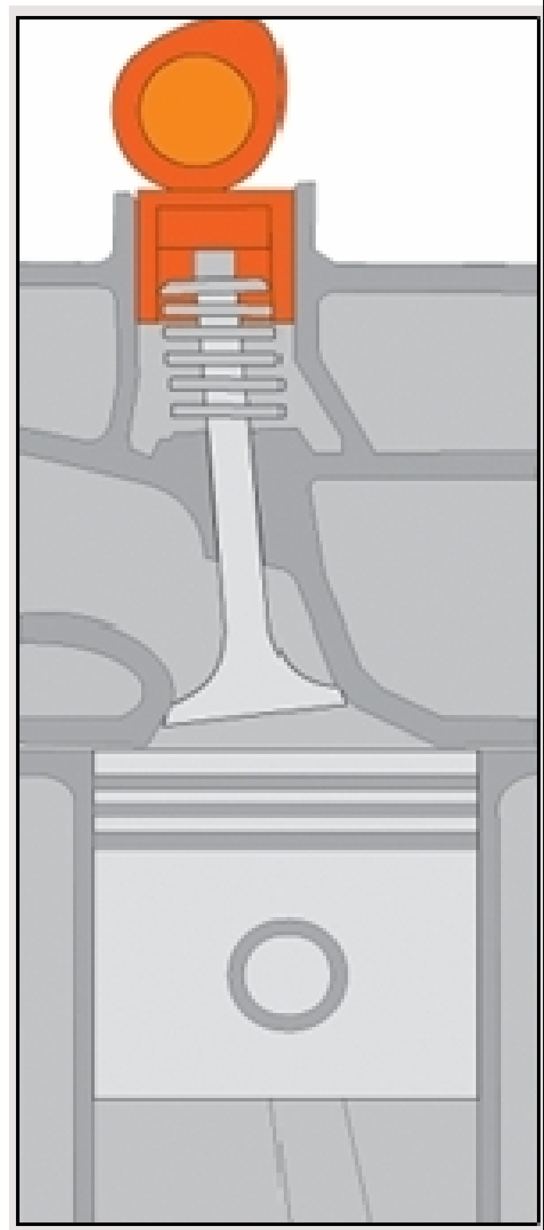
Fig. Double overhead camshaft-operated mechanism with inverted bucket type followers.



Comparison of the Side Camshaft and the Overhead Camshaft Mechanisms



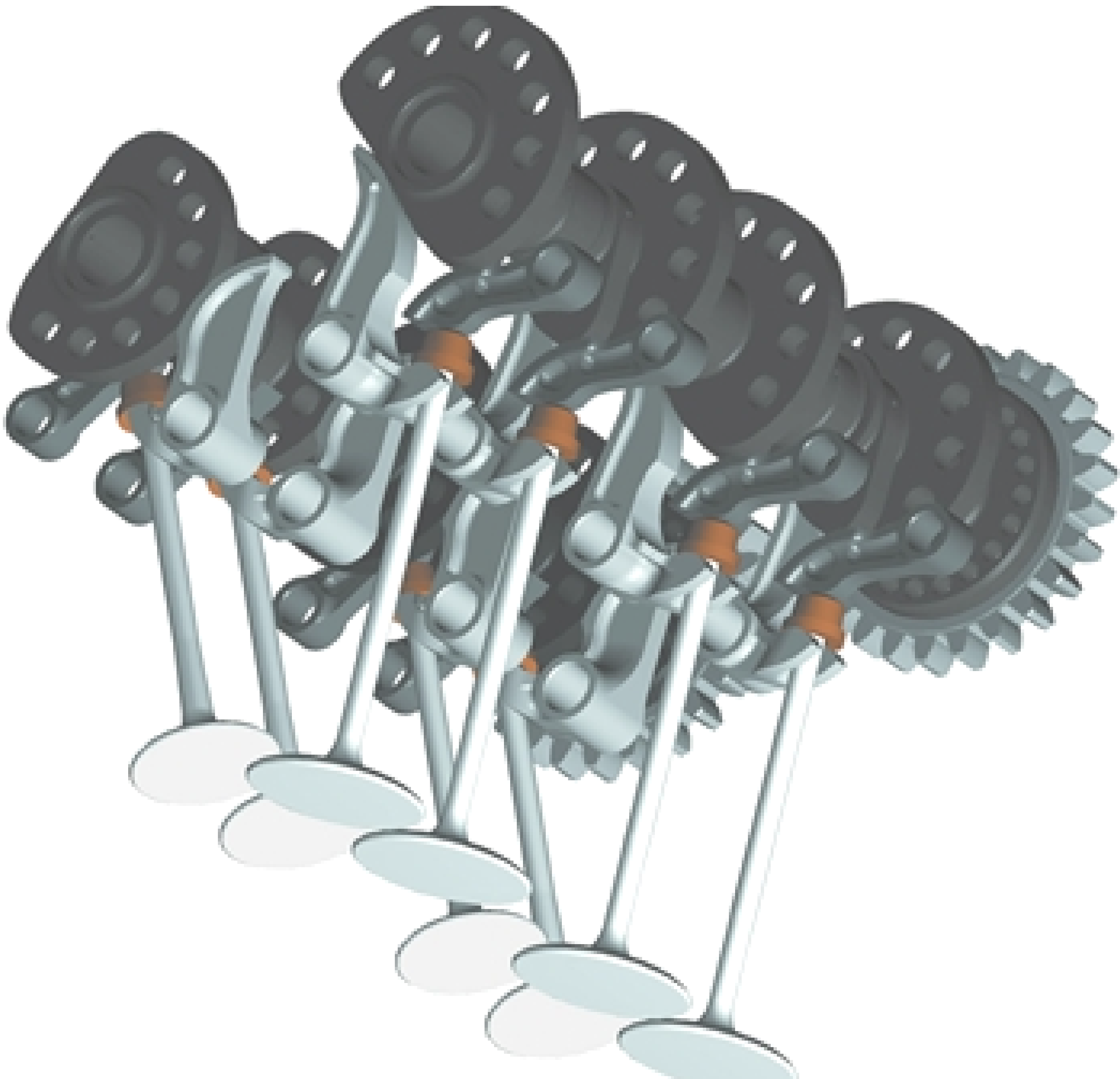
The overhead camshaft type valve actuating mechanisms is generally preferred over the side camshaft type mainly because of its greater rigidity since the camshaft directly operates the valve instead of operating through push rod and rocker arm. Due to this the valve is opened and closely quicker with decreased vibrations and undesirable oscillation. This means in case of high-lift, high-acceleration cam profile, the valve operation in case of overhead camshaft is much more precise and smooth than in case of the side camshaft valve system.



However, in case of overhead camshaft with inverted bucker follower, the valve lift is equal to the cam lift, whereas in case of the side camshaft, the valve lift can be adjusted by suitable design, for a given cam lift. This means that in case of overhead camshaft, the cam size has to be relatively larger for the same valve lift, which leads to higher cam-to-follower velocities and relative rubbing velocities resulting in side-thrust reaction caused by the cam action.

Desmodromic

A form of valve actuation that uses mechanical means to open & close the valves, thus eliminating valve springs & the resulting bounce at high speeds. They featured in the Mercedes racing cars of the mid-50's but are now associated with Ducati road & racing motor cycles



Valve Production

The forgings for conventional poppet valves may be produced by several processes, including drop-forging, upsetting extruding, and electric gathering. In each case the stock used comes in rod or bar form. The extrusion process employs stock of a diameter approximately 70 per cent that of the finished valve head and forms the stem by forcing some of the material through a die while at a red heat. To prevent fracture during the shearing operation, the bars are first brought up to red heat either by induction or in an open furnace. Burrs on the slugs are removed by tumbling.

The average valve **forging** is completed in one heating on a 500- ton or 750-ton press operating at about 45 rpm. Valve slugs are placed in a hopper which feeds them into an induction-heating coil. The rate of feed can be varied by the operator from 8 to 20 slugs per minute, by means of a variable-speed motor drive. The average automotive valve requires a 1-in. slug, and of these slugs 16 are heated to about 2000 F per minute, the power consumption amounting to 50kw.

After the Forging Process, next process is **Annealing**.
Most exhaust-valve and all intake-valve forgings are annealed to relieve forging stresses. The treatment varies with the material, annealing temperatures ranging from 1200 F to 1800 F, and annealing periods from one hour to six hours. The process usually is carried on in a chain-type conveyor furnace, a dual control system permitting of changing the temperature during the annealing cycle. Another operation in the heat-treating department consists in grit-blasting the forgings in a tumble blast unit, to remove scale formed in the forging operation and to improve the appearance of the forgings.

The next process in valve production is **Machining and Grinding Operations**
Machining and grinding operations are performed on machine tools set up to make possible progressive line production. After passing through this line and having been subjected to the **final inspection**, the valves go directly to the shipping room for oiling and packing. The lay-out of the line for a particular valve depends on such factors as size, type, material, and quantity.

All automotive valves have the following operations carried out on them: Roll straightening of stem and head, inspection for straightness, center-less rough-grinding of stem, hardening tip, finish grinding stem, finish grinding seat, inspection

The valve forging is straightened on a machine of the Waterbury- Farrell thread-roller type, the valves are heated to 1425 F in a Surface Combustion chain-type furnace, which is loaded through a hopper and discharges into a chute feeding the straightening machine. The center-less grinders used to grind the stems are pro vided with an infeed attachment which causes the valves to drop into position between the wheels, and with a "kicker" which removes the valves at the end of the grinding cycle. All valves are forged with a flash on the periphery of the head. Most automotive valves are "forge-finished" on top and under the head, but the heads must be finished on the outside diameter and on the seat. That operation, which is usually performed on multiple-spindle automatics with carbide tools is followed by machining of the tip of the valve stem and of the ,keeper groove chamfering of the tip, and facing the valve to length.

Heat Treatment

Valves made of XCR and chrome-manganese. steel usually are age-hardened after the semi-finish machining operation, and many intake valves of SAE 3140 steel also are hardened in the semi-finish stage. If the valve is to be heat-treated, semi finish grinding of the stem follows the heat treatment; otherwise it precedes machining of the retainer groove. Heat-treated valves usually are grit-blasted to remove surface scale, and then are hand straightened before any grinding is done on them. The semi-finish grind is performed on a Cincinnati centerless grinder.

Hardening and Grinding of Tip

Tips of high-production valves usually are hardened by induction heat, those of others by the conventional flame-hardening process. A 20-kw high-frequency generator supplies the current for induction hardening. Induction hardening permits much better control of the hardness than flame hardening. It is usually specified that tips shall be ground to 15 RMS surface finish, and square with the valve stem to within 0.0015 in.. Large-production valves have the tip ground on automatic grinder equipped with a rotating fixture in which the valves are located from the seat face.

Grinding of the seat is the last operation on the valve, and usually is done on a hydraulic grinder. The total indicator reading of seat runout to stem can be held to less than 0.001 in. in large-volume production. For this operation most valves are located from the tip end.

Inspection

All valves are visually inspected for surface defects, possible operations missed, etc., at 'the end of the line. Scleroscope and Rockwell machines are used to check the hardness. Stellited and welded valves are inspected 100 per cent. Magnaflux inspection is made to discover seams, subsurface stringers, and other defects difficult to recognize with the naked eye. Standard gauges are used throughout the line, masters being provided to check the dimensions from seat to tip, from seat to groove, and from groove to tip, and determinations are made of the runout of the tip and the seat relative to the stem. The machined retainer grooves are checked for form, radii, etc., in Comparators with a magnification of 25 to 1.

SLEEVE VALVES

As the term indicates, sleeve valves are cylindrical in shape. They surround the piston and actually form the working cylinder. There are two types of sleeves valves, *viz.,* the single sleeve and the double sleeve types.

A single sleeve valve is shown in Fig.. The sleeves are made of steel.

The advantages of sleeves are:

I. Simplicity of construction.

2. Silent in operation, because there are no valve cams, tappets, valves, etc. which make noise.

3. A longer period of running before decarbonization becomes necessary (50,000 km as compared to about 10,000 km for poppet valves).

4. Reduced tendency to denote, because there are no hot spots, path of flame travel is short and combustion chamber is of symmetrical shape.

5. Higher thermal efficiency is attained.

However there are certain disadvantages also because of which it has become obsolete:

I. High oil consumption, because larger area of sleeve surface has to be lubricated.

2. Gumming.

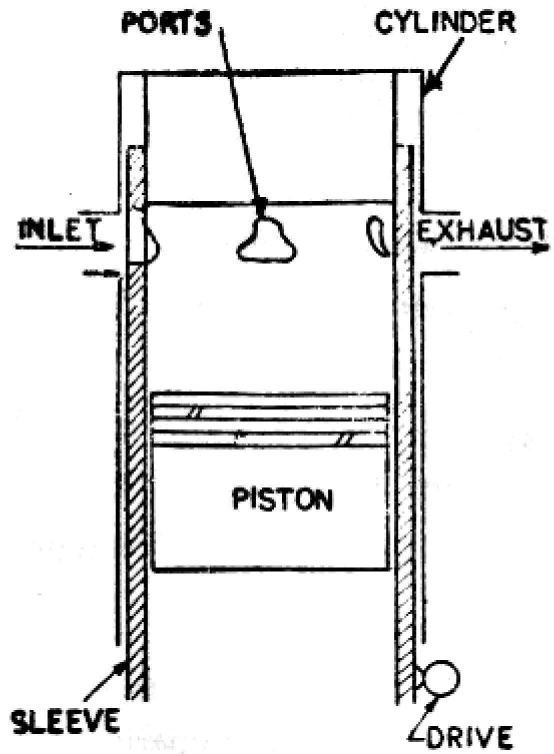


Fig. Single sleeve valve.

ROTARY VALVES

Many types of rotary valves have been developed. Fig. shows a disc type rotary valve. It consists of a rotating disc, which has a port. While rotating, it communicates alternately with inlet and exhaust manifolds. The main advantage of rotary valves is their uniform and noise- free motion. However, there are many difficulties in pressure sealing. Economical valve lubrication is another problem.

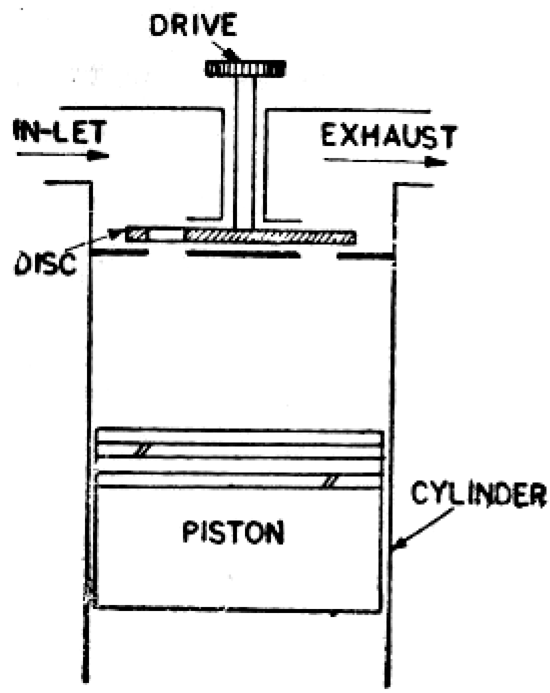


Fig. Disc type rotary valve.

References

- High speed Combustion Engines-P M Heldt
- Automobile Engineering-Dr. Kirpal Singh
- Machine Design-Abdulla sheriff
- Theory & Practice in I C Engines-C F Taylor
- Autocar India Illustrated Automotive Glossary

VALVE DESIGN

- Material -For valve -Nickel steel for inlet valves; & High nickel chromium steel for exhaust valves (due to high temp. and corrosive action)
  For valve seat-Cast iron or bronze – Replaceable, (Cast iron-for big engines – due to economic reasons.)

- Size of valve ports

  $V_g \times a = A_p \times C_{p\ ave.}$

  Where V_g=velocity of gas ≈2300 to 3300m/min-for stationary/marine engines
  ≈3300 to 5000m/min-for automobile engines

  a=port area= $\frac{\pi d_{port}^2}{4}$; A_p=area of piston= $\frac{\pi D^2}{4}$; $C_{p\ ave}$= average piston velocity=2LNm/min

*Fix vel. of gas, calculate port area & port diameter

$$V_g' = \frac{14.7 V_g T \eta_{ch} \times 180}{520P(180+\alpha+\beta)}$$

Where V_g=gas velocity – fixed – in ft/min (180+α+β) =duration of valve opening
T=temp. in Rankine - $T^oF=1.8T^oC+32$, and $T(R)= T^oF+459.67$
Intake temp.≈20^oC = 68^oF = 528Rankine; Exhaust temp.≈300^oC=1032Rankine
η_{ch} =charging efficiency for NA Engine≈85%; and SC Engine≈95 to 100%
P=pr. of gas in psi =14.7psi - for intake=1atm.
=29psi to 35psi – for exhaust=2 to 4atm.

Inlet valve -α=opening advance – generally = 10^o, & β=closing delay – generally = 20 to 30^o
Exhaust valve -α= opening advance – generally – 40 to 50^o, & β=closing delay – generally – 10 to 20^o

Hence calculate V_g' -*For stationary engines* ≤ 12000ft/min – for intake valve & ≤ 18000ft/min – for exhaust valve
-*For automobile engines* ≤ 18000ft/min – for intake valve & ≤ 27000ft/min – for exhaust valve

- $d_1=d_{port}$=port diameter= $D\sqrt{\frac{(pistonspeed)_{mean}}{velocityofgasthroughvalve}}$

- fix α_v=valve face angle=30^o or 45^o

- valve lift h

  Angular area of opening $\pi d_1 h \cos\alpha_v = \frac{\pi d_1^2}{4}$ =port area or $h = \frac{0.25 d_1}{\cos\alpha}$

  But this gives hammering effect ($h=0.1d_1$ to $0.2d_1$)
  Therefore empirical relation $h=0.2d_1$ may be adopted

- Thickness of valve disc = $t = k_1 d_1 \sqrt{\frac{P}{S}}$

Where k_1=0.54-for cast iron; 0.42-for carbon steel & high grade steel

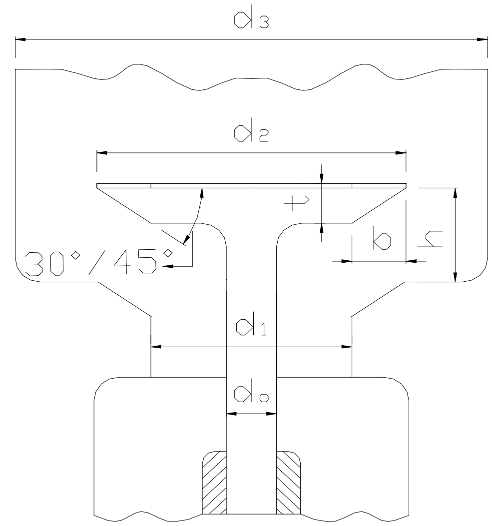
S =4000psi-forcast iron; 8000psi-forcarbon steel & 15000psi-for high grade steel

P =max. gas pressure; d_1=d_{port}=port diameter

[Or $t = 0.5 d_1 \sqrt{\frac{P_{max}}{\sigma}}$, where, σ =allowable stress=420ksc for carbon steel & 700 to 800ksc for high grade steel]

- $d_2 = d_1 + 2[t \times \sin(90 - \alpha_v)]$ or=d_1+2b

  $0.7854\left(d_3^2 - d_2^2\right) \geq 0.7854 d_1^2$



- $d_3 = \sqrt{\left(d_1^2 + d_2^2\right)}$

- $b = 0.5(d_2 - d_1) = 0.5 d_1 \left\{\sqrt{\frac{S_b}{S_b - P_{max}}} - 1\right\}$,

Where S_b=safe bearing pressure=4000psi for cast iron

b=0.05d_1 to 0.07d_1 an empirical formula

or $b = \frac{t}{\tan\alpha}$ =0.1d_1+4mm

- d_o=diameter of valve stem = $\frac{d_1}{18} + \frac{3}{16} inch$

  bearing pressure = $\frac{load}{bearingarea} = \frac{load}{\frac{(d_2 - d_1)}{2} \times \pi \times d_1}$

Example - 1

Determine the valve lift & valve dimensions of an engine from the following data;

Max. Gas Pressure = $5N/mm^2$, Cylinder Bore Diameter = 80mm,

Gas Velocity = 1500m/min, Mean Piston Speed = 300m/min,

Allowable Stress = $42N/mm^2$, Valve Seat Angle = 30^0,

Solution; Given, $P_{max} = 5N/mm^2$, D = 80mm,

$V = 1500m/min$, $\sigma = 42N/mm^2$,

$\alpha = 30^0$, $S = 300m/min = \pi DNm/min = \frac{\pi DN}{60} m/\sec$

Port diameter = $d_1 = D\sqrt{\frac{S}{V}} = 80\sqrt{\frac{300}{1500}} = 35.8mm$

Max. Valve Lift = $h = \frac{d_1}{4\cos\alpha} = \frac{35.8}{4\times\cos 30} = 10.33mm$

Thickness of valve head = $t = 0.5\times d_1\sqrt{\frac{p_{max}}{\sigma}} = 0.5\times 35.8\sqrt{\frac{5}{42}} = 6.2mm$

And Width of seating = $b = \frac{t}{\tan\alpha} = \frac{6.2}{\tan 30} = 10.74mm$

Also, $b = 0.1d_1 + 4mm = 0.1\times 35.8 + 4mm = 7.58mm$

$\therefore$ Diamter of Valve head = $d_2 = d_1 + 2b = 35.8 + 2\times 7.58 = 50.96mm$

(assuming, b = 7.58mm)

Diameter of valve stem = $d_0 = \frac{d_1}{8} + 4mm = \frac{35.8}{8} + 4mm = 8.5mm$

Diameter of valve head opening area = $d_3 = \sqrt{(d_1^2 + d_2^2)} = \sqrt{(35.8^2 + 50.96^2)}$

$= 62.27mm$