

Oct. 18, 1938.

A. TAUB

2,133,592

CYLINDER HEAD

Filed Aug. 28, 1935

3 Sheets-Sheet 1

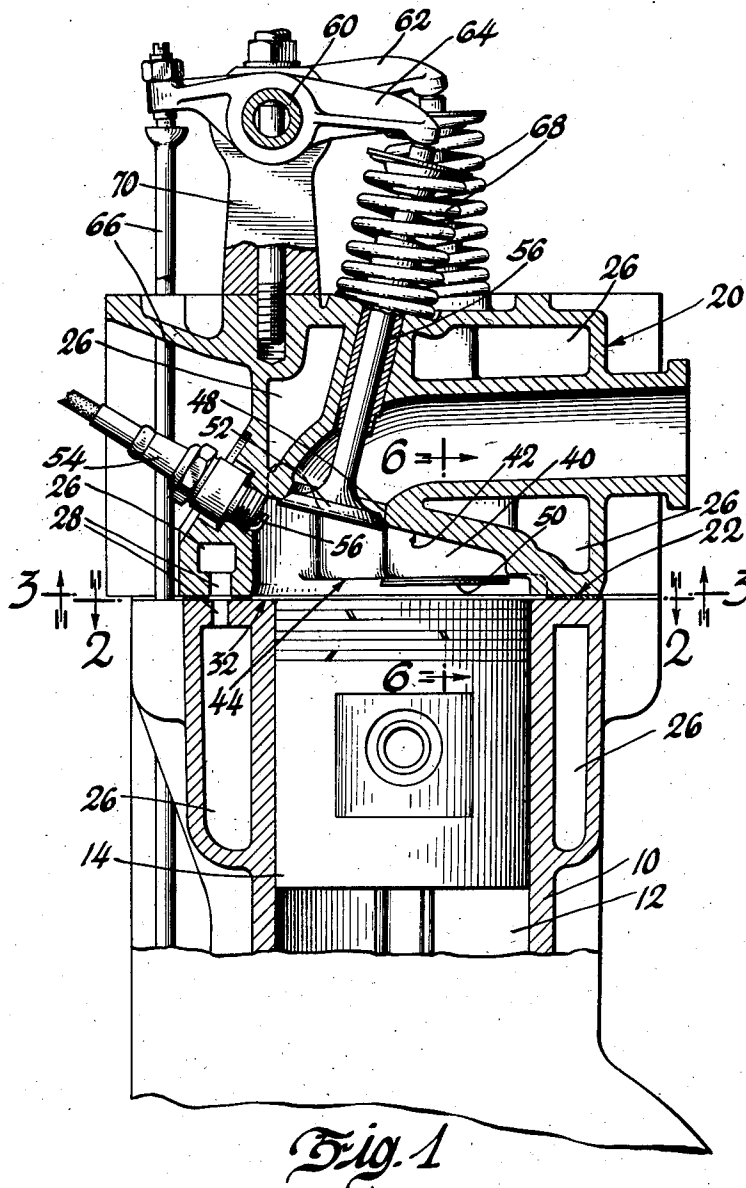


Fig. 1

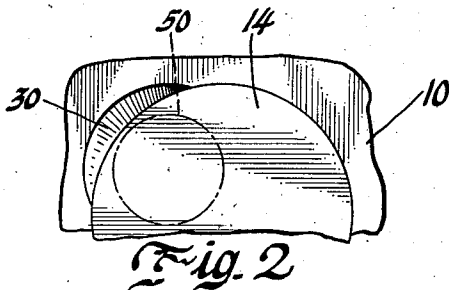


Fig. 2

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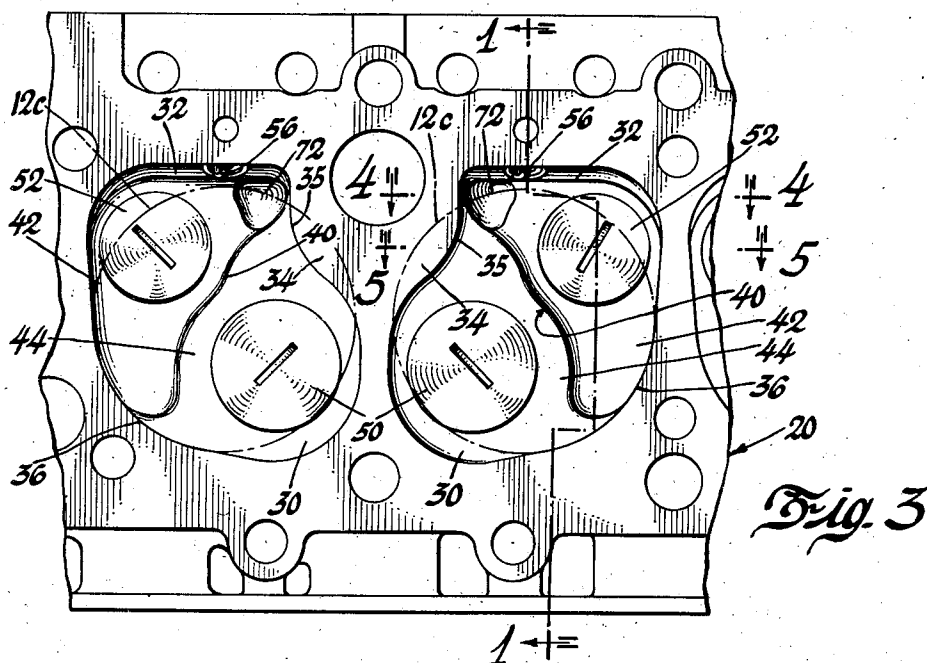
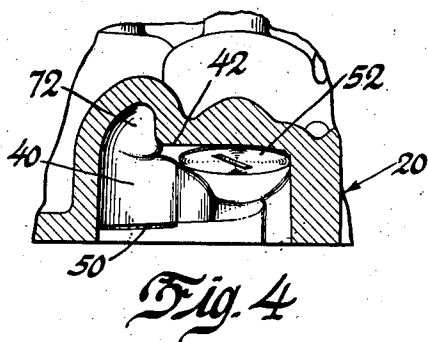
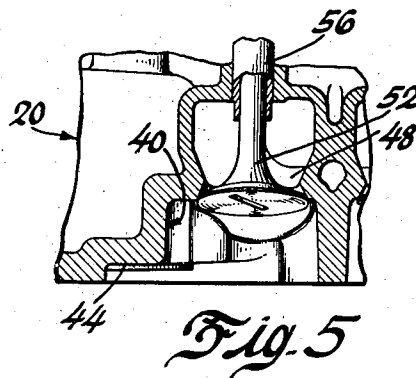
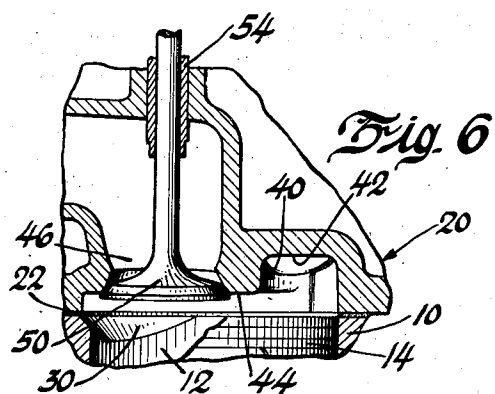
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3 Sheets-Sheet 2



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CYLINDER HEAD

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3 Sheets-Sheet 3

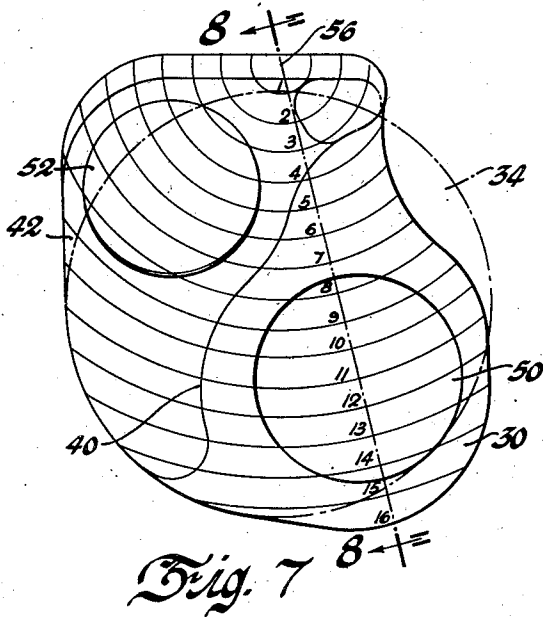


Fig. 7 8-8

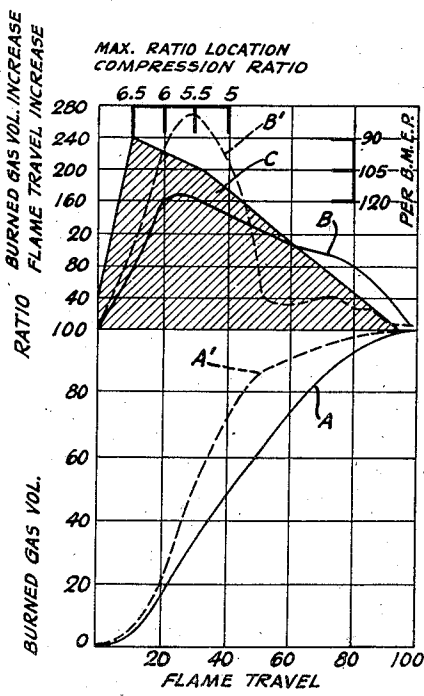


Fig. 9

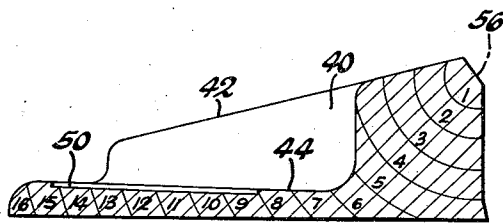


Fig. 8

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UNITED STATES PATENT OFFICE

2,133,592

CYLINDER HEAD

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5 Claims. (Cl. 123—191)

This invention relates to cylinders and cylinder heads for internal combustion reciprocating engines and particularly to the control of combustion in the combustion space, the form of the combustion space, its disposition with respect to the cylinder bore and the arrangement therein, and relative locations of the ignition means and valves.

A main object of the invention is to minimize shock and roughness due to combustion of the fuel in the operation of internal combustion engines. Objects contributory to successful attainment of the main object are: to regulate the temperature within the combustion chamber or in parts thereof so as to produce relatively low temperature in one part of the chamber for detonation control and to produce high temperature in other parts of the chamber in order to obtain highest practicable thermal efficiency; to afford free ingress of fuel mixture and free egress of combustion products; to simplify valving.

To attain these objects I propose to burn a combustible mixture in the inclosed combustion space of an engine at different ratios of volume burned to radial distance of flame-travel from the point of ignition, such that the maximum ratio of burned volume increase to flame travel increase will occur while the piston is approaching but before it reaches top dead center, that is, the end of the compression stroke.

The phenomenon of combustion of a gaseous fuel mixture in the combustion space of an engine during any one cycle is not instantaneous. It requires a definite time,—the flame front moving in all directions from the point of ignition at the rate, approximately, of 100 feet per second.

In order to secure best power output the fuel charge in the combustion space must be ignited before the piston reaches top dead center. How long a time or at how many degrees of crank travel before the piston reaches top dead center ignition should occur depends upon several factors, such as compression ratio and crankshaft velocity. It is apparent that pressure exerted upon the face of the piston before top dead center is reached is transmitted to the crank through the connecting rod at an angle to the central plane that includes the crankshaft axis and the cylinder axis; any sudden pressure or shock applied to the piston in this position is absorbed due to the position of the crank and the torsional elasticity of the shaft.

When the piston reaches top dead center or approximates to this position a shock or impact on the piston, as by a sudden increase of pressure,

is transmitted to the crankshaft and bearings through the solid mass of piston connecting rod and crank,—at that time all in one straight line,—so that a shock becomes evident throughout the structure.

After the piston has passed top dead center an appreciable extent and the connecting rod and crank are assuming an increasing angle to the center plane including crankshaft axis and cylinder axis, pressure on the piston face applied by the expanding gas is without appreciable shock due to the favorable position of the crank and connecting rod. And, furthermore, at this time the combustion space is rapidly increasing and subtracts somewhat from the pressure due to gas expansion.

The combustion chamber of this invention may be considered as divided into three regions correlated with the described portions of the crank and piston travel during one revolution of the engine shaft. The divisions may be thirds of the total distance of flame travel.

The first of the three regions or thirds of the chamber includes the ignition device. This region is relatively low in volume with respect to the total combustion space; and owing to the low volume and the described relations between connecting rod and crank, roughness of engine operation due to rapid increase in rate of burning and pressure rise is not apparent. In this first region sensitivity, as it were, to heat loss is greatest. Therefore in this first third the chamber is of high ratio of volume to surface, and in it is disposed the exhaust valve, which becomes highly heated in operation (1200° F. to 1400° F., approximately). Thus by reason of a relatively small heat-dissipating area of roof and wall as compared with the inclosed volume of gas, and by reason of the proximity of the hot exhaust valve, heat losses in the first third of the chamber are minimized. In this region of the chamber combustion occurs before top dead center is reached by the piston.

The middle one of the three regions or thirds of the combustion chamber is relatively high in volume and although also relatively high in volume-to-surface ratio, yet is more favorable to heat transference than the first third. Combustion occurs in this middle region while the crank, connecting rod and piston are near to, at and passing top dead center,—an unfavorable position with respect to transmission of shocks due to gas pressure on the piston, as has been pointed out.

The last of the three thirds or regions of the combustion chamber, which incloses the last

portion of the charge to burn during a combustion cycle, is definitely the region in which detonation occurs. In this region of the chamber the unburned mixture has accumulated the temperature of super-compression due to the higher pressure prevailing when two thirds or more of the contents of the fuel charge are burning or have been burned. The last unburned portion of the charge in the said third region of the combustion chamber is subject to detonation in proportion to the temperature attained by said unburned portion toward the end of the combustion cycle. Anything that tends to reduce this temperature tends to reduce sensitiveness to detonation. Therefore the third or last of the three regions of the combustion chamber described has a relatively high, though not extreme, ratio of surface to volume to facilitate transfer of heat to the circulating cooling water, or other cooling fluid in contact with the chamber walls. To further lower temperature within this region of the chamber an intake valve admitting fresh charges of combustible mixture is disposed within it. The relatively large cooling surface surrounding the mixture and the proximity of the intake valve are factors that tend to reduce sensitivity to detonation by keeping the temperature of the last portion of the mixture to be burned during a combustion cycle below the critical temperature of auto-ignition.

According to this invention the maximum ratio of volume of burned gas increase to flame travel increase should be attained before the crank and piston reach top dead center,—preferably when the crank has traveled not more than two thirds the distance from its position at time of ignition to top dead center or within two thirds of the time taken for the piston to so travel. This maximum is attained in the described first third of the chamber, which contains the ignition points, the exhaust valve, and is most favorable to conservation of heat. At this time also the crank position is favorable to avoidance of shock. Thereafter, in the described middle third while crank and piston are near and at top dead center, volume of burned gas rapidly increases while ratio of volume of burned-gas-increase to flame-travel-increase goes no higher and preferably goes lower. In this middle region pressure of expanding gas is applied to the crank shaft through the piston when the geometrical relation of crank, connecting rod and piston is most unfavorable to avoidance of shock. Roughness is guarded against by avoiding any increase in rate of pressure rise and preferably by lowering the ratio of volume-increase of burned gas to flame-travel increase. Some restraint upon increase of temperature is imposed by the smaller ratio of volume to surface in this region. In the last third of the chamber the relations of crank, connecting rod and piston are so favorable to avoidance of shock that roughness cannot be caused during combustion at this stage. Also, the piston is moving rapidly away from top center and tending to compensate somewhat for increasing pressure within the chamber; the large ratio of surface to volume and presence in this region of the intake valve tend to keep the temperature from rising above the point of auto-ignition.

One means for carrying out this invention in order to attain the objects thereof may consist of an internal combustion engine comprising a cylinder head having one or more combustion chambers of uneven depth, each chamber inclosing a space with a relatively high roof portion

opposed to and registering with approximately one-half of the circular area of the cylinder bore, and a space with a relatively low roof portion opposed to and registering with the other portion of said area, the division between said spaces extending diagonally across the chamber with reference to the axis of the engine shaft. Valve ports open respectively into said spaces through the respective roof portions, said valve ports being disposed at diagonally opposite positions, on opposite sides of the diagonal division between the spaces. The port in the higher roof portion is the exhaust port and that in the lower roof portion is the mixture inlet port. The ignition device is arranged to fire the charge at a point at one side of the chamber in the high roofed space adjacent the valve port therein, through which the hot products of combustion escape. The location of the ignition device may be approximately where the central dividing plane of the chamber that is normal to the engine shaft axis cuts the side wall at the deepest side of the chamber.

In the drawings, in which like reference characters indicate like parts throughout the several views:

Fig. 1 is a view showing an internal combustion cylinder head and part of a cylinder block in section cut transversely of the block through a cylinder axis, and through the head as indicated by the broken line 1—1 in Fig. 3;

Fig. 2 is a view of a fragment of the cylinder block as seen in section in the plane indicated by line 2—2 of Fig. 1 viewed in the direction of the arrows;

Fig. 3 is an inside plan view of a portion of the cylinder head separated from the block in the plane indicated by line 3—3 of Fig. 1 and looked at in the direction indicated by the arrows;

Fig. 4 is a section in a plane indicated by line 4—4 of Fig. 3 looked at in the direction of the arrows;

Fig. 5 is a section on plane indicated by line 5—5 of Fig. 3 viewed in the direction of the arrows; and

Fig. 6 is a section taken in a plane indicated by line 6—6 of Fig. 1, viewed in the direction indicated by the arrows;

Fig. 7 is a diagram of a combustion chamber in plan showing successive areas of the flame front as it progresses from the ignition point;

Fig. 8 is a diagram of a combustion chamber in section taken in a plane parallel with the cylinder axis and including line 8—8 of Fig. 7;

Fig. 9 is a chart with curves showing graphically combustion progress in two combustion chambers.

In the drawings numeral 10 indicates a cylinder block, which is surmounted by a cylinder head indicated as an entirety by numeral 20. The cylinder block and cylinder head may be cast integral or may be made as separate parts. In Fig. 1 the block and head appear as separate parts partly in section, viewed in the direction of the longitudinal axis of the engine,—that is, along a line parallel with the engine shaft (not shown). The block illustrated has a plane machined outer face. One cylinder bore is shown at 12, and a piston 14 operating in it. Piston 14 is shown at the end of one of its outward strokes, or, as commonly said, at top dead center.

The cylinder head 20 illustrated has a plane machined inner face separated from said machined face of cylinder block 10 by a gasket 22. 75

The head may be clamped to the block as usual by stud bolts, the gasket being squeezed between the two plane surfaces.

Both cylinder block and cylinder head are provided as usual with cooling-water passages, as indicated by numeral 26, the passages in the head communicating with the passages in the block by connecting ducts, one of which is indicated at 28.

The cylinder head is formed with one or several cavities constituting combustion chambers external of and arranged in communication with one or several cylinder bores, according to whether the engine is of single or multicylinder type. Each combustion chamber in the head registers approximately with a cylinder bore and is provided with valve ports in the roof. The chambers shown are of irregular outline, viewed in plan, the side walls extending in part slightly over the block outside the circumference of the cylinder bores, and in part somewhat within the circumferences of said bores. However, the cylinder bore axis in each instance coincides approximately with the center of greatest area of the chamber in a plane normal to said cylinder axis. If the head is constructed for a multicylinder engine the chambers may be arranged as rights and lefts as shown in Fig. 3, or at slightly different angles with respect to one another, but are otherwise similar.

In Fig. 3 the position of one cylinder with respect to the chamber registering therewith, when viewed in plan, is indicated by a broken-line circle 12c. The chamber shown extends over the block outside the circumference of the cylinder bore as indicated at the oppositely located areas 30 and 32. The wall of the chamber follows a reentrant curve 35 within the circumference of the cylinder bore, inclosing between said curve and the circle 12c of the cylinder bore a relatively very small area 34 where the plane surface of the cylinder head overhangs the cylinder bore. The piston 14 is shown as provided with a plane pressure receiving surface disposed at right angles to the axis. When the piston is at the end of an outward stroke,—that is, a compression or scavenging stroke, this pressure receiving surface or face may come flush or level with a plane normal to the axis of the cylinder bore dividing the cylinder head and block. In this position, in engines having separable cylinder heads, the pressure receiving face of the piston is separated from the surface on the cylinder head at area 34 only by the thickness of a gasket as shown. However, it is obvious that if the pressure surface of the piston were dome-like or other than a plane surface normal to the cylinder axis, the same clearance between piston and cylinder head at area 34 would necessitate providing a contour of the cylinder head at said area parallel with the contoured surface of the piston.

Areas 30 and 32 are opposite one another,—on opposite sides of a plane including the longitudinal axis of the engine and the axis of the cylinder,—and afford space for valves and valve ports, respectively adequate in size to allow free ingress and egress of unburned and burned fuel mixtures. A portion of area 30 on the cylinder block is shown beveled for a purpose to be stated. Between the areas 30 and 32 and opposite the reentrant wall portion 35 the side of the chamber wall follows substantially the curvature of the cylinder bore as shown at 36.

The roof of a combustion chamber made in

accordance with this invention is of irregular contour,—relatively high in one part and relatively low in another with respect to the piston face,—thus dividing the chamber into spaces of different depths and of different volume to surface ratios. These spaces are distinctly defined by a wall 40 dropping from the higher roof portion 42 to the lower roof portion 44. The wall 40 is diagonally disposed with reference to the longitudinal axis of the engine, dividing the chamber into parts which may be approximately equal in roof area. The part covered by roof portion 42 is obviously of greater volume-to-surface ratio than the part covered by roof portion 44. The roof contour shown is adapted to cylinders in which the pistons have plane faces disposed normal to the cylinder axes; should pistons with contoured faces be used the roof contour should be modified to preserve the same relative heights from piston face to the lower roof portion 44 adjacent to the beveled area 30 in the block 10. The outlet port 48 opens through the higher roof portion 42 adjacent the area 32. An inlet poppet valve 50 controls the inlet port 46. Outlet port 48 is controlled by an outlet poppet valve 52. An ignition device shown as consisting of a spark plug 54 is seated in an orifice in the cylinder head with its electrodes 56 occupying a position in the deeper portion of the chamber adjacent the outlet port 48 and approximately in the transverse plane that includes the cylinder axis and is normal to the engine shaft axis, where said plane intersects the chamber wall as indicated in Figs. 1 and 3.

Roof portion 42 is shown in Fig. 1 as sloping from the ignition side of the chamber toward the plane of junction of cylinder block and head, while roof portion 44 is shown as sloping very slightly in the opposite direction, although it may be parallel with the piston face. The axes of the ports 46, 48 and the stems of the valves 50 and 52 are substantially perpendicular to the oppositely inclined chamber-roof portions. The valve stems, which are slidable in guides 54 and 56, are relatively inclined one to the other in parallel planes normal to the engine shaft axis so as to intersect a line parallel to said engine shaft axis disposed adjacent and at one side of shaft 60 on which the valve operating rocker arms 62 and 64 are pivoted. The outer ends of the valve stems are in position to be forced in a direction to open the valves by the movement of the rocker arms in one direction (clockwise, as illustrated) when the rocker-arm operating rods 66 are lifted by the engine cam shaft (not shown). The valves are closed, as is usual in valve-in-head engines, by springs such as those indicated at 68. Rocker-arm-supporting shaft 60 is shown as mounted in brackets 70 bolted to the outer side or top of the cylinder head.

By inspection of Fig. 3, it will be apparent that the wall 40, demarking chamber portions of different depth intersects a plane parallel to the cylinder axis that includes the valve centers and substantially bisects the vertical angles formed by the intersection of a longitudinal plane including the engine shaft and cylinder axes with a transverse plane normal to said longitudinal plane and including the cylinder axis. The valve centers are therefore disposed in diagonally opposite quarters formed by the intersection of said longitudinal and transverse planes and may be said to be staggered.

The disposition of the outlet or exhaust valve 52 in the sloping-roof portion 42 of the deeper

chamber having the greater ratio of volume to surface leaves space for increasing the volume of the chamber if necessary, in engine designing, without entirely redesigning the chamber, by increasing the height of the roof portion 42 in the space at one side of the outlet valve and adjacent the ignition points. As illustrated, the roof height has been increased by a dome-like cavity 72 formed in the roof, adjacent the ignition points,—and is in the highest part of the chamber.

The beveled area 30 adjacent the inlet allows for the free flow of unburnt mixture into the chamber around the edge of valve 50 when the latter is open.

Although the center of greatest cross sectional area of the chamber is at or near the axis of the cylinder bore it will be apparent that the center of volume is somewhere between the center of area and that side of the chamber that contains the ignition points.

The staggered valve arrangement allows ports and valves to be made of sufficient size in an overhead valve engine designed to operate at high speed and high compression to permit the engine to operate at full volumetric efficiency. The position of the ports enabling the valve stems to be inclined as shown conduces to simplification of the valve operating mechanism.

The cooling effect of the low ratio of volume-to-surface in the space beneath the lower roof portion 44 and beneath the area 34, as well as that of the intake valve 50, upon the later-to-burn portions of the burning gas, tends to minimize detonation. However, proper volume distribution of the charge in order to regulate the progress of combustion to achieve the result desired in engine operation is facilitated by having the entire mixture content of the chamber involved in the combustion reaction. It is therefore undesirable to have any substantial portion of the mixture made unavailable by too close proximity of the chamber roof to the piston face at top dead center.

The advance of the flame front from the ignition point in a combustion chamber during a combustion cycle is diagrammatically illustrated in Figs. 7 and 8 by curved lines spaced about one quarter of an inch, more or less, apart. It is assumed that the flame front presents a substantially spherical surface and progresses from the ignition point as an ever increasing sphere across the combustion chamber. It is obvious that the pressure rise within the chamber should be proportional to the volume of fuel mixture available for burning at any one instant. Hence if the volume burned in any one instant can be controlled the rate of burning and therefore of pressure rise throughout the cycle can be controlled. The roof and walls of a combustion chamber limit the flame front area and may be so formed and disposed with reference to the point of ignition as to determine the area of the flame front in each successive position and thus control the rate of combustion as heretofore described. As, in the first third of the chamber, the roof is high and the side walls wide apart, a rapid increase occurs upon ignition in the area of the flame front and volume of fuel mixture burned. The area of the advancing flame front after the maximum ratio of increase of volume burned per increase of flame travel has been attained is controlled by the chamber walls which are so disposed as to begin to limit flame front area,—preventing further increase in area and reducing

that area as burning progresses,—by reason of a contraction in the average height of the roof or of the distance between side walls or both. And so, by suitable distribution of the volume of the chamber with reference to the ignition point, the progress of combustion can be controlled in such manner as to achieve the main object of this invention.

From measurements of the percentage of volume of mixture burned during each increment of flame travel, a curve of percentage of volume burned against percentage of flame travel may be plotted; and from such a curve there may be derived another curve representing the ratio of volume of burned gas increase in percentage to flame travel increase in percentage plotted against flame travel in percentage.

The volume of fuel mixture burned for each increment of flame travel in any combustion chamber may be ascertained by assuming a chamber subdivided into spherical layers having convex and concave concentric spherical surfaces and calculating the volume of each layer; or, successive spherical layers may be cut from a relief replica of the chamber under consideration, each layer having as a center the point corresponding to the ignition point, and being of a thickness equal to one given increment of flame travel. The chamber may, for example, be considered as divided into layers of one quarter inch thickness, as indicated in Figs. 7 and 8. The volume of each layer may be calculated mathematically, or otherwise determined.

Fig. 9 represents a construction chart containing curves derived from data obtained from measuring the volume of successive spaces between spherical zones,—progressing from the point of charge ignition,—of two combustion chambers. The data may most conveniently be obtained by cutting up a relief replica of the chamber as described.

The chart shown is divided into lower and upper portions. The lower portion contains a curve A drawn to show the volume of fuel mixture burned, in percentage, for the distance of flame travel in percentage. This curve is obtained by plotting the volume of each spherical layer of the combustion chamber against its thickness measured radially. The volume of the layers represents the volume of gas burned and their thickness the distance of flame travel. The curve B shown on the upper portion of the chart may be plotted by transferring the actual tangents at a plurality of points along curve A to the upper portion of the chart. The ordinate of the upper region of the chart represents the ratio of percentage of burned gas volume increase to percentage of flame travel increase. The abscissa represents the percentage of flame travel. The important fact about the curve B on the upper portion of the chart is the location of the point of maximum rate of burned gas volume increase.

Although the location of this maximum rate point relative to the flame travel is most important, it can never be in the same position if compression ratios change; it must vary with compression ratios,—and also with engine output in brake mean effective pressure.

As compression ratio increases angle of ignition spark lead decreases; that is, ignition occurs nearer top dead center. Consequently the peak of acceleration or highest rate of burned gas volume increase must occur within a shorter distance of flame travel. On the upper portion

of chart of Fig. 10 there is shown a scale of compression ratios,—from 5:1 at the right-hand end to 6.5:1 at the left-hand end. This scale is identified on the chart by the legend "Max. ratio location compression ratio." It indicates that in a combustion chamber where compression ratio is for example 6:1 volume distribution should be such that peak of ratio of percentage of burned gas volume increase to percentage of flame travel should be attained by the time the flame has traveled about twenty per cent of the total distance. If the compression ratio is 5.5:1 the volume distribution may be such that the peak will be attained by the time the flame has traveled thirty per cent of the total distance. Of course the maximum rate of burned gas increase occurs when maximum area of flame front is attained. The greater the compression ratio is, the shorter is the distance that the flame front must travel to arrive at its maximum area.

As engine output is a factor in smoothness or roughness of engine operation the maximum ratio of percentage of burned gas volume increase to percentage of flame travel increase should be lower as engine output increases for equal smoothness (or roughness) of engine operation. A scale indicating the position of said peak for brake mean effective pressure ranging from 90 to 120 appears at the right. This scale indicates, for example, that with a compression ratio of 6:1 and brake mean effective pressure of 105 the peak of the upper curve B should occur at a ratio of about 2:1 when the flame had traveled about twenty per cent of the total distance. As the brake mean effective pressure increases the ratio indicated by the peak of the upper curve must be lower, and as the brake mean effective pressure decreases the peak of curve B may be higher.

The upper portion of the chart illustrated in Fig. 10 contains a shaded area C of pentagonal form. Within this area the peak of the rate curve B should be included. If it extends beyond this area the chamber form from which the curve is derived is unsatisfactory in the aspect of smoothness or roughness of engine operation. Curve B shown extends outside of this area in the region of the third portion of the chamber referred to where gas pressure cannot produce roughness because of the favorable geometrical relations of piston connecting rod and crank, as explained. Curve B is derived from the combustion chamber of an engine free from roughness. Curves A' and B' shown in Fig. 10 are derived from the combustion chamber of an engine which was markedly rough in operation.

Although there has been described and illustrated, a specific form of combustion chamber adapted particularly for valve-in-head engines, the invention as explained may be embodied in different forms of chambers, and it will be understood that the scope of the invention is not limited to the exemplary structure illustrated and specifically described, but is limited only by the claims.

I claim:

1. In an internal combustion engine, a cylinder, a cylinder head having a combustion chamber of uneven depth disposed with its center of greatest cross sectional area approximately in line with the axis of the cylinder bore and its center of volume eccentric thereto; valved ports in the chamber roof disposed respectively on opposite sides of longitudinal and transverse planes normally intersecting substantially in the cylinder axis, and an ignition device arranged at one side of the chamber in the space of greater depth.

2. A combination as defined in claim 1, wherein the combustion chamber of uneven depth is divided into spaces of different volume-to-surface ratios by a division extending across the chamber oblique to the engine axis, and the ignition device is disposed within the space of greater volume-to-surface ratio.

3. A combination as defined in claim 1, wherein the combustion chamber of uneven depth is divided into spaces of different volume-to-surface ratios by a division extending across the chamber oblique to the engine axis, and the inlet valve is disposed in the roof portion covering the space of lesser volume-to-surface ratio and the outlet valve is disposed in the roof portion covering the space of greater volume-to-surface ratio.

4. A combination as defined in claim 1, wherein the chamber of uneven depth is divided diagonally with respect to the engine axis into two spaces one of which is covered by a roof portion of greater height joined to a roof portion of lesser height by a depending wall extending obliquely to the engine axis, said roof portion of greater height sloping from that side of the chamber in which the ignition device is disposed toward the plane of junction of cylinder block and head.

5. In an internal combustion engine, a cylinder block having a cylinder bore, a cylinder head having a combustion chamber divided diagonally of the engine axis into spaces having different volume-to-surface ratios, the roof portion covering the space of lesser volume-to-surface ratio being of lesser height than the roof portion covering the space of greater volume-to-surface ratio; the side wall of said chamber extending slightly beyond the circumference of the cylinder bore at diametrically opposite locations, one of which is in the space having a greater volume-to-surface ratio and the other in the space having the lesser volume-to-surface ratio, inlet and outlet valves in the chamber roof adjacent said diametrically opposite locations the inlet valve lying wholly within the roof portion of lesser height and the outlet valve lying wholly within the roof portion of greater height; and an ignition plug seated in the side wall of the chamber adjacent the valve in the space having the greater volume-to-surface ratio.

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