March 22, 1938. H. RABEZZANA ET AL 2,111,601

DOUBLE IGNITION COMBUSTION CHAMBER

Filed Nov. 5, 1934 2 Sheets-Sheet 1

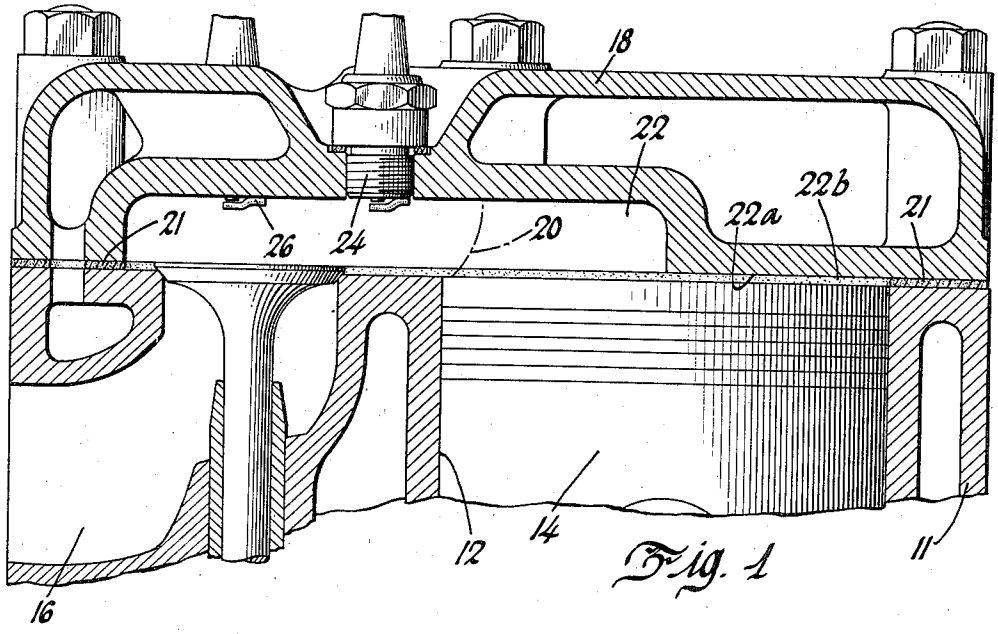


Fig. 1

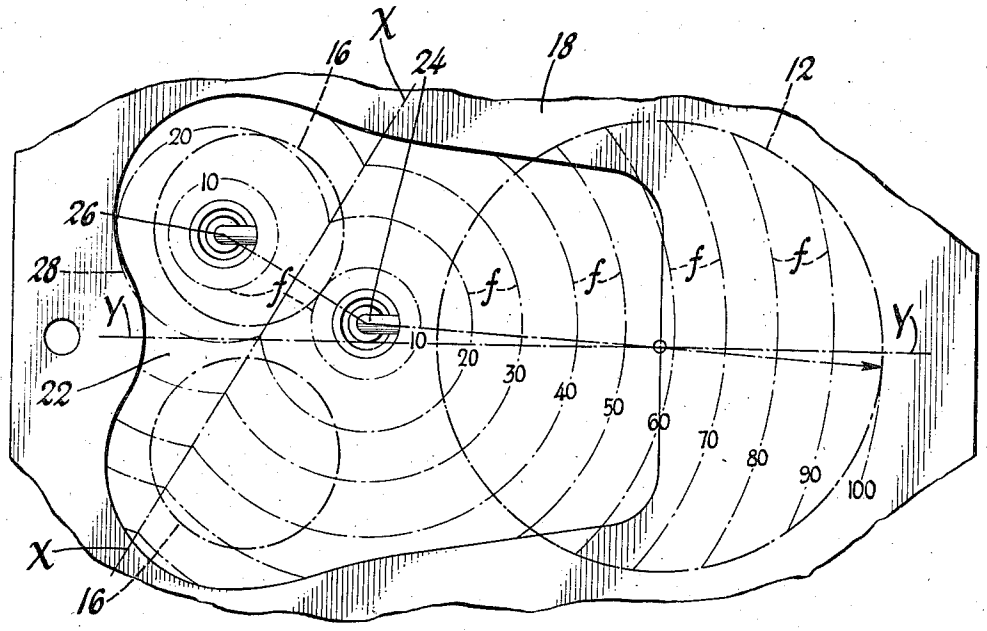


Fig. 2

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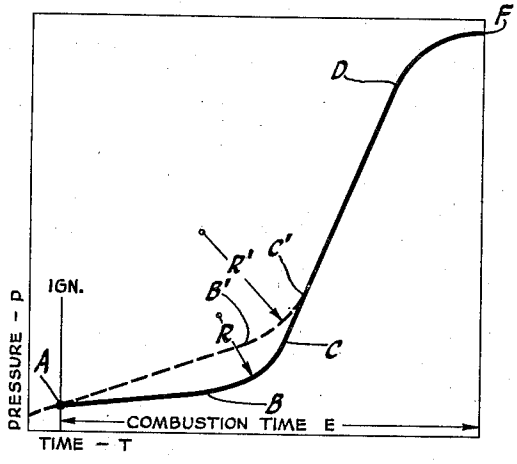


Fig. 3

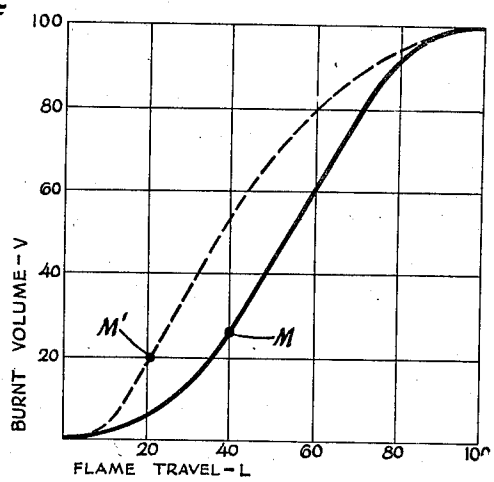


Fig. 4

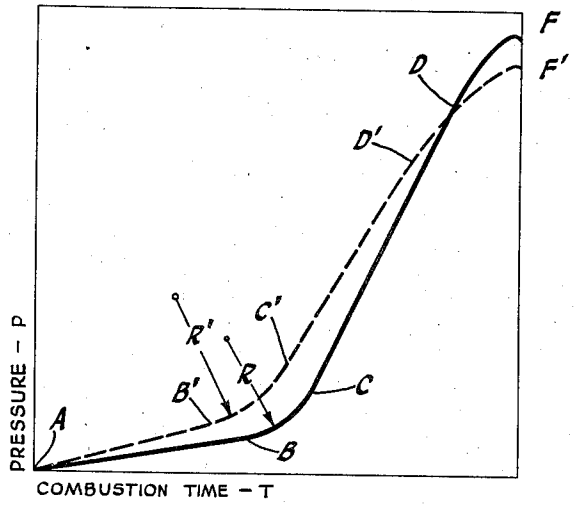


Fig. 5

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UNITED STATES PATENT OFFICE

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DOUBLE IGNITION COMBUSTION CHAMBER

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4 Claims. (Cl. 123—191)

This invention relates to internal combustion engines equipped with means for igniting at two points each fuel charge regularly introduced into the combustion chamber or chambers during operation. More specifically it contemplates the presence in each combustion chamber of two firing devices, such as spark plugs.

The purpose of the invention is to make possible burning of the fuel charges in such manner as to realize the highest efficiency of the impulses exerted on the pistons by the expanding gases, thereby deriving from the engine good idling performance, maximum output with minimum detonation tendency, and smoothness of operation.

The invention consists in an engine comprising a cylinder block having one or more cylinder bores, and a cylinder head having one or more valved combustion chambers, equipped with plural ignition devices, such as spark plugs, so spaced one from another and from the chamber walls, and so positioned with respect to the piston and valves as to produce within the chambers during a combustion period, an initial rate of pressure rise, a maximum rate of increase (acceleration) of pressure rise, and a maximum rate of pressure rise, all as predetermined in order to produce a highly efficient application of the pressure of the burning gas upon the pistons and smoothness of operation.

By cylinder block is meant a casting or other rigid metal structure having one or more than one cylinder bore therein. By cylinder head is meant the structure that closes the end of one or more cylinder bores in a cylinder block, whether formed integral with the cylinder block or as a separate attached part.

In the drawings, which disclose one embodiment of the invention, Fig. 1 is a section through a cylinder block and cylinder head, illustrating a combustion chamber equipped with two ignition devices; Fig. 2 is an underside plan view of a fragment of the cylinder head shown in Fig. 1, and showing in broken line circles the relative location of the cylinder and valve ports; Fig. 3 is a chart of theoretical pressure-time curves comparing a curve derived by an indicator from firing a charge in a combustion chamber of the form shown by an advantageously placed single spark plug and one derived from firing a charge in the same chamber by two spark plugs arranged as shown in Fig. 2; Fig. 4 is a chart of two curves indicating percentage of increase of volume of burned gas plotted against percentage of flame travel in a combustion chamber of the form illustrated wherein the charges are fired, respectively, by one and by two spark plugs; Fig. 5 is a chart of two pressure-time curves respectively derived from actual operation of an engine fired by one and by two spark plugs in a combustion chamber of the form illustrated.

In Fig. 1 of the drawings the reference numeral 11 indicates an engine cylinder block having one or more cylinder bores 12, and one or more pistons 14 adapted to reciprocate therein. In the exemplary construction illustrated the block is formed at one side of each cylinder with valved fuel gas inlet and burned gas outlet passages, one of which is indicated at 16, communicating with the combustion space or spaces of the engine.

A cylinder head 18, preferably removably secured to the face of block 11, with a gasket 21 interposed between them, has formed therein one or more relatively voluminous combustion chamber cavities 22, each in communication with a cylinder bore 12 and with the passages 16, which, in the construction illustrated, open into the cavity 22 through the face of the block.

When the piston 14 is at the end of a compression or scavenging stroke as indicated in Fig. 1 the pressure receiving face thereof approaches closely to a portion of the inner surface of the cylinder head that constitutes the roof of the combustion cavity therein. During the periods when the piston is in the position illustrated the combustion cavity consists of the thin space 22_b between the piston and roof portion 22_a of the combustion cavity and the deeper communicating space 22 consituting the remainder of said combustion cavity. The complete combustion chamber, it is apparent, is bounded by the floor consisting of the pressure face of the piston, the valves, the face of the block around the valves, by the roof and side walls of cavity 22, the roof 22_a, of space 22_b and the inner edge of gasket 21. The combustion chamber illustrated, as seen in Fig. 2, is of greater linear dimension measured in one direction than in the direction at right angles thereto, the valves and the space 22_b being at opposite ends of the long dimension.

One characteristic of this invention is a combination including two ignition devices, such as spark plugs 24 and 26, arranged in a new relation to one another and to the combustion chamber. As shown in Fig. 2, both plugs are disposed at that end of the chamber into which the valve passages 16 open, remote from the space 22_b. Both plugs, in the chamber shown, therefore, are on the same side of a diameter of the cylinder—

at that side which is most remote from the space 22_b—and are so located that the flame front of a charge ignited by the spark plugs will reach the space 22_b last during the progress of combustion. If the combustion space be divided transversely midway of the longitudinal center line *y—y*, the spark plugs are in that portion remote from the cylinder and piston; and in the preferred form disclosed herein both spark plugs and valve ports are disposed in a portion of the chamber which is wholly beyond a tangent to the cylinder circumference at the longitudinal center line of the chamber. The points of both spark plugs are shown located on the same side of the longitudinal center line of the chamber and in a straight line oblique to said center line.

In order to aid in understanding the invention, reference is made to the theoretical pressure-time curves shown in Fig. 3. The curve represented by the solid line is a pressure-time curve obtained by the combustion of a fuel charge in an internal combustion engine fired at one most advantageous point; that in dotted lines indicates the modification obtained by firing at two points as in the illustrations Figs. 1 and 2. The five characteristic components of any pressure-time curve are as follows:

(1) The component indicated by the section extending from A (the point of ignition) to B, which represents the nearly uniform or slowly increasing pressure rise at the beginning of combustion, and will be called the "initial pressure rise."

(2) The component indicated by the section extending from C to D, which represents that phase of the reaction within the combustion chamber during which the rate of pressure rise becomes fairly uniform for an appreciable duration of time and likewise attains "the maximum rate of pressure rise" in the cycle.

(3) The component indicated by the section extending from B to C, representing that period of time during which the pressure rise changes from a nearly uniform or slowly increasing initial rate to the fairly uniform maximum rate of rise and the rate of increase of the pressure rise becomes maximum which will be called "maximum rate of increase of pressure rise".

(4) The time interval E from ignition to the point where combustion is completed (not always at peak pressure), which will be called "the combustion time".

(5) The highest value in the pressure curve, which will be called "maximum pressure" (at F).

Each of the components of the pressure-time curve has a definite effect upon the capacity of the burning charge to apply torque to the crankshaft.

"Maximum pressure" and "combustion time" determine jointly the indicated power.

"Maximum rate of pressure rise" and "maximum rate of increase of pressure rise" determine jointly the smoothness of the turning effort or torque.

"Maximum pressure," "maximum rate of pressure rise" and "combustion time" jointly affect, to a certain degree, detonation.

Ideal conditions fulfilling satisfactorily all requirements would be represented by a pressure-time curve having a high "maximum pressure" value, short "combustion time" (giving high indicated mean-effective pressure), low combined value of "maximum rate of pressure rise" and "maximum rate of increase of pressure rise" (giving smoothness of engine operation); but a relatively high "maximum rate of pressure rise" (giving minimum detonation).

Ideal conditions cannot be had from a charge in the combustion chamber ignited at only one point, because both high "indicated mean effective pressure" and minimum detonation require short "combustion time" and a high "maximum rate of pressure rise". "Smoothness", on the other hand, requires that the combined values of maximum rate and maximum rate of increase of the pressure rise should be low. "Smoothness" therefore can be achieved by keeping the rate of increase (acceleration) of the pressure rise very low, so as to compensate for the high maximum rate of pressure rise which is necessary to secure high output and reduce detonation tendency.

Inspection of Fig. 3 reveals that low rate of increase of pressure rise requires (on the chart) a large radius in the phase represented on the chart by the region including section B—C of the pressure-time curve; if the maximum rate of pressure rise remains the same, the radius can increase only if the initial rate of pressure rise is increased. By firing a fuel charge from two points disposed in the valve region of a combustion chamber as shown, the radius (R) of the curve (B—C), representing "rate of increase of pressure rise", is increased to radius R', curve (B'—C') indicating a much lower rate of increase of pressure rise in this region, thus giving greater smoothness of engine operation.

By igniting the fuel charge simultaneously at two points, as shown in Figs. 1 and 2, the initial rate of burning (flame spread) and consequently the initial rate of pressure rise can be increased any amount up to twice the initial rate obtained by igniting the charge at one point only. For satisfactory results the initial rate only of burning should be increased. Consequently the charge in the combustion chamber should not be ignited at opposite ends, or diametrically opposite portions of the chamber, because in that case not only the initial rate of burning or flame spread would be doubled, but also during the whole reaction the rate would be approximately double the rate of burning when ignited at one point near one end of the chamber.

It is possible to translate the pressure-time characteristics of a combustion chamber into terms of percent of volume of charge burned (V) against percent of flame travel (L). Fig. 4 shows two V—L curves, the curve in solid line representing the V—L characteristics of a chamber fired at one most advantageous point; and the curve in broken line representing the characteristics of a chamber fired from two points, as in the chamber illustrated. Both curves show that the rate of burnt volume increase per unit of flame travel continuously proceeds until a maximum rate of increase is reached at M in the case of single ignition and at M' in the case of dual ignition, as indicated.

The result of this gain in initial rate of burnt volume increase of the V—L curve due to dual ignition, as herein disclosed, upon the P—T (pressure-time curve) is indicated in Fig. 5, showing indicator curves derived from actual operation of an engine. The solid curve is derived from an operating engine having a combustion chamber of the form illustrated with single spark plug in the best position ascertained by tests; the broken line curve is derived from an operating engine having a combustion chamber and dual ignition as described and shown herein. The initial pressure rise (A—B') Fig. 5, is higher for double igni-

tion than the rise (A—B) for single ignition. The maximum rate of pressure rise for double ignition (C'—D') is slightly lower than C—D, for single ignition. The maximum rate of increase in pressure rise for double ignition (B'—C') is considerably lower than B—C, for single ignition, curved section B'—C' having a larger radius R' than the radius R of curve section B—C. The maximum pressure attained with the dual ignition disclosed is slightly less than with single ignition, but the pressure is more advantageously and smoothly applied.

In order to obtain most beneficial pressure-time characteristics, the two ignition points should be fired simultaneously and should be so positioned in the combustion chamber relative to one another and the chamber wall as to cause maximum volume increase of burnt gas per flame travel (the point M' in Fig. 4) to be reached as early as possible in the movement of the flame front. From extensive analysis of many combustion chamber types it has been ascertained that maximum volume increase of burnt gas (point M', Fig. 4) should be attained when the flame front has moved 10 to 25% of its maximum length of travel within the chamber. From the geometry of the flame front propagation it can be determined that maximum volume increase of burnt gas per travel of the flame front occurs when the two flame fronts (propagated from the two ignition points) merge and when at the same time the chamber walls have not substantially cut off flame spread.

Referring again to Fig. 2, the curved broken lines *f* indicate successive positions of the spherical flame front. These lines are marked for convenience **10**, **20**, **30** up to **100** in concentric arcs, **100** indicating the position of the flame front at extinction or end of combustion period. Each successive arc proceeding from an ignition point indicates an advance of 10% of the extreme linear distance to be traveled by the flame front. When the flame, spreading from ignition point **24**, has reached the spherical area represented by broken line arc **20** it has advanced 20% of its total possible linear advance and the two flame fronts spreading from points **24** and **26** have merged. Line *x*—*x*, Fig. 2, represents a plane normal to a line joining the firing points **24**—**26** at a point midway between said firing points and dividing the chamber into two parts, the gas on one side of said plane being ignited by firing point **26** and the gas on the other side of said flame being ignited by the firing point **24**. At 20% of the flame travel in a chamber of the form illustrated in Fig. 1, a small part of the flame spread, preferably not more than 30%, has been intercepted by the wall of the chamber as indicated at **28**.

If the chamber roof is parallel with the chamber floor, as shown in Fig. 1, the projected area of the burnt gas is roughly proportional to its volume. If the roof is not parallel with the floor, (height not uniform in the major portion of the chamber) corrections must be made when substituting areas for volumes.

In the combustion chamber illustrated in Fig. 1, it becomes apparent upon measurement and calculation that the increase in volume burned between flame fronts (spreading from the two ignition points) corresponding to 10% of maximum flame travel and 20%, is larger than the increase in volume burned between flame fronts corresponding to 20% and 30% of maximum travel. If the flame front intervals were taken as 1% of maximum travel instead of 10% it could be ascertained with reasonable accuracy where maximum volume increase of burnt gas per extent of flame travel occurs. By calculation and trial it has been ascertained that it is possible to arrange two firing points in a chamber of the type disclosed so that when or after the flame fronts merge, and the chamber walls contact with the flame front, the rate of volume increase of burnt gas per distance of flame travel is maximum. In the drawings Fig. 1, this ratio is reached when the flame front has traveled approximately 20% of the greatest distance of flame travel.

Having disclosed a preferred form of our invention, explained the principle thereof and the best way now known to us for utilizing it, what we claim is:

1. An internal combustion engine comprising a cylinder block having therein a cylinder bore, a cylinder head having therein a combustion chamber communicating with and partly overlying the cylinder bore and partly offset therefrom, there being valved fuel inlet and outlet passages communicating with the offset portion, and ignition means having a total of two firing points disposed entirely within the offset portion of the chamber, a straight line connecting said firing points forming an oblique angle with a plane passing between the inlet and outlet passages and perpendicular to a plane normal to the cylinder axis.

2. An internal combustion engine comprising a cylinder block having therein a cylinder bore, a cylinder head having therein an elongated combustion chamber communicating with the cylinder bore and having one end portion overlying it and the opposite portion offset therefrom, there being valved fuel inlet and outlet passages communicating with the chamber, and ignition means having a total of two firing points disposed in the offset end portion of the chamber at the same side of the longitudinal center plane of the chamber perpendicular to a plane normal to the cylinder axis, the point of greatest distance from said firing points to the wall of the combustion chamber being in that portion of the wall that terminates the end portion of the combustion chamber that overlies the cylinder bore.

3. An internal combustion engine comprising a cylinder block having therein a cylinder bore, a cylinder head having therein a combustion chamber partly overlying the cylinder bore and partly offset therefrom, there being valved fuel inlet and outlet passages communicating with said chamber, and ignition means having a total of two firing points disposed in the offset portion of the chamber, one nearer to the axis of the cylinder bore than the other, and positioned so that the two firing points are at the centers of two equal intersecting spherical zones the radii of which are within 10 and 25% of the maximum distance between the firing point nearest the cylinder bore axis and the chamber wall, when, at the same time, the wall of the chamber does not intercept more than 30% of the volume between said intersecting zones.

4. An internal combustion engine comprising a cylinder block having therein a cylinder bore, a cylinder head having therein a combustion chamber communicating with the cylinder bore and having a portion overlying it and a portion offset therefrom, there being valved inlet and outlet passages communicating with said chamber and ignition means having a total of two firing

points disposed in the offset portion of the chamber so that the length of each radius of the non-intersecting spherical surfaces of largest area that can be generated within the chamber about said two firing points is from 10 to 25% of the maximum distance between either firing point and the chamber wall on the same side of a plane normal to a straight line connecting the two firing points at a point midway of said connecting line.

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