PUBLISHED

JUNE 15, 1943.

BY A. P. C.

L. LEIZAOLA

CYLINDERS OF INTERNAL-COMBUSTION ENGINES WITH COMBUSTION-AND-WHIRLING CHAMBERS IN THE PISTONS

Filed July 27, 1939

Serial No.

286,744

10 Sheets-Sheet 1

FIG. 1

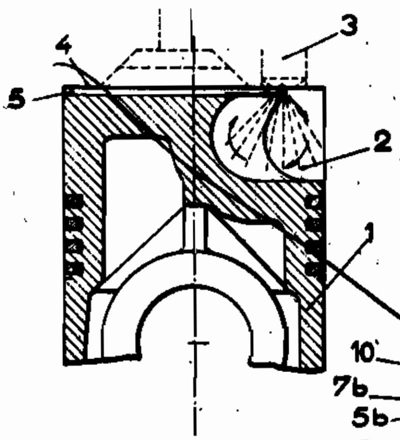


FIG. 4

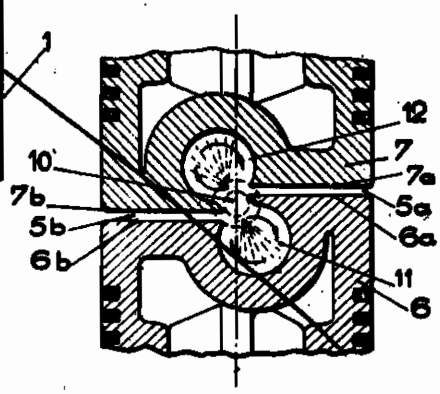


FIG. 2

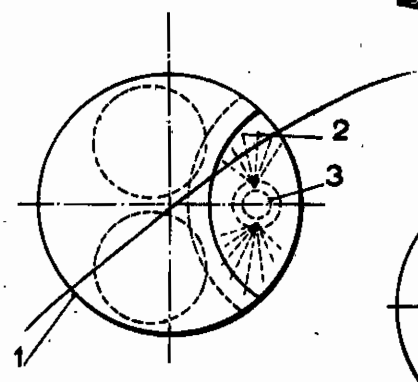
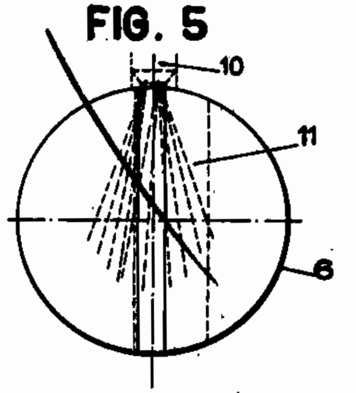


FIG. 5



Inventor
Luis Leizaola
By Williams, Bradbury, McCaleb & Hinkle. Attys.

PUBLISHED

JUNE 15, 1943.

BY A. P. C.

L. LEIZAOLA

CYLINDERS OF INTERNAL-COMBUSTION ENGINES WITH COMBUSTION-AND-WHIRLING CHAMBERS IN THE PISTONS

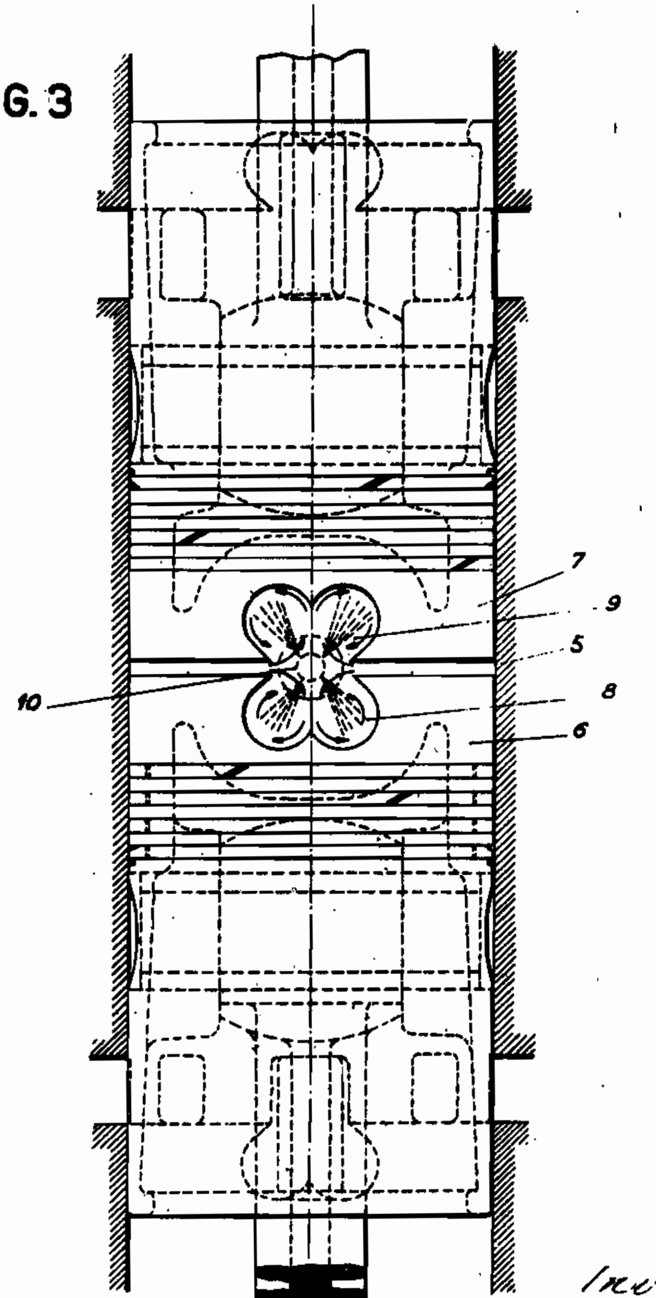
Filed July 27, 1939

Serial No.

286,744

10 Sheets-Sheet 2

FIG. 3



Inventor
Luis Leizaola
By Williams, Bradbury, McCaleb & Hinkle Attys.

PUBLISHED

JUNE 15, 1943.

BY A. P. C.

L. LEIZAOLA

CYLINDERS OF INTERNAL-COMBUSTION ENGINES WITH COMBUSTION-AND-WHIRLING CHAMBERS IN THE PISTONS

Filed July 27, 1939

Serial No.

286,744

10 Sheets—Sheet 3

FIG. 6

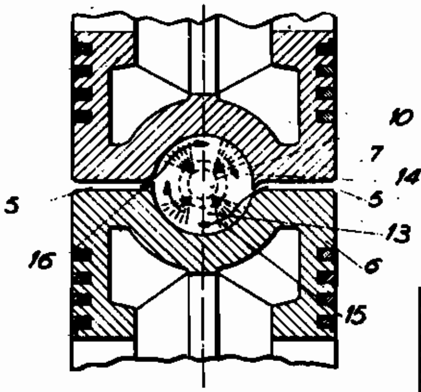


FIG. 8

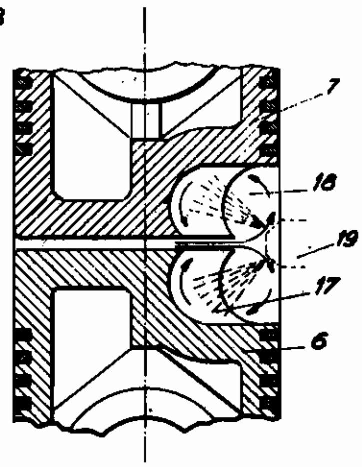


FIG. 7

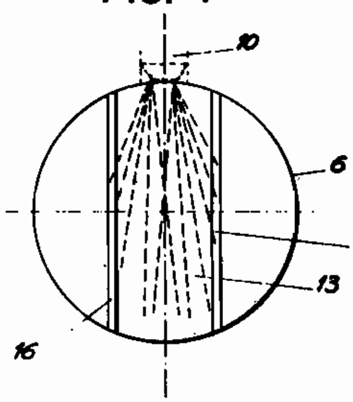
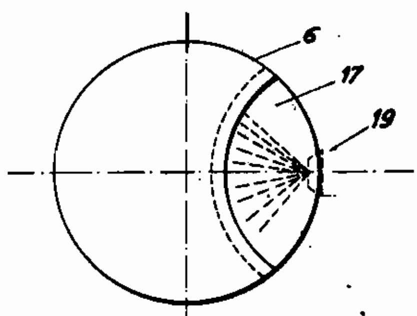


FIG. 9



Inventor:
Luis Leizaola
By Williams, Bradbury, McCaleb & Hinkle Attys.

PUBLISHED

JUNE 15, 1943.

BY A. P. C.

L. LEIZAOLA

CYLINDERS OF INTERNAL-COMBUSTION ENGINES WITH COMBUSTION-AND-WHIRLING CHAMBERS IN THE PISTONS

Filed July 27, 1939

Serial No. 286,744

10 Sheets-Sheet 4

FIG. 10

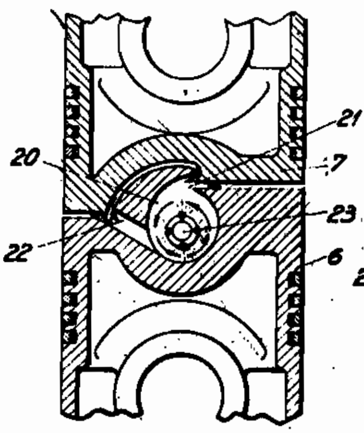


FIG. 12

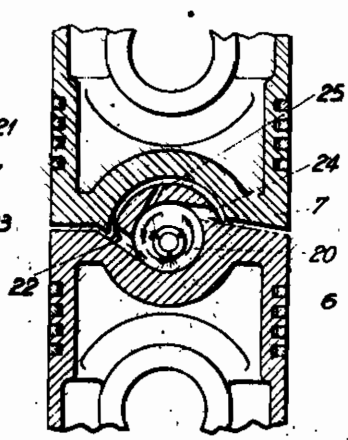


FIG. 11

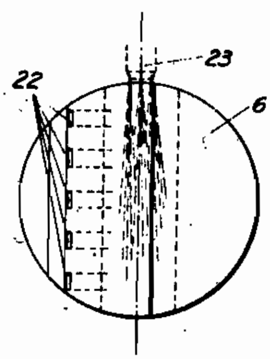
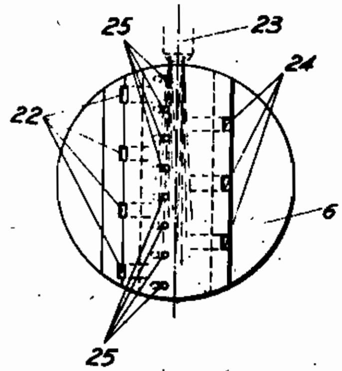


FIG. 13



Inventor.
Luis Leizaola
By Williams, Bradbury, McCaleb & Hinkle
Attys.

PUBLISHED

JUNE 15, 1943.

BY A. P. C.

L. LEIZAOLA

CYLINDERS OF INTERNAL-COMBUSTION ENGINES
WITH COMBUSTION-AND-WHIRLING
CHAMBERS IN THE PISTONS

Filed July 27, 1939

Serial No.

286,744

10 Sheets-Sheet 5

FIG. 14

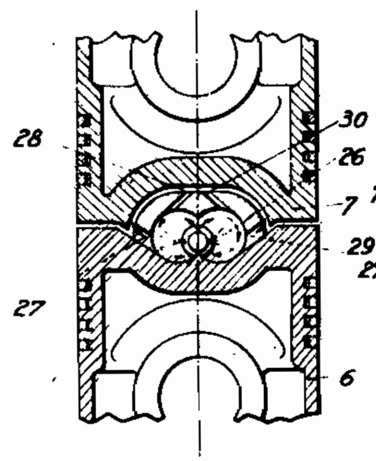


FIG. 16

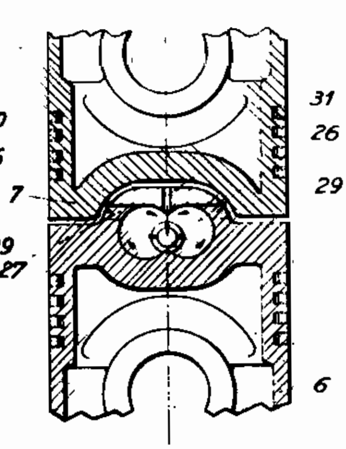


FIG. 15

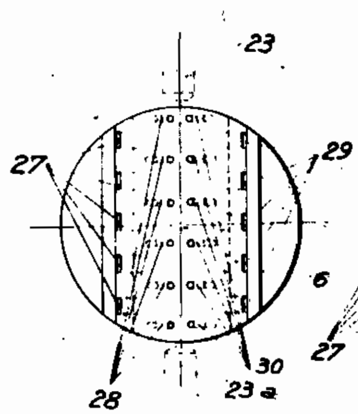
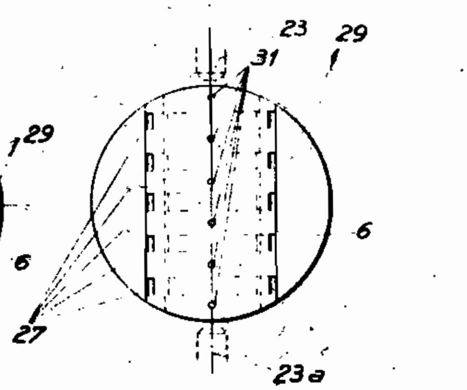


FIG. 17



Inventor
Luis Leizaola
By Williams, Bradbury, McCaleb & Hinkle
Attys

PUBLISHED
JUNE 15, 1943.
BY A. P. C.

L. LEIZAOLA

CYLINDERS OF INTERNAL-COMBUSTION ENGINES
WITH COMBUSTION-AND-WHIRLING
CHAMBERS IN THE PISTONS

Serial No.
286,744
Filed July 27, 1939
10 Sheets-Sheet 6

FIG. 18

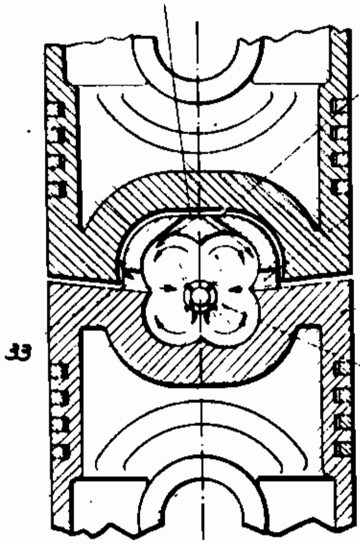


FIG. 21

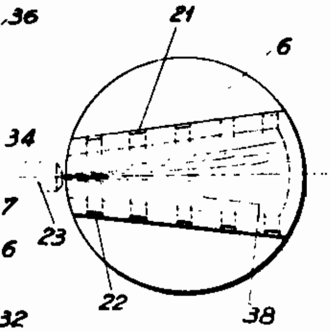


FIG. 22

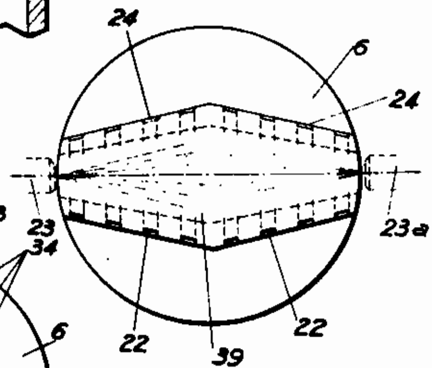


FIG. 19

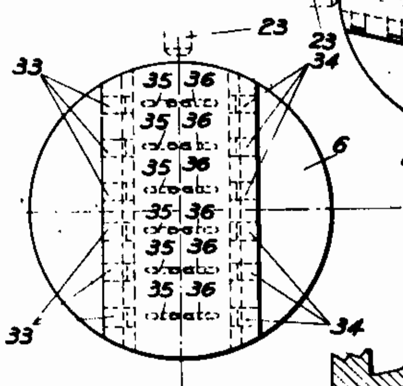
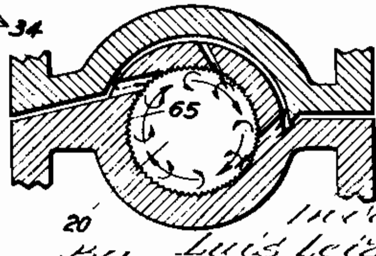


FIG. 41



Inventor.
Luis Leizaola
By Williams, Bradbury, McCaleb & Hinkle Attys.

PUBLISHED

JUNE 15, 1943.

BY A. P. C.

L. LEIZAOLA

CYLINDERS OF INTERNAL-COMBUSTION ENGINES WITH COMBUSTION-AND-WHIRLING CHAMBERS IN THE PISTONS

Filed July 27, 1939

Serial No. 286,744

10 Sheets-Sheet 7

FIG. 24

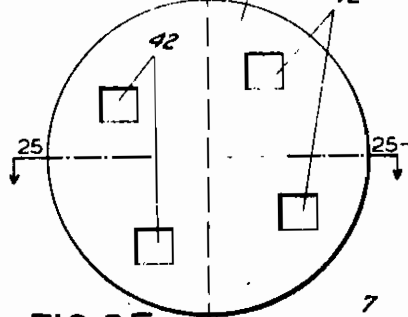


FIG. 20

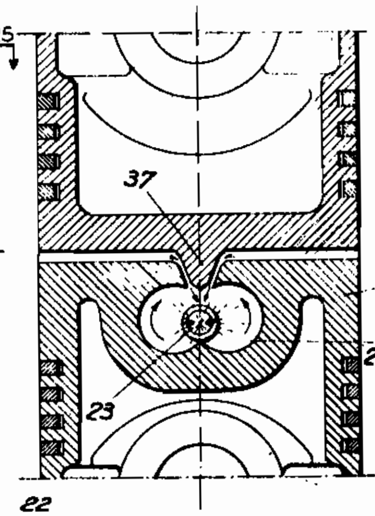


FIG. 25

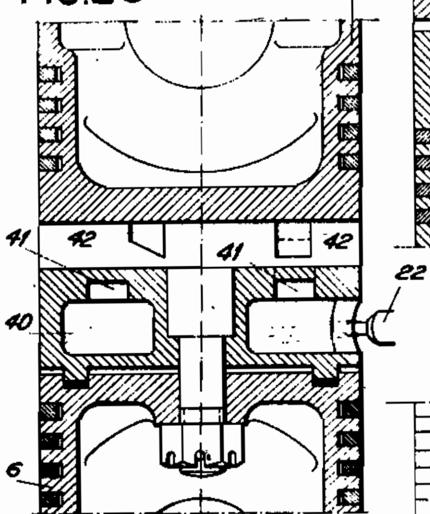


FIG. 26

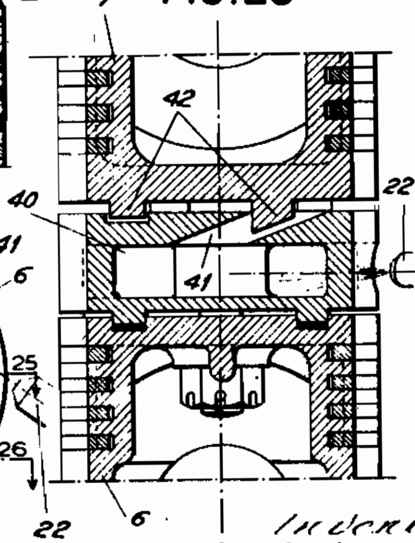
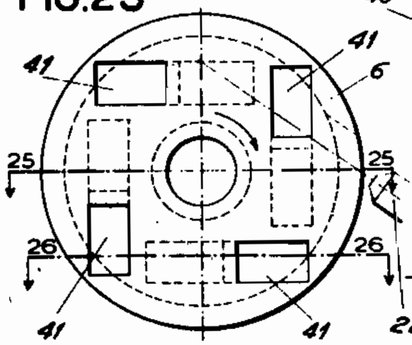


FIG. 23



Inventor
Luis Leizaola

PUBLISHED

JUNE 15, 1943.

BY A. P. C.

L. LEIZAOLA

CYLINDERS OF INTERNAL-COMBUSTION ENGINES
WITH COMBUSTION-AND-WHIRLING
CHAMBERS IN THE PISTONS

Filed July 27, 1939

Serial No.

286,744

10 Sheets-Sheet 8

FIG. 28

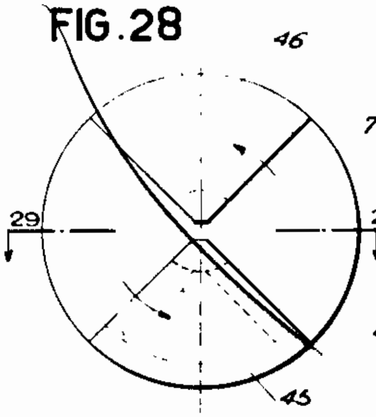


FIG. 27

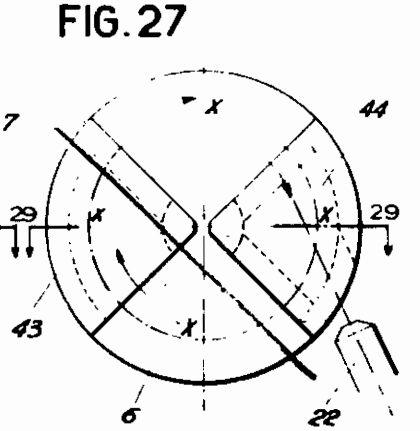


FIG. 29

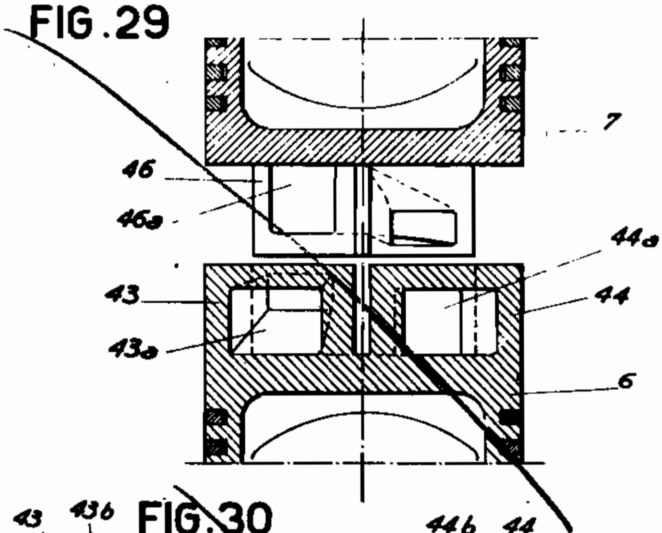
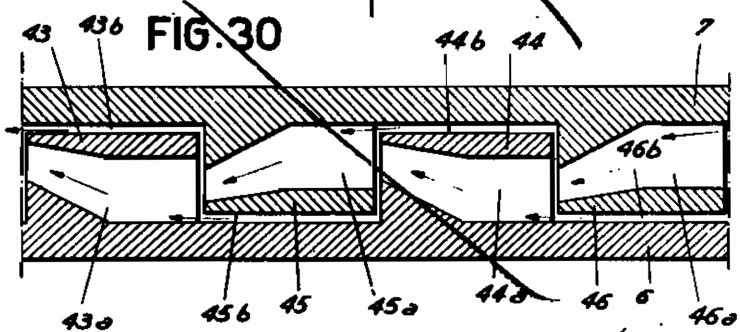


FIG. 30



Inventor
Luis Leizaola
By
Williams, Bradbury, McCaleb & Hinkle Attys

PUBLISHED
JUNE 15, 1943.
BY A. P. C.

L. LEIZAOLA

CYLINDERS OF INTERNAL-COMBUSTION ENGINES WITH COMBUSTION-AND-WHIRLING CHAMBERS IN THE PISTONS

Filed July 27, 1939

Serial No. 286,744

FIG. 32

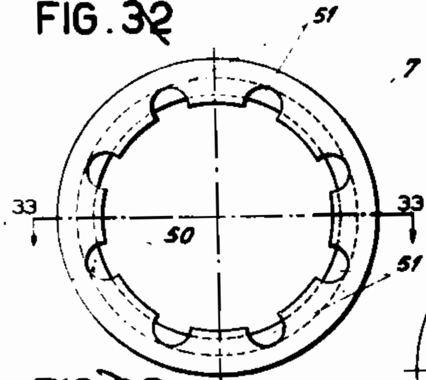


FIG. 34

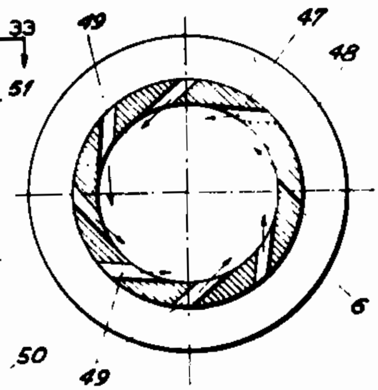


FIG. 33

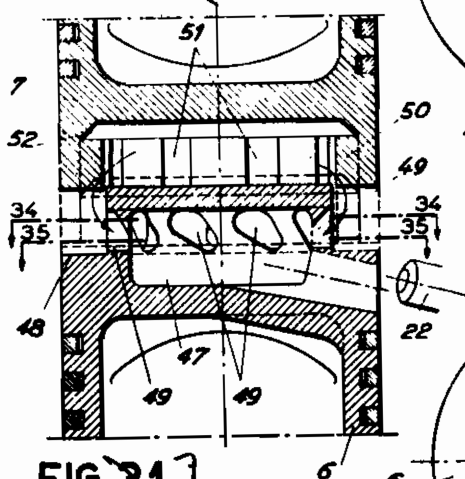


FIG. 35

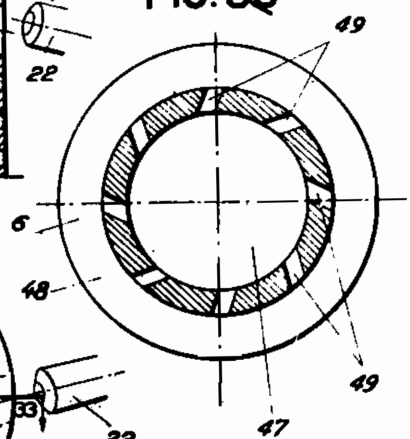
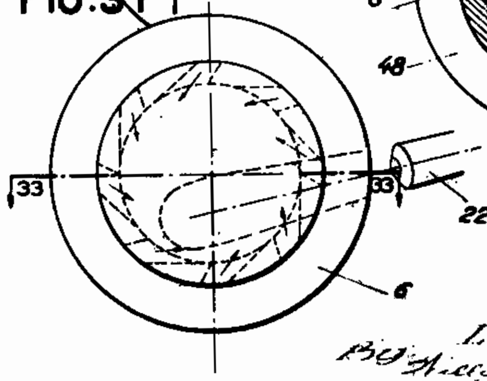


FIG. 31



Inventor:
Luis Leizaola
By Williams, Bradbury, McCaleb & Hinkle
Attys.

PUBLISHED
JUNE 15, 1943.
BY A. P. C.

L. LEIZAOLA
CYLINDERS OF INTERNAL-COMBUSTION ENGINES WITH COMBUSTION-AND-WHIRLING CHAMBERS IN THE PISTONS
Filed July 27, 1939

Serial No.
286,744
10 Sheets-Sheet 10

FIG. 37

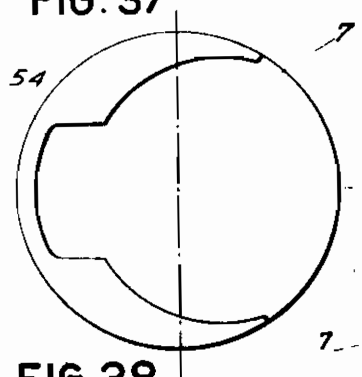


FIG. 40

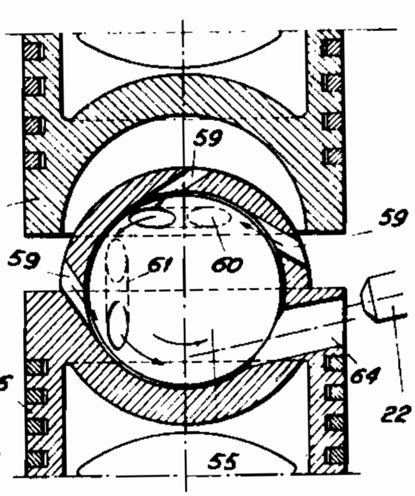


FIG. 38

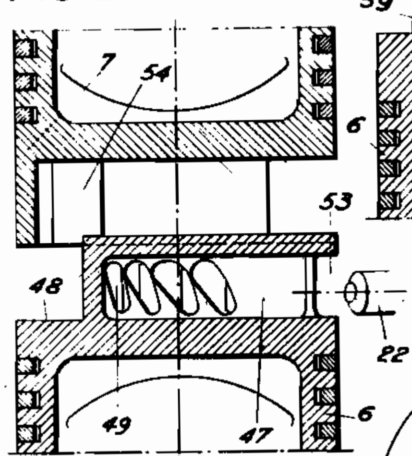


FIG. 39

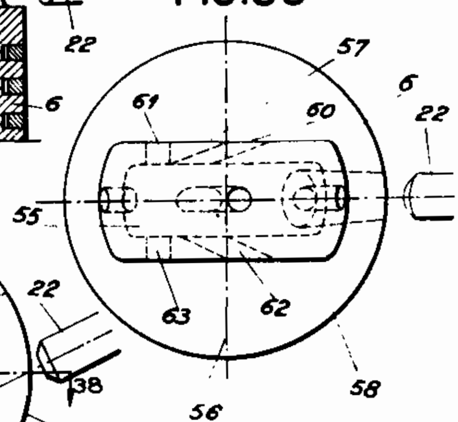
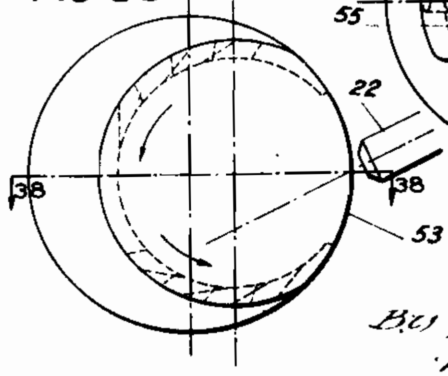


FIG. 36



Inventor:
Luis Leizaola
By Williams, Bradbury, McCaleb & Hinkle, Attys.

Published June 15, 1943 **Serial No. 286,744**

ALIEN PROPERTY CUSTODIAN

CYLINDERS OF INTERNAL-COMBUSTION ENGINES WITH COMBUSTION - AND - WHIRLING CHAMBERS IN THE PISTONS

Luis Leizaola, Anglet, France; vested in the Alien Property Custodian

Application filed July 27, 1939

This invention relates to mixing and combustion chambers in the cylinders of internal-combustion engines of the liquid-fuel or constant-pressure-combustion type such as Diesel engines, or the like, and is more particularly concerned with the construction of such chambers.

It is generally admitted by those skilled in the art that it is of high importance for the efficiency of the engines of this type to introduce the liquid fuel into the engine cylinder or cylinders so as to be animated therein with strong whirling or turbulent movements or eddy currents. In general, the fuel injection begins some degrees before the end of compression; at this moment, the engine cylinder piston approaches to its head-end dead center and moves slowly, so that the air bulk confined thereon is practically immovable, and with the arrangements hitherto in common use it is impossible to impart thereto notable turbulence movements.

In contradistinction thereto, this invention aims to provoke at this very moment, strong turbulence movements which will subsequently be maintained throughout the injection period or during a notable fraction thereof, so as to cause the air and the incoming fuel liquid to be intimately mixed together.

According to this invention, a suitable chamber is provided in the engine piston on or/in its head or adjacently thereto forming, at the end of compression, both the combustion chamber and the mixing or turbulence chamber; the liquid-fuel spraying nozzle or nozzles open directly into this chamber the inner wall sides of which are so incurved or inwardly curved as to guide in desired sense turbulence or whirling movements of the gases within the chamber which communicates with the engine cylinder space by means of openings arranged so as to form or define at the end of compression, in cooperation with the opposite surfaces of the cylinder combustion head, conduits or passages of very narrow cross-section disposed or oriented tangentially to whirling trajectories in the interior of the chamber. At the end of compression, the air is thus forced to flow with high velocity and in desired direction in the turbulence or mixing chamber.

The said chamber may be provided in the very head of the engine piston or it may be formed within a separately attachable member secured to the piston head and thermo-insulated therefrom more or less completely to prevent high temperature in the combustion chamber from being transmitted to the remainder of the piston and from deleteriously affecting good operation thereof, and the chamber from cooling.

The present invention is particularly readily applicable to engine cylinders having two opposite pistons which are movable in opposite directions; in this case, the head of one piston performs with respect to the other piston the part of a combustion or cylinder head. All the arrangements which will be described hereinafter may be applied indifferently to an engine cylinder having fixed combustion head or to a cylinder having two movable opposite pistons.

The invention may be carried out in numerous manners. In one series of embodiments of the invention, the chamber provided in the head of the engine piston or in that of one of the two pistons has a large opening through which it communicates with the cylinder barrel; it will be only at the end of compression cycle, when the piston is in the vicinity of the cylinder head or the opposite piston head, that owing to cooperating opposite surfaces in the cylinder head or in the opposite piston the communication of the piston inner chamber with the cylinder barrel is reduced to narrow conduits or passages conveniently disposed or oriented.

In another series of the embodiments of the invention, the combustion and turbulence chamber provided in the piston is nearly entirely closed and communicates with the cylinder barrel through relatively narrow conduits or passages which open in the chamber tangentially to a circumference of whirling, and their cross-section of communication with the cylinder barrel remains invariable almost throughout the stroke of the piston; at the end of compression, the said cross-section is reduced to very small dimensions owing to the approach to one another of opposite surfaces conveniently arranged in the cylinber head or the opposite piston head. Thus, the volume of the chamber arranged in the piston remains invariable throughout the compression stroke, while the volume comprised between the piston and the cylinder head or the opposite piston simultaneously decreases, resulting throughout this stroke in a stream of air flowing through the tangential conduit or conduits, whereby the air thus introduced is caused to whirl within the chamber from the beginning of the compression stroke. Such whirling is actually not necessary at this very moment, but being subsequently maintained throughout the compression stroke it will help in establishing desired turbulence currents by the maximum of velocity at the beginning of fuel injection. When the pistons are in the vicinity of one another their relative speed is considerably decreased, and the opposite piston head begins to reduce the cross-section of the passages provided for admitting the air into the chamber, thereby accelerating the velocity of the inflowing air resulting in very vigorous whirling or turbulence currents. The openings in the piston chamber and the cooperating surfaces of the cylinder head or the opposite piston head are so arranged that the stream of air, which so far has penetrated in the chamber begins to grow thin and to attack tangentially the inner turbulence currents a shorter distance from the chamber axis than precedingly, resulting in secondary eddy or turbulence currents which contribute to causing the air and the fuel to be intimately mixed together, thus abridging the ignition time and improving the combustion.

The combustion and turbulence chambers constructed as just described have also the advantage of diminishing the engine's knocking, for the combustion first takes place within the chamber and some time will go on before the burnt or burning gases pass into the cylinder barrel, the chamber outlet openings hindering the velocity of the outflowing gases and a sudden increase of pressure on the pistons. On the other hand, by abridging the ignition time, the turbulence currents will also diminish said knocking.

In the aforesaid two series of embodiments of the invention, the combustion and turbulence chamber may be constituted by a cavity formed in the piston only, or it may be constituted by two similar cavities, one being formed in the piston head and the other in the cylinder head or the opposite piston head, these two individual cavities forming at the end of compression one single chamber communicating with the cylinder barrel as hereinabove explained.

Whatever may be the disposition of the combustion chamber, it will be advantageous to provide the inner wall thereof with serrations substantially at right angles to whirling or turbulence movements therein for the purpose of forming small secondary eddy or turbulence currents to contribute to causing the air and the injected atomized oil fuel to be intimately mixed together in the chamber, and also for preventing the oil fuel from contacting with hot chamber walls to avoid to a great extent the oil cracking phenomenon.

In particular, the combustion chamber may be of cylindrical, conic or conic-cylindrical shape, or more generally it may have any suitable form of revolution about an axis registering with one piston diameter or parallel to the piston head. The fuel spraying nozzle or nozzles will then, of course, be oriented parallelly to said axis; in the case of a chamber closed on its top portion, it will be convenient to position the spraying nozzles so that their axis be a certain distance below the axis of the chamber, for the purpose of preventing certain nozzle jets from being momentarily masked by the top wall of the chamber, or the nozzle jet from striking against the said wall. It is to be noted that in fact the fuel injection generally begins some degrees before the top dead center be reached by the piston and that the injection finish some degrees thereafter; in other terms, the piston has not yet reached the end of its upward stroke when the injection begins, and the piston has already started downwards before the injection be finished.

In order that the invention may be more easily understood and readily carried into effect, the same will now be described with reference to the accompanying drawings which show preferred embodiments of the invention and are not to be construed in a limiting sense.

Fig. 1 is an axial sectional view of a four-cycle engine cylinder head, with a piston having a lateral combustion chamber; Fig. 2 is a plan view of the piston head.

Fig. 3 is an axial sectional view of a double-acting engine cylinder each of its two opposed pistons having a combustion chamber diametrally arranged in the piston head.

Fig. 4 is an axial sectional view of a modified form of combustion chambers diametrally arranged in two opposed piston heads; Fig. 5 is a plan view of one of these pistons.

Figs. 6 and 7 are axial sectional and plan views of another modified form of combustion chambers diametrally arranged in two opposite piston heads.

Figures 8 and 9 are axial sectional and plan views of two opposed pistons having their lateral combustion chambers disposed oppositely to one another.

Figures 10 and 11 are axial sectional and plan views of two opposite pistons having their diametral combustion chambers almost entirely closed.

Figures 12 and 13 show a modified form of the arrangement shown in Figures 10 and 11.

Figures 14 and 15 are axial sectional and plan views of two opposite pistons one of which has a combustion chamber almost entirely closed.

Figures 16 and 17 show a modified form of the arrangement shown in Figures 14 and 15.

Figures 18 and 19 show another modified form of the arrangement shown in Figures 14 and 15.

Fig. 20 is an axial sectional view of still another modified form of the preceding arrangement.

Figures 21 and 22 are plan views of other forms of diametral combustion chambers.

Figures 23 and 24 are plan views of two opposite pistons one of which comprises a coaxial annular chamber having openings on the head thereof which may be partly throttled by corresponding projections on the opposite piston head Figures 25 and 26 are sectional views of the two pistons taken on lines **25—25** and **26—26**, respectively, of Figure 23, showing the two pistons at the end of compression cycle.

Figures 27 to 30 illustrate the embodiment of the invention comprising an annular combustion chamber which may be said to operate in a telescope-like manner.

Figures 27 and 28 are plan views of two opposite pistons; Fig. 29 is a coaxial sectional view of the two pistons taken on the line **29—29** of Figures 27 and 28; Fig. 30 is the evolution of a section of the two pistons in their telescoped position at the end of compression cycle, following the line **X—X** in Fig. 27.

Figures 31 to 35 illustrate another combustion chamber of the telescoping type, in the form of a cylinder coaxially shaped in one piston head. Figures 31 and 32 are plan views of two opposite piston heads;

Figure 33 is an axial section of the two pistons taken on the line **33—33** of Figures 31 and 32; Figures 34 and 35 are transverse sections of the combustion chamber taken on the lines **34—34** and **35—35** of Fig. 33, respectively.

Figures 36 to 38 show a modified form of the preceding arrangement; Figures 36 and 37 being plan views of the opposite pistons and Fig. 38 being the axial section thereof.

Fig. 39 is a plan view of a piston comprising a nearly closed combustion chamber of spherical segment or zone shape with its plane faces perpendicular to the piston head; Fig. 40 is a sectional view of the piston taken through the median plane of this segment or zone.

Fig. 41 is a sectional view showing a particular arrangement of the inside walls of the combustion chambers.

The embodiment of the invention shown in Figures 1 and 2 comprises a lateral outwardly opening chamber **2** of spherical-zone-like shape hollowed out in the barrel and the head of the piston **1** so that it cuts laterally the piston head along a circular arc and has its lateral wall of circular section. The liquid-fuel spraying nozzle **3** has its axis at right angle to the piston head and its jets atomize the liquid fuel uniformly round its axis. The piston head and the opposite combustion head are perfectly plane. The volume of the chamber **2** is so calculated that towards the end of compression stroke the distance between the plane piston head and the combustion head is reduced to a very narrow spacing **5**, wherefrom the air comprised therein is caused to rush into the chamber **2** forming a very thin stream which penetrates thereinto with a high velocity in the direction of the arrow thereby producing a violent shock against suitably shaped walls of the chamber **2** and causing desired eddy or turbulence currents to be formed therein;

When the piston, after finishing its compression stroke in the conditions just stated, moves back on its suction stroke the compressed hot gases resulting from the combustion and whirling in the chamber **2** are sucked at high velocity into the increasing suction spacing **5**; this suction and the movement which results therefrom maintain whirling or turbulence currents during the end of the fuel injection.

Figure 3 shows an example of application of the invention to a two-cycle engine cylinder having two opposite pistons **6** and **7**. The pistons **6** and **7** are provided on their heads with chambers **8** and **9**, respectively, each such chamber being of cylindrical shape and hollowed out about one diameter of the respective piston head and the generating lines thereof being parallel to said diameter; the cross-sections thereof are of cardioid-like shape and open up oppositely to one another on the head of each piston, both piston heads being perfectly plane. As precedingly, the volume of these chambers is so calculated that towards the end of compression stroke the distance between both piston heads is reduced to a very narrow spacing **5**. The liquid-fuel spraying nozzle **10** the axis of which is oriented parallelly to the generating lines of said chambers opens into the cylinder barrel at equal distance from both piston heads and atomizes the liquid fuel in the cavity formed by the two chambers **8** and **9**.

At the end of compression stroke the compressed air comprised in the spacing **5** between the two piston heads is caused to rush into the chambers **8** and **9** forming a very thin stream inflowing with high velocity in the direction indicated by the arrows, thereby producing a violent shock against the circular walls of said chambers and causing desired eddy or turbulence currents to form therein which will be maintained, as previously, when the two pistons begin to move away from one another on suction stroke.

Of course, two liquid-fuel spraying nozzles facing one another may be disposed in the said mixing chambers **8** and **9** at will.

The arrangement just described comprising two cavities facing one another may also be applied to an engine cylinder having a single piston, one of the cavities being then formed in the piston head, while the other one will be provided in the fixed combustion head. It is to be noted that this observation is applicable to all the modified forms of the invention which will hereinafter be described in connection with two opposite pistons.

The embodiment of the invention shown in Figures 4 and 5 comprises the opposite pistons **6** and **7** having cylindrical mixing or turbulence chambers **11** and **12**, respectively, which are hollowed out diametrally in the respective piston heads; these chambers **11** and **12** of circular cross-section are preferably laterally slightly offset or stepped relatively to one another; each piston is so shaped that the portions of its head disposed, respectively, at the right and at the left of the mixing chamber opening are on slightly different levels, for example the right hand plane portions **6*a*** and **7*a*** are on a little higher level than the left hand plane portions **6*b*** and **7*b***. In these conditions, when the pistons approach to one another, their plane heads form or define two narrow spacings **5*a*** and **5*b*** which open into respective chambers **12** and **11** obliquely relatively to the opposite portions of the inner wall thereof. The liquid-fuel spraying nozzle **10** or two nozzles are arranged as in the embodiment shown in Fig. 3. At the end of compression stroke, the air compressed in the narrow spacings **6*a*** and **5*b*** is forced into the mixing chambers **11** and **12** forming a very thin stream inflowing with high velocity, thereby producing a shock against the chamber walls and thus causing a very violent whirling or turbulence movement therein, as may be desired.

In the embodiment shown in Figures 6 and 7 each of the opposite pistons **6** and **7** is provided with diametral cylindrical chamber of semicircular cross-section; the respective chamber openings **13** and **14** are opposite to one another; the piston heads are plane, and the respective portions thereof on each side of the central mixing or turbulence chamber are in the same plane.

The opposite plane piston heads are joined to the mixing chamber by means of parallel inclined plane portions; owing to this arrangement, when the pistons approach to one another, the compression spacing **5** between the plane piston heads opens into the mixing cavity on turbulence chamber **13—14** by the medium of two short oblique passages **15** and **16** parallel to one another and having a straight line cross-section of still lesser width than that of the spacing **5**, thereby imparting a still higher velocity to the air forced into the mixing chamber from the spacing **5** and causing a violent whirling or turbulence movement to form in the mixing chamber.

The Figures 8 and 9 illustrate an example of opposite pistons or of a piston and a combustion head, each of them having a lateral mixing chamber. Such chambers **17** and **18**, each one being similar to the chamber **2** shown in Fig. 1, are open to one another on the plane heads of the pistons **6** and **7**. The liquid-fuel spraying nozzle is positioned in 18 and its axis is parallel to the plane heads of the said pistons and at equal distance therefrom.

The examples hereinafter set forth refer to the embodiments of the invention wherein the mixing or turbulence chamber is arranged either in the piston or in the piston and the combustion head and nearly completely closed and conserves an invariable volume during the compression cycle.

In the examples shown in Figures 10 and 11, the head of the piston 6 is provided with a chamber 20 of substantially cylindrical shape and nearly completely closed. This chamber 20 has a longitudinal slot 21 cut out in its top wall portion along a generating line thereof and opened into the interior of the chamber 20 tangentially to the wall of the latter, and a plurality of passages 22 with their outer mouths disposed along a generating line of said chamber and with their inner mouths tangential to the interior thereof at points approximately diametrally opposed to the said longitudinal slot 21 and in the same sense, said passages 22 being preferably of oblong cross-section in the direction of the cylinder axis. The head of the opposite piston 7 is shaped so as to partly overlap said outer passage mouths 22 and the slot 21 when this piston 7 arrives at the vicinity of the head of the piston 6, thereby reducing the inlet sections thereof and increasing the velocity of the air flowing into the chamber 20, at the moment that the injection of the fuel will take place. The air confined between the two pistons is thus forced tangentially into the chamber 20.

With the chamber thus arranged, a single liquid-fuel spraying nozzle 23 axially disposed may be used, or two axial nozzles may be used, if desired. The nozzle or nozzles may have a single central jet, or they may have three or four jets or even more, circularly arranged.

In the examples according to Figures 10 and 11, as well as in those shown in Figures 12 to 19, the axis of the nozzle or nozzles may be conveniently disposed a little below the axis of the mixing chamber.

Figures 12 and 13 illustrate an arrangement similar to that shown in Figures 10 and 12. The mixing chamber 20 is substantially of the same shape and disposed substantially in the same manner as in the preceding example; but instead of the longitudinal slot 21 a row of tangential openings 24 is employed, and, between the two rows of openings 22 and 24 an intermediary row of tangential holes 25 of smaller cross-section is provided, the tangency thereof being oriented in the same sense. The two rows of outer openings 22, 24 of larger cross-section may be partly closed by the piston 7 when it approaches to the piston 6. The holes 25 of smaller cross-section have for their object to direct into the chamber 20 the air confined within the upper portion of the space between the two pistons, thereby contributing to the formation of eddies or turbulence currents on the entire piston stroke. The fuel spraying nozzle or nozzles are disposed as hereinbefore.

In the embodiment shown in Figures 14 and 15 the piston 6 is provided with a bi-cylindrical mixing chamber 26 of laid-down 8-shaped cross-section to form two eddy or turbulence currents in two opposite directions. The left-hand half-chamber has in its lower portion a plurality of tangential holes 27 of relatively large cross-section and in its upper portion a plurality of holes 28 of relatively small cross-section similarly tangential at their junction with the chamber; also, the right-hand half-chamber has two rows of holes: one row of holes 29 of relatively large cross-section and the other row, 30 of relatively small cross-section holes, and their tangential junction with the chamber is inverse of that of the holes 27 and 28. The object of the rows of holes 28 and 30 of relatively small section located in the upper portion of the chamber is the same as that of the holes of the row 25 shown in Figures 11 and 12.

The fuel spraying nozzle or nozzles employed have at least two diametrically opposed jets registering with the principal axis of the laid down 8.

Figures 16 and 17 illustrate a modified form of the arrangement shown in Figures 14 and 15. The two rows of holes 28 and 30 of Figures 14 and 15 are here united into a single row of holes 31 of relatively small cross-section disposed along the generating line of the upper sharp edge of the 8 and taking care of the two halves of the chamber. The left-hand half of the chamber is also taken care of by a row of passages 27 of relatively large cross-section tangentially joined to its upper portion, while the right-hand half thereof is similarly taken care of by the row of passages 29 of relatively large cross-section.

In the arrangement shown in Figures 18 and 19, the piston 6 is provided with a cylindrical combustion chamber 32 the cross-section of which shows four symmetrical earlap-like portions so as to produce four eddy or turbulence currents. Two rows of passages 33 and 34 face one another at the mid-height of the chamber; the upper portion of the chamber has two rows of passages 35 and 36 of relatively small cross-section tangentially joined thereto in inverse sense. The openings 33 and 34, as hereinbefore, are overlapped by the piston 7 on the end of compression stroke; the smaller openings 35 and 36 are designed for the purpose hereinbefore explained. The form of chamber 32 is particularly suitable to engines of large dimensions. One or two fuel spraying nozzles will be advantageously employed therewith each one having at least four jets crosswise disposed.

In the arrangement shown in axial section in Fig. 20, the mixing chamber 26 formed in the piston 6 is bi-cylindrical and its cross-section is of laid-down-8-shape, as in Figures 5 and 6. However, the chamber 26 has in its top portion one single longitudinal slot parallel to the principal axis of the laid down 8 and upperly expanded so as to receive on the compression stroke a corresponding diametral projection 37 on the piston 7, the said projection while being engaged into the said slot forms or defines two lateral oblique passages the cross-section of which gradually decreases as the pistons approach to one another; the air is thereby forced into the chamber 26 and produces two eddy or turbulence movements in two opposite senses. The fuel spraying nozzle or nozzles are disposed as in Figures 5 and 6.

In the embodiments of the invention hereinbefore described the mixing chamber is not necessarily of cylindrical shape. For example, in the case of using a single fuel spraying nozzle and as shown in Figure 21, the chamber may be of truncated-cone-shape 38, the nozzle being then disposed parallelly to the axis of the frustum of cone. Also, when two opposed nozzles are used, the chamber 39 (Figure 22) may be formed by two coaxial truncated cones connected at their larger bases, or it may be formed by two truncated cones or two spherical caps united by means of a cylinder, with fuel spraying nozzles axially disposed.

The combustion or turbulence chamber may also be of annular shape or form. One such embodiment of the invention is shown in Figures 23 to 26. The piston 6 here comprises two portions thermo-insulated from one another and bolted together by a central bolt. The upper portion thereof comprises an annular combustion chamber 40 having plane heads and lateral cylindrical walls perpendicular to the plane piston head.

Four oblique conduits 41 of substantially rectangular cross-section are opened upwardly on the upper plane head of the piston 6 and cause the chamber 40 to communicate with the space comprised between the two pistons. All the conduits 41 join the chamber 40 in similar manner. The plane head of the piston 7 is provided with heel-like projections or projecting plugs 42 disposed so as to respectively engage into the outer openings of the said conduits 41 in connection with the two pistons moving towards one another; each projecting plug 42 is obliquely cut on its lowermost end so as to form an oblique face thereon parallel to the oblique face in each corresponding conduit 41. At the end of compression stroke, the plugs 42 engaged into the conduits 41 will define oblique narrow passages for the flow of the air into the chamber 40, as is most clearly shown in Figure 26. The air in this chamber takes a whirling movement in the direction of the arrow shown in Figure 23; the trajectories of eddy movement are located in plans at right angles to the piston axis. The horizontal fuel spraying nozzle 22 injects the liquid fuel obliquely into the chamber preferably in a direction opposite to that of eddy or turbulence movement.

Figures 27 to 30 illustrate another example of annular cylindrical chamber according to this invention, said chamber being formed but at the end of compression stroke by juxta-position of hollow projecting elements provided on each piston.

The plane head of the piston 6 is shaped so as to have, for example, two prismatic projections 43 and 44 the plane bases of which are constituted respectively by two opposite quadrants of the piston head. Similarly, the plane head of the piston 7 has two prismatic projections 45 and 46, but located in the other pair of opposite quadrants for engagement between the former prismatic projections 43 and 44. In each of the said projections are provided annular passages 43*a*, 44*a* and 45*a*, 46*a*, respectively; at the end of compression stroke, the projections of the two pistons are reciprocally engaged, as is shown by their evolution in Figure 30, causing the said passages to form a single annular chamber. It will be noted that the projections 43, 44, 45, 46, when approaching to the plane heads of the opposite piston, form or define narrow spacings, respectively 43*b*, 44*b* and 45*b*, 46*b* wherefrom the air escapes with high velocity into the annular passage in the neighbouring projection; in order to cause the air to circulate in the same direction in these successive portions of the annular chamber, the inlet opening of each passage is larger than its outlet opening and the latter is off-set or stepped in height relatively to the inlet opening, as is most clearly shown in Figure 30. In these conditions, the air compressed in the spacing 45*b*, for example, may flow without obstacle into the inlet opening of the annular passage 43*a*, but cannot be forced into the passage 44*a* situated on the other side, owing to the obstacle opposed by the solid portion of the lateral wall of the projection 44. Thus the air is caused to whirl in the annular chamber in the direction of the arrows as shown in Figures 27 and 30. The fuel spraying nozzle 22 is disposed preferably so as to inject the liquid fuel in a direction opposite to that of whirling or turbulence movement.

The combustion chamber may also be formed by a cylindrical cavity generated by a line parallel to the piston axis, with the whirl movement in planes perpendicular to this axis. The cylindrical combustion chamber 47 (Figures 31 to 35) is located in the piston 6 and has about the same axis as the latter and forms above the piston head 48 a cylindrical protuberance having its head plane and solid. In the lateral wall of this protuberance are provided horizontal conduits 49 causing the chamber 47 to communicate with the space comprised between both pistons. The conduits 49 are obliquely cut out and each of them has for its outer orifice an oblong slot substantially as high as the cylindrical wall in the chamber 47, and they are so shaped within this wall that they open into the chamber 47 tangentially to the inner wall side of the latter at their top portions, whereafter in the downward direction the horizontal section thereof is changed so as to open into the chamber, no more tangentially to the inner wall side but tangentially to a coaxial circumference of lesser radius. The head of the piston 7 is circularly hollowed out so as to be able, at the end of compression stroke, to cap the projecting portion of the chamber 47; the lateral inner wall 50 of the hollow portion of the piston 7 is provided with longitudinal grooves 51 corresponding in number and disposition to the conduits 49. It will also be advantageous to shape in the bottom of said hollow portion an annular recess 52 in communication with all the grooves 51. When both pistons move towards one another, the piston 7 gradually caps the chamber 47; the air is then caused to flow from the grooves 51 into the annular spacing comprised between the engine cylinder and the projecting outer wall of the chamber 47; therefrom the air penetrates into the conduits 49, the outer orifice of which is gradually throttled by the solid portions of the wall 50, whereby the air is forced into the chamber 47 through the conduits becoming more and more narrow which let pass air streams with velocities more and more increased and which, owing to the peculiar shape thereof, tangentially attack the inner eddy or turbulence currents according to circumferences of decreasing diameter as the pistons approach one another. The fuel spraying nozzle 22 is positioned obliquely, following the axis of an inclined conduit opening into the bottom portion of the chamber 47; it is disposed, for example, so as to inject the fuel in the direction opposed to that of the turbulence movement.

In this arrangement, the fact that the chamber 47 is coaxial with the piston causes to provide in its wall a substantially long conduit for introducing the fuel resulting in a rather important dead space; the latter may, however, be reduced with the aid of the modified form of the invention shown in Figures 36 to 38.

According to Figures 36 to 38, the combustion chamber 47 is disposed eccentrically relatively to the axis of the pistons 6 and 7 and has in 53, where it is joined to the lateral wall of the piston 6, an opening for introducing the fuel jet from the horizontal nozzle 22. The head of the piston 7 is hollowed out so as to cap at the end of compression stroke the cylindrical protuberance formed by the chamber without masking the opening 53; the hollow of the piston 7 has a recessed portion 54 through which the compressed air between the outer head of the chamber 47 and the head of the piston 7 may reach into the free annular space comprised between the inner wall of the engine cylinder and the outer wall of the chamber 47.

Figures 39 and 40 illustrate a modified form of the invention wherein the combustion and mixing chamber is arranged in a manner somewhat similar to that shown in Figures 10 to 13, but modified so as to permit the use of a spraying nozzle in an oblique lateral position relatively to the charge.

According to Figures 39 and 40, the combustion chamber 55 is formed by a spherical segment or zone the axis of which is the straight line 56 and which is laterally limited by two vertical plane faces 57 and 58. In the median plane parallel to the faces 57 and 58, the wall of the chamber 55 is projecting from the piston 6 and has, cut therethrough, air inlet passages 59 all of them inclined in the same manner and opening tangentially to the inner wall and creating a turbulence movement in the sense of the arrows shown in Figure 40. Furthermore, the plane lateral wall 57 is obliquely cut through by two passages 60 and 61, the former being disposed in a horizontal plane and the latter in a vertical plane. The face 58 is cut through by similar passages 62 and 63; these four passages are disposed so as to cooperate for the turbulence movement in the same sense as the passages 59. The fuel spraying nozzle 22 is positioned laterally inclined to the chamber and it injects the fuel into the latter through the passage 64 tangentially to its inner wall and, for example, in the direction opposed to that of the turbulence movement.

Figure 41 shows a cylindrical chamber 20 similar to that shown in Fig. 12, the inner wall of which is provided with circumferential serrations 65 for the purpose of promoting, in contact therewith, secondary eddy or turbulence currents.

LUIS LEIZAOLA.