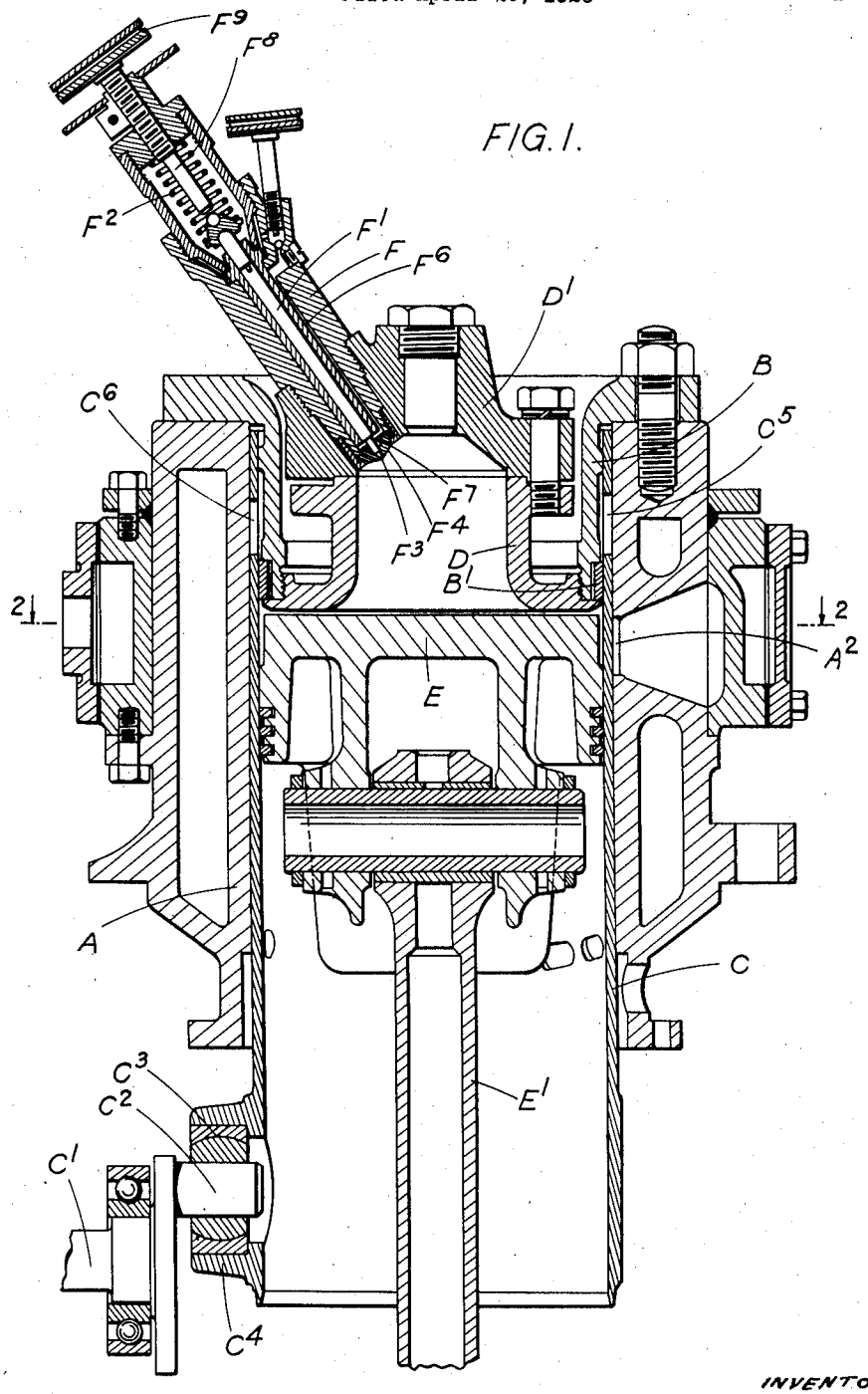
March 29, 1927. 1,622,885

H. R. RICARDO

INTERNAL COMBUSTION ENGINE

Filed April 29, 1926 3 Sheets-Sheet 1

FIG. 1.



INVENTOR

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March 29, 1927. 1,622,885

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Filed April 29, 1926 3 Sheets-Sheet 2

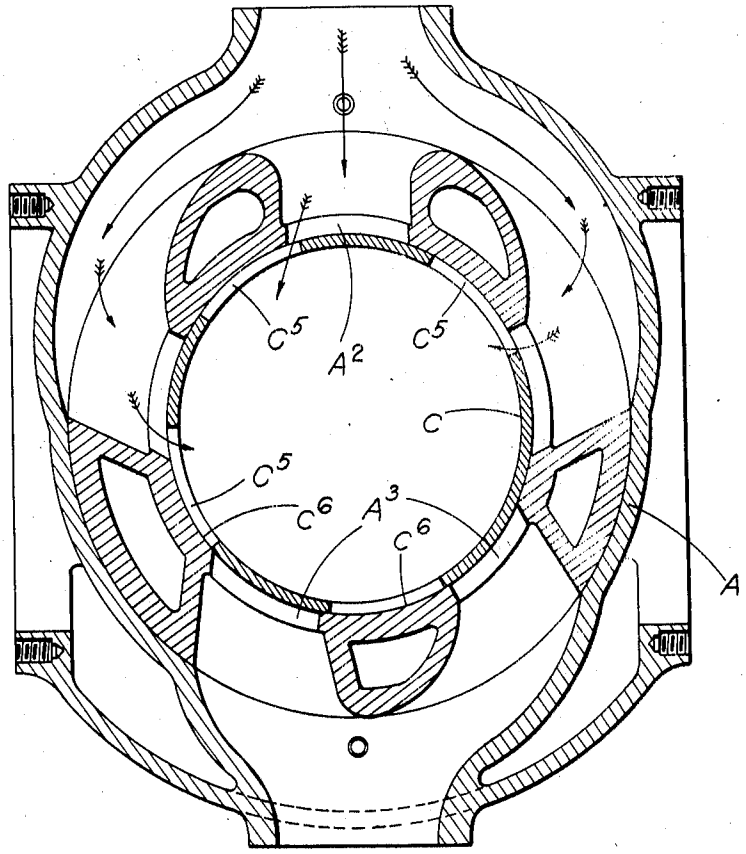


FIG. 2.

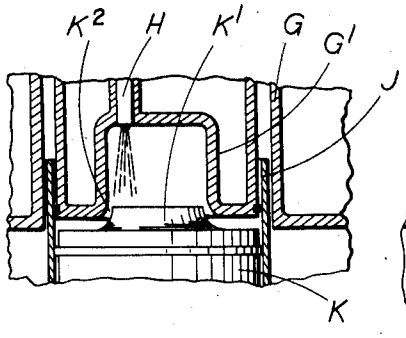


FIG. 3.

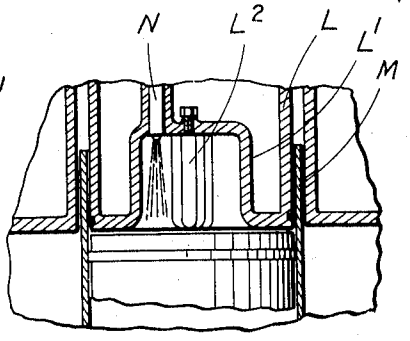


FIG. 4.

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March 29, 1927. 1,622,885

H. R. RICARDO

INTERNAL COMBUSTION ENGINE

Filed April 29, 1926 3 Sheets-Sheet 3

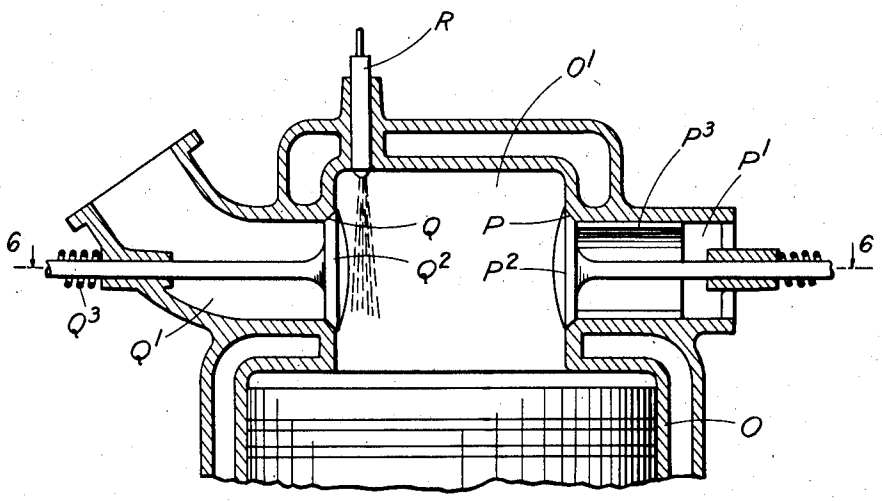


FIG. 5.

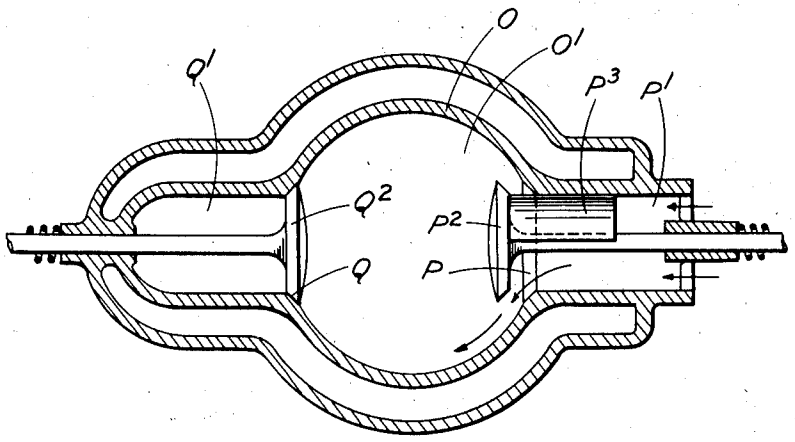


FIG. 6.

INVENTOR

By Harry R. Ricardo,

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ATTYS.

Patented Mar. 29, 1927. 1,622,885

UNITED STATES PATENT OFFICE.

HARRY RALPH RICARDO, OF LONDON, ENGLAND.

INTERNAL-COMBUSTION ENGINE.

Application filed April 29, 1926, Serial No. 105,558, and in Great Britain May 21, 1925.

This invention relates to internal combustion engines of the type in which liquid fuel is injected into a combustion chamber containing an air charge which whirls about the cylinder axis.

Hitherto in engines of this type the combustion chamber has been constituted by the upper end of the cylinder bore so that it was of relatively small height and large diameter, while the fuel injection device has been situated near the centre line of the cylinder so as to deliver fuel in small radial jets. In such cases the relatively large diameter of the combustion chamber in relation to its height necessitated a large cooling surface for the compressed charge while the large number of radial jets required involved the use of fine fuel orifices which were liable to become choked.

The object of the present invention is to provide a construction which will overcome these disadvantages and improve the mixture between the fuel and air.

To this end according to the present invention the combustion chamber, which is of substantially circular cross section in a plane at right angles to the axis of the cylinder, is disposed in the cylinder head and has a diameter where it opens into the cylinder which is less than that of the cylinder bore, while one or more fuel injection devices are disposed a substantial distance from the axis of the combustion chamber and are each adapted to deliver into the air charge, to which a rotational motion about the cylinder axis is imparted a fuel spray the mean direction of which is either parallel to or has a substantial component in a direction parallel to the axis of the combustion chamber. Each fuel injection device may either deliver a single jet of spray the mean direction of which is parallel to or has a substantial component in a direction parallel to the axis of the combustion chamber, or may deliver several jets and where a fuel injection device is adapted to deliver several jets one or more of these jets may be directed in a radial or nearly radial direction but in this case the other jets must be so disposed that the mean direction of all the jets has a substantial component in a direction parallel to the combustion chamber axis.

Conveniently the combustion chamber is substantially cylindrical while its height is preferably approximately equal to its diameter, the fuel injection device or devices being disposed in the upper wall of the combustion chamber adjacent to the circumference and injecting fuel in a direction either parallel to the combustion chamber axis or diagonally across it so as to mingle with the air charge as it rotates.

In some cases turbulence in addition to that produced by the rotational motion of the air charge may be produced, in a manner known per se, by providing a projection on the face of the piston having such a shape and dimensions that towards the end of the instroke of the piston this projection can enter the combustion chamber leaving a small annular space through which towards the end of the compression stroke a residual part of the gaseous charge will be forced at high velocity into the combustion chamber. Movement of the gaseous charge in the axial direction is thus produced in addition to the rotational motion previously imparted to it, the resultant turbulence tending to improve the mingling of the fuel and the air and thus to facilitate combustion.

In yet another arrangement according to this invention a plug of substantially circular cross section is disposed in the combustion chamber coaxially therewith so as to fill up the centre portion or "core" of the combustion chamber. The combustion chamber is thus given a substantially annular form at the end of the compression stroke of the piston and, the centre portion of the combustion chamber being filled up, the whole of the air charge will tend to be brought into contact with the fuel spray. The plug may be secured either to the cylinder head or to the upper face of the piston or part of the plug may be carried by each of these members, the plug preferably being uncooled so as to assist combustion.

Where the plug is substantially cylindrical the mean direction of the fuel spray is preferably substantially parallel to the axis of the combustion chamber. In some cases, however, it may be found convenient to make the plug other than cylindrical, for example barrel shaped, conical or with its end portions of greater diameter than its centre portion according to the shape of the combustion chamber and the direction of the fuel spray, but in most cases a cylindrical combustion chamber, a cylindrical plug and a spray the mean direction of which is sub-

stantially parallel to the axis of the combustion chamber are preferable.

Each fuel injection device may be of some known type employing either solid injection or air injection and may have one or more spraying orifices but, preferably, where solid injection is employed, a sprayer giving a single jet or cone of spray is used. This sprayer may conveniently comprise a body portion within which is disposed a spring-controlled needle valve having a conical end which normally closes a conical fuel injection orifice in the end of the sprayer. This needle valve can be moved automatically under the pressure of the fuel in a direction away from the combustion chamber against the action of its spring so as to open the fuel delivery orifice and thus permit the delivery of the fuel to the combustion chamber direct through an annular space between the fuel valve and its seat. This eliminates the trouble experienced from choking where a number of fine jets are employed. Preferably a short "director" or cylindrical extension of the fuel valve stem is provided to steady the spray. In some cases, however, when convenient, a fuel injection device of the type having a valve which moves in the direction of fuel flow to open the fuel delivery orifice or orifices may be employed.

Some other known method of fuel injection may be employed, however, as for example that in which the combustion of air in a subsidiary combustion chamber is used to spray the fuel into the main air charge. In such systems the opening leading into the auxiliary chamber is disposed a substantial distance from the axis of the main combustion chamber as is the fuel sprayer in the single stage systems, the fuel valve being located in some convenient position in the auxiliary chamber.

The invention is particularly applicable to internal combustion engines of the sleeve valve type and, when applied to such engines, the cylinder head in which the combustion chamber is formed is conveniently of a plug-like construction fitting within the outer end of the cylinder and of such dimensions as to leave an annular space between the wall of the cylinder and that of the cylinder head so as to accommodate the outer end of the sleeve valve.

The rotation of the air charge may be effected in some known way but with certain types of sleeve valve, such as those having a combined reciprocating and oscillating motion, the inlet ports are normally so constructed and caused to open in such a manner that the required rotary motion is imparted to the charge without the provision of further means.

When the invention is applied to an engine of the poppet valve type, on the other hand, the inlet port or ports may be partially masked so that the air charge enters wholly through one side of such port or ports, thus tending to cause the desired rotary motion of the air charge. In a two-stroke engine the inlet port or ports may be provided with guide vanes or the piston face may be so formed as to impart the desired motion to the incoming air charge.

The invention may be carried out in various ways but four alternative constructions according to the present invention are illustrated somewhat diagramatically by way of example in the accompanying drawings, in which—

Figure 1 is a vertical section through the cylinder of one construction according to this invention as applied to an engine of the sleeve valve type,

Figure 2 is a section on the line 2—2 of Figure 1 showing the parts in the position they occupy at the beginning of the suction stroke,

Figure 3 is a somewhat diagrammatic sectional view of an alternative construction of cylinder head cooperating with a piston of special construction also as applied to a sleeve valve engine,

Figure 4 is a similar view to Figure 3 of a third construction of cylinder head in which a plug-like member is provided to fill the centre portion of the combustion chamber,

Figure 5 is a vertical section through the cylinder head of a construction showing how the invention may be applied to an engine of the poppet valve type, and

Figure 6 is a section on the line 6—6 of Figure 5 showing the inlet valve open.

In the construction illustrated in Figures 1 and 2 the engine comprises a water-cooled cylinder A having an open end within which is bolted or otherwise secured a plug-like cylinder head B. The external diameter of the plug B is such in relation to the internal diameter of the cylinder A that there is an annular space between the wall of the plug B and that of the cylinder A to accommodate the outer end of a sleeve valve C, a junk ring B^1 being provided on the plug B to reduce leakage between this member and the sleeve C. The sleeve C conveniently has a combined oscillating and reciprocating motion imparted to it by suitable mechanism comprising, in the construction shown, a small shaft C^1 driven from the engine crank shaft through suitable gearing (not shown) and carrying a crank pin C^2 which engages a self-aligning spherical joint C^3 mounted in a boss C^4 formed on the sleeve adjacent to its lower end. Inlet ports A^2 and C^5 and exhaust ports A^3 and C^6 are provided respectively in the cylinder A and in the sleeve C, the inlet ports A^2, C^5 being constructed in known manner as shown in Figure 2 so as to impart a rotational movement about the cylinder axis

these ports being substantially diametrically opposite to one another and opening respectively into an inlet passage P^1 and an exhaust passage Q^1. Controlling the inlet and exhaust ports are poppet valves P^2, Q^2. The exhaust valve Q^2 is of normal construction and is controlled by a spring Q^3. The inlet valve P^2, on the other hand, is provided on one side with a substantially semi-cylindrical mask P^3 which causes all the air flowing through the inlet passage P^1 on the induction stroke of the engine to enter through the side of this port remote from the mask as shown in Figure 6 whereby a rotational motion about the axis of the combustion chamber tends to be imparted to the air on the induction stroke.

A fuel injection device R which may be of some convenient construction, for example similar to that shown in Figure 1, is provided in the upper wall of the combustion chamber O^1 adjacent to the circumference thereof this fuel injection device delivering a spray the mean direction of which is substantially parallel to the axis of the combustion chamber.

Although where the invention has been described with reference to internal combustion engines in which the ports are controlled by a sleeve valve, a single sleeve valve to which combined oscillating and reciprocating motion is imparted has been particularly indicated, it is to be understood that it may be applied to engines employing other forms of sleeve valves or to engines other than those of the sleeve or poppet valve type wherein a rotary motion about the cylinder axis is imparted to the gaseous part of the charge.

Further, the position and number of the fuel sprayers and the dimensions of the combustion chamber may be varied and other details of construction modified to suit the type of engine to which the invention is applied and the properties of the fuel to be used.

What I claim as my invention and desire to secure by Letters Patent is: —

1. An internal combustion engine of the liquid fuel injection type including in combination a cylinder, a cylinder head, a piston reciprocating within the cylinder, a combustion chamber in the cylinder head of substantially circular cross section in a plane at right angles to the axis of the cylinder, the diameter of the combustion chamber where it opens into the cylinder being less than that of the cylinder bore, means for admitting a charge of air to the cylinder, means for causing this charge of air to rotate about the axis of the combustion chamber, and at least one fuel injection device disposed a substantial distance from the axis of the combustion chamber and adapted to deliver a spray the mean direction of which has a substantial component in a direction parallel to the axis of the combustion chamber.

2. An internal combustion engine of the liquid fuel injection type including in combination a cylinder having inlet and exhaust ports in its wall, a cylinder head, a combustion chamber in the cylinder head of substantially circular cross section in a plane at right angles to the axis of the cylinder, the diameter of the combustion chamber where it opens into the cylinder being less than that of the cylinder bore, a sleeve valve disposed within the cylinder and adapted to control the ports therein in such a manner that a rotational motion about the cylinder axis is imparted to the air charge on entering the cylinder, a piston reciprocating within the sleeve, and at least one fuel injection device disposed a substantial distance from the axis of the combustion chamber and adapted to deliver a spray the mean direction of which has a substantial component in a direction parallel to the axis of the combustion chamber.

3. An internal combustion engine of the liquid fuel injection type including in combination a cylinder, a cylinder head, a piston reciprocating within the cylinder, a cylindrical combustion chamber in the cylinder head of less diameter than the cylinder bore, means for admitting a charge of air to the cylinder, means for causing this charge of air to rotate about the axis of the combustion chamber, and at least one fuel injection device disposed a substantial distance from the axis of the combustion chamber and adapted to deliver a spray the mean direction of which has a substantial component in a direction parallel to the axis of the combustion chamber.

4. An internal combustion engine of the liquid fuel injection type including in combination a cylinder having inlet and exhaust ports in its wall, a cylinder head, a cylindrical combustion chamber in the cylinder head of less diameter than that of the cylinder bore, a sleeve valve disposed within the cylinder and adapted to control the ports therein in such a manner that a rotational motion about the cylinder axis is imparted to the air charge on entering the cylinder, a piston reciprocating within the sleeve and at least one fuel injection device disposed a substantial distance from the axis of the combustion chamber and adapted to deliver a spray the mean direction of which has a substantial component in a direction parallel to the axis of the combustion chamber.

5. An internal combustion engine of the liquid fuel injection type including in combination a cylinder having inlet and exhaust ports in its wall, a cylinder head comprising a plug fitting within the outer end of the cylinder and of such dimensions as to leave

to the air charge entering the cylinder therethrough as indicated by the arrows in Figure 2. Carried by or formed integral with the plug B is a member D constituting a water jacketed combustion chamber. This combustion chamber D is substantially cylindrical its height being substantially equal to its diameter. The upper end of the combustion chamber D is closed by a cap D^1 and mounted in the cap adjacent to its circumference is a fuel injection device F. Reciprocating within the sleeve C and connected to the crank shaft (not shown) by a connecting rod E^1 is a piston E the stroke of which is such that substantially the whole of the air charge is compressed within the combustion chamber D on the compression stroke.

The fuel injection device is adapted to direct a spray diagonally across the combustion chamber D and comprises a body portion F in which is disposed a needle valve F^1 controlled by a spring F^2 and having a conical end F^3 adapted normally to close a conical fuel injection orifice in the end F^4 of the injection device, the movement of this valve to open the orifice being in a direction away from the combustion chamber. The fuel is delivered to the body of the injection device through a passage (not shown) and flows down a groove F^6 into a space F^7 surrounding the end of the needle valve F^1 so that the pressure of the fuel acts on the valve to move it against the action of its spring and thus permit delivery of the fuel through the annular space thus opened between the conical end F^3 of the valve F^1 and its conical seat. The extent to which the valve F^1 can move under the action of the fuel pressure may be limited by a stop F^8 which is screw-threaded and provided with a knurled head F^9 so as to be adjustable, whereby the lift allowed to the valve can be varied so as to vary the dimensions of the annular space through which the fuel is actually sprayed into the cylinder. In the arrangement shown the fuel is conveniently delivered to the fuel injection device by an engine operated fuel pump, and a conical cone of spray of good penetration may be produced.

Alternatively to the above sprayer a mechanically operated valve may be employed to control the injection of fuel with or without an air blast.

In the alternative construction diagrammatically illustrated in Figure 3 a plug-like cylinder head G is formed with a water-cooled cylindrical combustion chamber G^1 the height of which is substantially equal to its diameter. A fuel sprayer H is disposed in the upper wall of this combustion chamber adjacent to its circumference and adapted to deliver a spray in a direction substantially parallel to the axis of the cylinder. A sleeve valve J engages the circumference of the plug-like cylinder head this sleeve conveniently being constructed and operated in a similar manner to the sleeve shown in Figures 1 and 2 so as to impart a rotational motion about the cylinder axis to the air charge entering the cylinder. Within the sleeve J reciprocates a piston K carrying on its upper face a projection K^1 of slightly less diameter than the base of the combustion chamber within which it is adapted to extend at the end of the instroke of the piston. In this way a residual part of the gaseous charge contained in the cylinder is forced in known manner at high velocity into the combustion chamber at the end of the instroke of the piston through the annular space K^2 between the circumferential walls of the plug K^1 and of the combustion chamber, thus producing considerable axial turbulence in the combustion chamber in addition to the rotational motion about the cylinder axis already imparted to the air charge.

In the alternative construction diagrammatically illustrated in Figure 4 a plug-like cylinder head L is formed with a water-cooled cylindrical combustion chamber L^1 the height of which is substantially equal to its diameter. A sleeve valve M conveniently constructed and operated in a similar manner to the sleeve valve shown in Figures 1 and 2 so as to produce the desired rotational movement of the air charge about the cylinder axis is disposed within the cylinder. A sprayer N is disposed in the upper wall of the combustion chamber adjacent to its circumference and is adapted to deliver a spray in a direction substantially parallel to the axis of the combustion chamber. Centrally disposed within the combustion chamber is a cylindrical plug L^2 adapted to fill the centre portion or "core" of the combustion chamber where the gaseous charge would not readily be reached by the liquid fuel delivered by the sprayer N. Thus in this construction the combustion chamber has a substantially annular form and the proper mixing of the liquid fuel with the gaseous charge which is caused to circulate around the axis of the combustion chamber is facilitated.

In either of the constructions illustrated in Figure 3 or Figure 4 a construction of sprayer similar to that described with reference to Figure 1 may be employed.

In the construction illustrated in Figures 5 and 6 the engine is of the poppet valve type and comprises a water cooled cylinder O having formed in its head a combustion chamber O^1, also water-cooled, this combustion chamber being of substantially cylindrical form with its height substantially equal to its diameter which is less than the diameter of the cylinder bore. Inlet and exhaust ports P, Q are provided in the cylindrical wall of the combustion chamber O^1,

an annular space between the wall of the cylinder and the wall of the plug, a combustion chamber in the cylinder head of substantially circular cross section in a plane at right angles to the cylinder axis, the diameter of the combustion chamber where it opens into the cylinder being less than that of the cylinder bore, a sleeve valve disposed within the cylinder and adapted to control the inlet ports therein in such a manner that a rotational motion about the cylinder axis is imparted to the air charge entering the cylinder, the outer end of the sleeve being adapted to move in the annular space between the wall of the cylinder and the wall of the plug like cylinder head, a piston reciprocating within the sleeve and at least one fuel injection device disposed a substantial distance from the axis of the combustion chamber and adapted to deliver a spray the mean direction of which has a substantial component in a direction parallel to the axis of the combustion chamber.

6. An internal combustion engine of the liquid fuel injection type including in combination a cylinder having inlet and exhaust ports in its wall, a cylinder head comprising a plug fitting within the outer end of the cylinder and of such dimensions as to leave an annular space between the wall of the cylinder and the wall of the plug, a cylindrical combustion chamber in the cylinder head of less diameter than that of the cylinder bore, a sleeve valve disposed within the cylinder and adapted to control the inlet ports therein in such a manner that a rotational motion about the cylinder axis is imparted to the air charge entering the cylinder, the outer end of the sleeve being adapted to move in the annular space between the wall of the cylinder and the wall of the plug like cylinder head, a piston reciprocating within the sleeve and at least one fuel injection device disposed a substantial distance from the axis of the combustion chamber and adapted to deliver a spray the mean direction of which has a substantial component in a direction parallel to the axis of the combustion chamber.

7. An internal combustion engine of the liquid fuel injection type including in combination a cylinder, a cylinder head, a piston reciprocating within the cylinder, a cylindrical combustion chamber in the cylinder head of less diameter than the cylinder bore the height of this combustion chamber being substantially equal to its diameter, means for admitting a charge of air to the cylinder, means for causing this charge of air to rotate about the axis of the combustion chamber, and at least one fuel injection device disposed a substantial distance from the axis of the combustion chamber and adapted to deliver a spray the mean direction of which has a substantial component in a direction parallel to the axis of the combustion chamber.

8. An internal combustion engine of the liquid fuel injection type including in combination a cylinder having inlet and exhaust ports in its wall, a cylinder head comprising a plug fitting within the outer end of the cylinder and of such dimensions as to leave an annular space between the wall of the cylinder and the wall of the plug, a cylindrical combustion chamber in the cylinder head of less diameter than that of the cylinder bore the height of this combustion chamber being substantially equal to its diameter, a sleeve valve disposed within the cylinder and adapted to control the inlet ports therein in such a manner that a rotational motion about the cylinder axis is imparted to the air charge entering the cylinder, the outer end of the sleeve being adapted to move in the annular space between the wall of the cylinder and the wall of the plug like cylinder head, a piston reciprocating within the sleeve and at least one fuel injection device disposed a substantial distance from the axis of the combustion chamber and adapted to deliver a spray the mean direction of which has a substantial component in a direction parallel to the axis of the combustion chamber.

9. An internal combustion engine of the liquid fuel injection type including in combination a cylinder, a cylinder head, a piston reciprocating within the cylinder, a combustion chamber in the cylinder head of substantially circular cross section in a plane at right angles to the axis of the cylinder, the diameter of the combustion chamber where it opens into the cylinder being less than that of the cylinder bore, means for admitting a charge of air to the cylinder, means for causing this charge of air to rotate about the axis of the combustion chamber, at least one fuel injection device disposed a substantial distance from the axis of the combustion chamber and adapted to deliver a spray the mean direction of which has a substantial component in a direction parallel to the axis of the combustion chamber, and a projection on the upper face of the piston having such a shape and dimensions that towards the end of the instroke of the piston this projection can enter the combustion chamber leaving a small annular space through which towards the end of the compression stroke a residual part of the gaseous charge will be forced at high velocity into the combustion chamber.

10. An internal combustion engine of the liquid fuel injection type including in combination a cylinder, a cylinder head, a piston reciprocating within the cylinder, a cylindrical combustion chamber in the cylinder head of less diameter than the cylinder bore, means for admitting a charge of air to the

cylinder, means for causing this charge of air to rotate about the axis of the combustion chamber, at least one fuel injection device disposed a substantial distance from the axis of the combustion chamber and adapted to deliver a spray the mean direction of which has a substantial component in a direction parallel to the axis of the combustion chamber, and a projection on the upper face of the piston having such a shape and dimensions that towards the end of the instroke of the piston this projection can enter the combustion chamber leaving a small annular space through which towards the end of the compression stroke a residual part of the gaseous charge will be forced at high velocity into the combustion chamber.

11. An internal combustion engine of the liquid fuel injection type including in combination a cylinder having inlet and exhaust ports in its wall, a cylinder head comprising a plug fitting within the outer end of the cylinder and of such dimensions as to leave an annular space between the wall of the cylinder and the wall of the plug, a cylindrical combustion chamber in the cylinder head of less diameter than that of the cylinder bore, a sleeve valve disposed within the cylinder and adapted to control the inlet ports therein in such a manner that a rotational motion about the cylinder axis is imparted to the air charge entering the cylinder, the outer end of the sleeve being adapted to move in the annular space between the wall of the cylinder and the wall of the plug like cylinder head, a piston reciprocating within the sleeve, at least one fuel injection device disposed a substantial distance from the axis of the combustion chamber and adapted to deliver a spray the mean direction of which has a substantial component in a direction parallel to the axis of the combustion chamber, and a projection on the upper face of the piston having such a shape and dimensions that towards the end of the instroke of the piston it can enter the combustion chamber leaving a small annular space through which towards the end of the compression stroke a part of the gaseous charge will be forced at high velocity into the combustion chamber.

12. An internal combustion engine of the liquid fuel injection type including in combination a cylinder having inlet and exhaust ports in its wall, a cylinder head comprising a plug fitting within the outer end of the cylinder and of such dimensions as to leave an annular space between the wall of the cylinder and the wall of the plug, a cylindrical combustion chamber in the cylinder head of less diameter than that of the cylinder bore, the height of this combustion chamber being substantially equal to its diameter, a sleeve valve disposed within the cylinder and adapted to control the ports therein in such a manner that a rotational motion about the cylinder axis is imparted to the air charge entering the cylinder, the outer end of the sleeve being adapted to move in the annular space between the wall of the combustion cylinder and the wall of the plug like cyinder head, a piston reciprocating within the sleeve, a projection on the upper face of the piston having such a shape and dimensions that towards the end of the instroke of the piston it can enter the combustion chamber leaving a small annular space through which towards the end of the compression stroke a part of the gaseous charge will be forced at high velocity into the combustion chamber, and at least one fuel injection device disposed a substantial distance from the axis of the combustion chamber and adapted to deliver a spray the mean direction of which has a substantial component in a direction parallel to the axis of the combustion chamber.

In testimony whereof I have signed my name to this specification.

HARRY RALPH RICARDO.