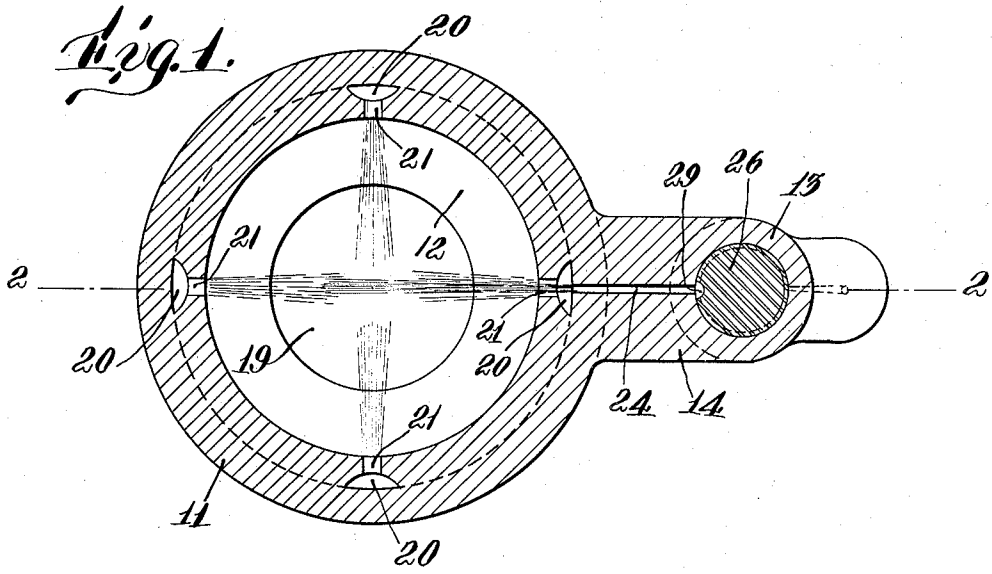
Nov. 10, 1925. 1,560,556

E. A. FORD

FUEL INJECTION AND MIXING MEANS FOR INTERNAL COMBUSTION ENGINES

Filed July 3, 1920

Fig. 1.



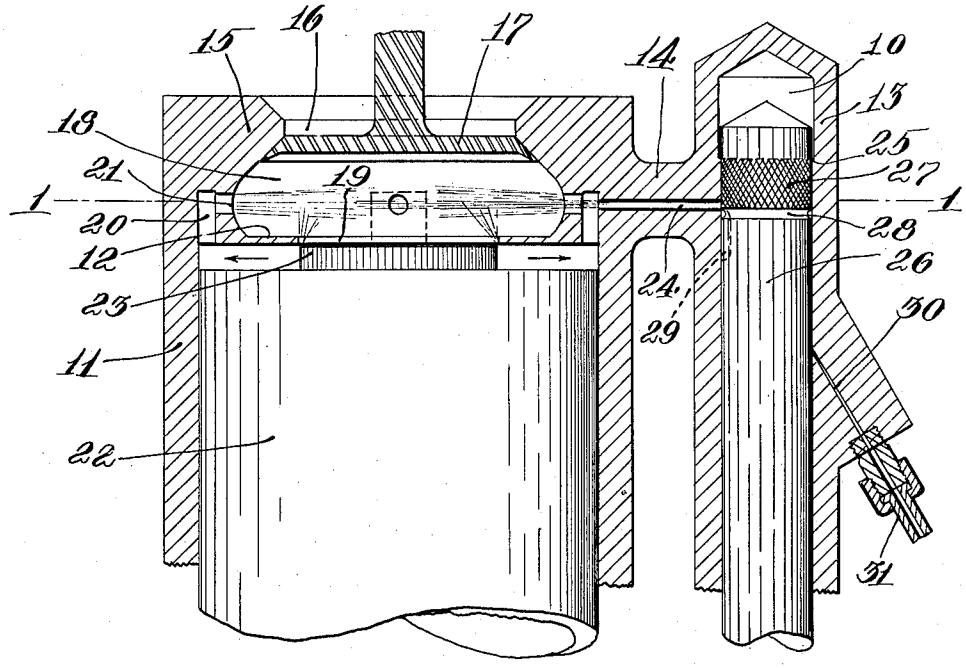


Fig. 2.

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UNITED STATES PATENT OFFICE.

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FUEL INJECTION AND MIXING MEANS FOR INTERNAL-COMBUSTION ENGINES.

Application filed July 3, 1920. Serial No. 393,937.

To all whom it may concern:

Be it known that I, EUGENE A. FORD, a citizen of the United States, residing at Newton, in the county of Middlesex and State of Massachusetts, have invented new and useful Improvements in Fuel Injection and Mixing Means for Internal-Combustion Engines, of which the following is a specification.

This invention has reference primarily to internal combustion engines of the high compression type, that is, the type in which air is compressed until its temperature is raised to the point at which it will ignite fuel, and finely divided fuel is injected into the air so compressed. In such engines liquid fuel is generally employed and most commonly the fuel used is oil of the quality commercially known as fuel oil. But as other fuels than oil may be used, the references in the following description to fuel oil are to be taken as illustrative or typical of any liquid fuel which may be used in engines of this type, and not as in any sense a restriction in the scope in which protection is claimed for the invention.

It is essential with engines of the type here specified that the fuel be divided into the most minute particles possible and that these particles be thoroughly mixed with the air in the combustion chamber of the motor, in order that the fuel may be fully, quickly, and efficiently burned, for the time period available for mixing and combustion of the fuel is extremely brief, due to the high speed at which such engines are commonly run and the small proportion of the cycle during which fuel is admitted. In the well known Diesel type engine, the fuel oil is blown into the combustion chamber by cooled aid at a higher compression pressure than the air in the combustion chamber, and there is customarily used for that purpose about one-tenth as much air as already exists in the combustion chamber, and also a large excess of air (approximately 100%) more than the quantity required according to the laws of chemical reaction for complete combustion of the fuel.

The objects of my invention are to furnish an improved means for effecting injection of liquid fuel into the combustion space of a high compression engine, by which such a fine subdivision of the liquid fuel, preliminary heating of the fuel, and intimate mixture of the fuel with the compressed air in the combustion chamber are effected that only a relatively very small excess of air need be supplied to effect complete combustion; to cause combustion to commence in the central part of the combustion chamber; and to accomplish the fuel injection and air mixing by very simple means.

The preferred form of means by which these objects are accomplished is described in the following specification and illustrated in the drawings forming a part thereof; and the invention consists in said means and equivalent devices having substantially the same function and result within the scope of the appended claims. In said drawings,

Figure 1 is a cross section of an engine cylinder and the fuel injection means containing the form of the invention above referred to, said section being taken on the line 1—1 of Figure 2.

Figure 2 is a longitudinal section taken on line 2—2 of Figure 1.

Like reference characters designate the same parts in both figures.

Before entering into a detailed description of the invention here illustrated I would say that this illustration is intended to show simply so much of an engine as is necessary to an understanding of the fundamental principles of the invention, and is not intended as a restriction to matters of detail of the scope in which I claim protection for my invention. No attempt has been made to show structural details which may be provided for convenience in a commercial form of engine containing the invention, but all such are left to be supplied by the designer from facts available to those acquainted with the art. Hence I have shown as integrally connected parts a cylinder 11, with an interior partition 12, an auxiliary cylinder 13, and a connection 14 between the cylinder and auxiliary cylinder, although in practice these elements may be made of a number of parts suitably fastened together.

The cylinder 11 has a head 15 containing a port 16 controlled as to opening and closing by a valve 17 which may be operated by any effective mechanism to be opened during the suction and exhaust strokes and to be closed during the compression and working strokes of the engine. The partition 12

above mentioned partly divides the combustion chamber 18 within the cylinder head from the balance of the cylinder, but has a large opening 19 in its central part of sufficient area to permit free flow back and forth through it of air and products of combustion, without substantial impedance. It is located close to the point reached by the head end of the piston at the end of its compression and exhaust strokes. A number of passages 20 lead through the head from the cylinder proper and open into the space 18 through radial jet orifices 21 located approximately in a plane midway between the partition 12 and the valve 17, whereby jets are driven through said passages in the manner presently described which converge at and around the central point of the chamber. Said passages may be considered as by-pass channels which conduct air around the outer parts of the partition to the combustion space when the interior opening is obstructed, as presently explained.

22 represents the piston which reciprocates in the cylinder in the usual manner and has a boss 23 adapted to enter and substantially fill the hole 19 at the end of the piston travel toward the cylinder head, the surface of the cylinder surrounding such boss being at those times nearly in contact with the partition 12.

The chamber 10, formed between the walls and head of the auxiliary cylinder 13 and the piston 26 therein, is in communication with the combustion space 18 by a passage 24 through the connection 14, which extends in line with one of the jet orifices 21. This auxiliary chamber extends past the communicating passage 24 in the direction of the compression strokes of the engine. Its head end is slightly enlarged in diameter beyond the shoulder 25. An auxiliary piston 26 operates in this auxiliary cylinder and so closely fits the interior thereof, except the enlarged part, that, while it may be reciprocated freely, no appreciable leakage of gas and fuel oil past it is permitted. A zone 27 of the surface of the auxiliary piston somewhat removed from the extreme end thereof is knurled, the knurling providing a multiplicity of intersecting helical shallow grooves; and at the lower limit of the knurled zone is an encircling deeper groove 28, from which there passes a longitudinal groove 29 in the side next to the passage 24.

In the side of the auxiliary cylinder is a fuel inlet 30 adapted to be supplied with oil by a pump or a control valve, or any other means which may be operated periodically to cause or permit injection of a regulated quantity of fuel oil at given times. I have not shown such pump or other means, for I may use for the purpose of supplying oil in the manner indicated, various devices already known and used in connection with high compression engines. The pipe 31 coupled to the fuel inlet passage typifies generally any means which may be provided for delivery of oil. This fuel passage is located below the communicating passage 24 on an inclination such that its axial line crosses the line of said communicating passage close to the entrance of the latter into the auxiliary chamber.

It is to be understood that the piston 22, which may for the purposes of this description be called the main engine piston, is coupled by a connecting rod and crank in the usual way, or by equivalent means, with a crank shaft, and that the auxiliary piston is driven from the crank shaft by mechanism which causes it to travel in general in the same directions with the main piston but with a variation in speed relatively thereto in different parts of the stroke. I may use various mechanisms for driving the auxiliary piston, such for example, as the mechanism illustrated in my pending application for Letters Patent of the United States Serial Number 259,974 filed October 28, 1918 entitled Internal combustion motors. Such mechanism causes the auxiliary piston to travel (in proportion to its displacement) relatively slower than the main piston during the first part of the compression stroke, and relatively faster during the last part of such stroke and to lag behind the main piston at the completion of the compression stroke. Preferably the auxiliary piston reaches the end of its compression stroke when the main piston crank has run past the dead point 15° of the cycle after full compression. This lagging of the auxiliary piston is provided merely to avoid generation of excessive explosion pressure when running at low speeds, and it may be greater or less than the degree indicated, or there may be no lag at all. Preferably also the auxiliary piston approaches the head of its cylinder with no appreciable clearance in order that substantially all of the gas and fuel oil trapped in said cylinder may be expelled therefrom and injected into the combustion space.

The position on the auxiliary piston and width of the grooved zone 27, the position of the encircling groove 28, and the length of the longitudinal groove 29 are determined with reference to the time and duration of the fuel injection. Hence the upper limit of the knurled or grooved zone 27 crosses the shoulder 25 and and the groove 28 begins to register with the passage 29 at about the same time, which is approximately the instant when the boss or projection 23 on the main piston begins to enter the opening 19 in the partition 12; and the groove 29 is made long enough to maintain communica-

tion between the passage 24 and groove 28 throughout the entire balance of the compression stroke of the auxiliary piston.

The mode of operation of the engine equipped with this invention is as follows. Commencing with the suction stroke:—The valve 17 is then open and air is then drawn into the main cylinder, and into the auxiliary cylinder also when the piston therein has traveled far enough to uncover the passage 24. During this stroke the variations in speed of the auxiliary piston relatively to the main piston are unimportant, since the purpose and result of the suction stroke is to fill both cylinders with air. The auxiliary piston moves far enough to uncover the orifice of the fuel passage 30, and at some time while this orifice is so uncovered a regulated quantity of fuel oil is injected through the passage 30. Owing to the inclination of this passage the stream of oil is thrown across the current of air coming through the passage 24, whereby a certain amount of mixing of fuel and air then takes place.

On the compression stroke the main piston first travels relatively faster than the auxiliary piston, as previously stated, whereby a certain amount of the air in the main cylinder is transferred to the auxiliary cylinder, the valve 17 being then closed. Before the auxiliary piston begins to travel faster than the main piston, or at any rate before its acceleration over the main piston has become great enough to cause any appreciable return flow of air into the main cylinder, it crosses and closes the entrance to the passage 24. It is possible to cause closing of this passage in this manner to take place at any exactly determined point simply by properly determining the length of the auxiliary cylinder extension beyond the passage and of the corresponding part of the auxiliary piston, because these dimensions can be made of any value without causing any modification of construction or adjustment of the auxiliary piston driving mechanism.

At this time the air pressure in the two cylinders is the same, but thereafter the more rapidly (in proportion to its displacement) traveling auxiliary piston compresses the air in the auxiliary cylinder more and more highly above the pressure in the main cylinder.

At first during the compression in the main cylinder air passes into the combustion space mainly through the large opening 18, but when the projection 23 approaches and enters such opening possibility of flow therethrough is substantially excluded and the air trapped between the projection, the flanking end wall of the piston, and the partition, is then forced to flow through the passages 20, and is violently impelled through the jet orifices 21 toward the center of the combustion chamber. About at the time when this action commences, the grooved zone 27 commences to cross the shoulder 25 bounding the enlarged chamber in the head part of the auxiliary cylinder, whereupon oil under pressure of the air entrapped in said chamber is forced in many zigzag channels through the grooves of the knurling to the encircling groove 28, and thence through the passage 24. The passage of the oil through these narrow zigzag channels breaks it up into as small particles as is practically possible to be done mechanically, and the high and increasing pressure of air above the piston propels these particles with great velocity and compels an intimate mingling of air with them. Part of the fuel is vaporized and that which remains unvaporized is divided into minute particles. The small volume of the maximum charge of oil, less than sufficient to fill completely the grooves of the knurling, the more sluggish character of the oil flow than of the air flow, the tendency of the oil to lag in contact with the metal surfaces, and the splitting up of the liquid bodies by the groove intersections, all contribute to cause mixing of air in a thorough and intimate way with the separated particles of liquid and vaporized oil, whereby the matter which enters the deep encircling groove 28 and streams through the communicating passage into the combustion chamber is an intimate mixture of fuel and air.

This stream of air and oil particles violently forced through the communicating passage mingles with the stream of air flowing through the nearest one of the by-pass channels 20, 21 and is carried with the air stream into the center of the combustion chamber. As all of the air then in contact with the fuel is compressed to a temperature higher than the ignition temperature, the oil is ignited. Combustion in large measure commences at the center of the combustion space, where the streams of air from the by-pass channels meet; and by the agitation due to the meeting of these streams, the oil particles are thoroughly dispersed and mixed with air. At the same time the heat generated forces flow of the gases at high velocity from the center throughout the whole combustion space. By this means, namely, agitation of the air and central initial combustion, a rapid and thorough intermingling of fuel particles and air is accomplished and the fuel is completedly burned in the limited time of the subsequent working stroke of the engine and without requiring any large excess of air.

Although the air in the auxiliary chamber is heated by compression above the fuel ignition temperature before injection commences, that is no detriment because the

quantity of air is not sufficient to burn any large proportion of the fuel, while the heat thereby generated is of advantage in causing instantaneous ignition when the fuel enters the combustion space. Injection of fuel, of course, continues until the auxiliary piston has reached the end of its stroke.

The balance of the cycle of the engine is unimportant so far as this invention is concerned, consisting of working and exhaust strokes carried out in a manner common to internal combustion engines. On the exhaust stroke, of course, the auxiliary piston displaces the spent gases which have entered during the working stroke, in the same way that it displaces air and fuel oil upon the compression stroke, whereby complete scavenging of the spent gases takes place.

The invention embodied in the means here described may be applied to an engine of any number of cylinders; and any working cylinder may have a plurality of auxiliary cylinders, or the same auxiliary cylinder may inject fuel into more than one cylinder in the case of an engine having so large a number of cylinders that more than one have their events in common.

The foregoing explanation has been given as of the application to an engine operating on the four stroke cycle, but the essential principles of means for injecting the fuel and agitating and mixing fuel and air are applicable to two cycle engines as well; and these same principles may be embodied in other mechanical forms and other proportions, dimensions, and arrangements than the specific ones here shown. Therefore I do not restrict the scope in which I claim protection to the precise design shown; and of course no restriction is to be implied from the fact that the cylinder is shown upright rather than inverted, recumbent, or inclined, or from the words used in the specification indicating relative height, such as "above", "below", and so forth.

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

1. A fuel injection means for a high compression internal combustion engine, comprising the combination with the cylinder and piston of such an engine, of an auxiliary chamber, a transfer passage between said auxiliary chamber and the combustion space of said cylinder, and an auxiliary piston working in the auxiliary chamber closely fitting the same and adapted at one end to cross the entrance from said chamber of the transfer passage, the auxiliary chamber having an enlarged portion between said passage and its head and the piston having a zone carrying a multiplicity of intersecting grooves arranged to establish communication between said enlarged portion and the transfer passage when the auxiliary piston nears the head of the auxiliary chamber.

2. A high compression internal combustion engine comprising in combination with the main cylinder and piston, an auxiliary chamber closed at one end, a piston working therein, means for delivering oil fuel into the auxiliary chamber between its closed end and the adjacent end of the latter piston, and a communicating passage leading from the side of the auxiliary chamber to the combustion space of the main cylinder, the auxiliary piston being arranged to cross said passage and constructed to cause mechanical subdivision of the fuel in its flow from said closed end part of the auxiliary chamber to said passage.

3. A high compression internal combustion engine comprising the combination with a main cylinder and a piston, of an auxiliary cylinder, a transfer passage from the combustion chamber of said main cylinder to the side of the auxiliary cylinder, a fuel oil inlet passage in the side of the auxiliary cylinder extending in a line crossing the prolongation of the transfer passage within the auxiliary cylinder, an auxiliary piston working in the latter cylinder adapted to cross the inner orifices of both said passages and having its external surface formed to permit flow past it of oil and air from the head end of the auxiliary cylinder through the transfer passage in numerous fine and obstructed streams.

4. A fuel injection means for an internal combustion engine comprising a chamber adapted to receive air and oil, a piston fitting approximately leakage tight in said chamber, and a transfer passage leading from the side of the chamber, the piston having a zone provided with numerous shallow and narrow intersecting grooves forming zigzag channels, the diameter of the chamber being enlarged near its end to provide an annular space giving access to said channels.

5. A fuel injection means for an internal combustion engine comprising a chamber adapted to receive air and oil, a piston fitting approximately leakage tight in said chamber, and a transfer passage leading from the side of the chamber at a point where its entrance orifice is traversed by the end part of said piston, the piston having in its side a zone provided with numerous shallow and narrow intersecting grooves forming zigzag channels, the diameter of the chamber being enlarged near its end to provide an annular space giving access to said channels, and said piston having also an encircling groove into which said channels lead and a longitudinal groove adapted to register with the transfer passage.

6. An internal combustion engine com-

prising a main cylinder and piston, an auxiliary cylinder and piston adapted to receive air and fuel oil, a transfer passage from the auxiliary cylinder into the main cylinder directed toward the center of the combustion space in the latter, means for actuating the auxiliary piston to expel compressed air and fuel oil through said passage at the time of highest compression in the main cylinder, and guiding means in the main cylinder arranged to cause streams of air undergoing compression therein by the main piston to meet in the neighborhood of the center of said combustion space, whereby to cause agitation of the air and fuel in such space at the time of fuel injection.

7. An internal combustion engine of the high compression type comprising in combination with a main cylinder and a piston, an auxiliary cylinder, a transfer passage adapted to conduct air between the main cylinder and the auxiliary cylinder, a fuel inlet to the auxiliary cylinder arranged to direct a stream of liquid fuel across the stream of air flowing through said transfer passage into the auxiliary chamber, and a piston operable in said auxiliary cylinder to displace mingled air and fuel therefrom into the main cylinder.

8. An internal combustion engine of the high compression type comprising in combination with a main cylinder and piston, an auxiliary cylinder, a transfer passage adapted to conduct air from the main cylinder to the auxiliary cylinder, means for supplying liquid fuel to the auxiliary cylinder, and a piston operating in the auxiliary cylinder to compress the air therein and to force the fuel by pressure of the air so compressed through said transfer passage into a body of highly compressed air in the main cylinder, the piston having means for mechanically subdividing the fuel.

In testimony whereof I have affixed my signature.

EUGENE A. FORD.