March 8, 1927. 1,619,825

C. E. LUCKE

INTERNAL COMBUSTION ENGINE

Filed July 25, 1921 2 Sheets-Sheet 1

Fig. 1.

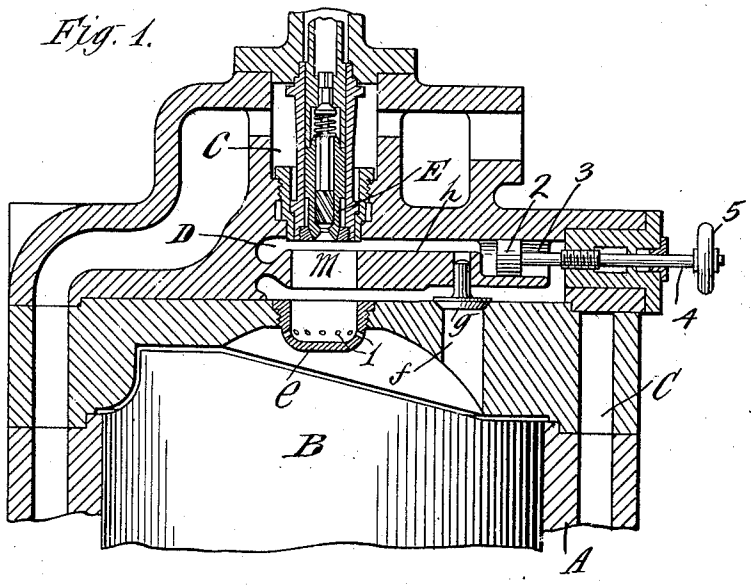

Fig. 2.

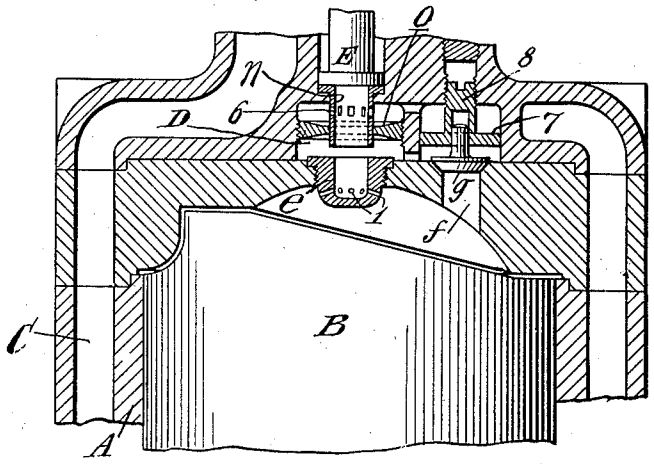

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Fig. 3.

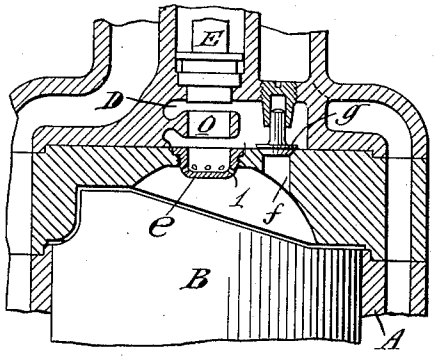


Fig. 4.

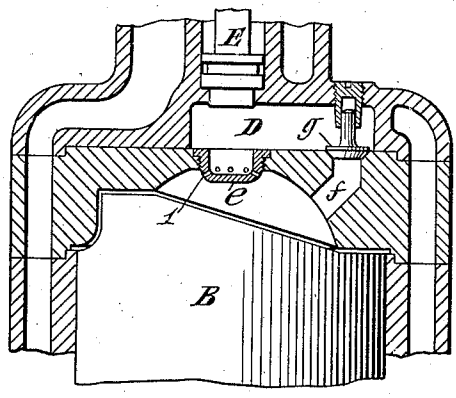
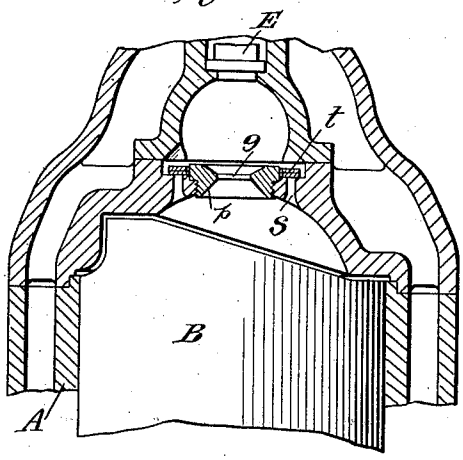


Fig. 5.



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UNITED STATES PATENT OFFICE.

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INTERNAL-COMBUSTION ENGINE.

Application filed July 25, 1921. Serial No. 487,260.

This invention relates to the feeding and vaporization of fuel in internal combustion engines, and is particularly applicable to that class of engines operating on the Diesel or constant pressure system.

The especial object of the invention is to provide an apparatus and method employing solid injection of the oil or other liquid or solid fuel, by which the proper feed of the fuel to the cylinder for securing the maximum power and economy may be attained. The specific means used for this purpose falls within the class of precombustion fuel supply by which partial combustion occurs in a precombustion chamber communicating with the cylinder, and the fuel is gradually fed to the cylinder by the relative pressures in the precombustion chamber and cylinder, and the particular object is to control the time, rate and amount of combustion in the precombustion chamber and the time and rate of fuel feed to the cylinder independently of the character and rate of fuel feed to the chamber, so as to secure the results desired.

The present invention includes especially two features which are important in securing the results desired. One feature consists in the provision of means for assuring a high pressure being attained in the precombustion chamber during compression, notwithstanding the restriction of the opening between the cylinder and precombustion chamber that is desirable for securing the proper fuel feed to the cylinder, this result being secured by a pressure equalizing non-return connection between the cylinder and precombustion chamber which is open during compression but closed during the feeding of fuel to the cylinder. The air compressed into the precombustion chamber is thus at the high pressure of the cylinder, and prompt delivery of fuel to the cylinder upon stoppage or reversal of the piston is thus secured. Another feature consists in providing for reserving a portion of the air in the precombustion chamber behind the fuel, so that this air by expansion secures the complete expulsion of the fuel from the chamber to the cylinder and scavenges the chamber, creates currents in the cylinder that aid in securing fuel contact with the air, and supplies air to support combustion later in the stroke than otherwise possible, while the other portion of the air near the fuel opening to the cylinder, or a portion thereof, combines with the fuel to secure vaporization or gasification of the fuel with the partial combustion and increase of pressure desired. The air in the precombustion chamber is thus divided into a body of fuel-combining air near the fuel feed opening to the cylinder, and a body of fuel-displacing air in the outer part of the chamber, and means preferably are provided for adjusting the relative amounts of air in these bodies so as to secure the results desired under different engine conditions.

Fuel is injected into the precombustion chamber during or about the end of compression, and preferably near the end of the compression stroke and after the air has been compressed to igniting temperature. The arrangement of the spray is such that the fuel is wholly or largely delivered to the fuel-combining air near the fuel feed opening to the cylinder and thus the fuel, wholly or partially vaporized or gasified, is positioned in the part of the chamber next to the cylinder opening, and prompt ignition and combustion thus secured at the time the reverse flow of air to the cylinder begins on the completion of the compression stroke and the stoppage or reversal of the piston. The chamber may be provided with fuel guards or other devices against which the fuel is injected and which aid in vaporizing or gasifying the fuel and in restricting contact of the fuel and air, or the precombustion chamber may be an open space without such tubes or devices of any kind. The partial combustion in the precombustion chamber increases the pressure of the air and vapor in the chamber, or, on later injection, prevents undue falling of the pressure in the precombustion chamber, and upon stoppage or reversal of the piston the fuel, in the form of vapor and possibly some liquid, is fed gradually to the cylinder combustion space by the flow from the precombustion chamber, first by the pressure in the portion of the precombustion chamber next the cylinder opening, and then by the expanding air in the outer portion of the chamber, until all the fuel is consumed.

For a full understanding of the invention, a detailed description of constructions embodying and for carrying out the invention in the best forms now known to me, will now be given in connection with the accom-

panying drawings forming a part of this specification, and the features forming the invention then be specifically pointed out in the claims.

In the drawings—

Figure 1 is a central section through the cylinder head, precombustion chamber and oil injection nozzle, showing the piston in elevation, the engine being shown as of the two-cycle type, and

Figures 2, 3, 4 and 5 are partial sections corresponding to Fig. 1 and showing modifications.

Referring now particularly to Fig. 1, A is the engine cylinder, B the piston, C the cooling or water jacket, D the precombustion chamber, and E the oil injection nozzle mounted on the cylinder head through which the oil is forced by a suitable pump. This oil injection nozzle is shown as of the well-known type adapted to deliver the oil in a coned spray at a suitable angle, but it will be understood that any other suitable form of nozzle securing similar results may be used. The nozzle is jacketed as usual by extension *c* of cylinder jacket C.

The cylinder head is provided with an opening preferably opposite the nozzle E, as shown, which opening receives a plug *e* which carries the fuel feed opening, this opening being shown as consisting of small perforations 1 arranged to distribute the fuel through the cylinder space and approximately parallel to the piston face. The openings 1 form a restricted opening between the cylinder and precombustion chamber through which air is forced during the compression stroke of the piston. With the small openings desired for gradual fuel feed to the cylinder, however, the pressure in the precombustion chamber may lag behind the pressure in the cylinder, and to avoid this a pressure equalizing passage *f* controlled by valve *g* is shown connecting the cylinder with the precombustion chamber during the compression stroke, while excess pressure in the precombustion chamber will close the valve *g* for a restricted fuel feed from the precombustion chamber to the cylinder through openings 1. The precombustion chamber is divided horizontally by a partition *h*, and the two bodies of air above and below the partition are connected by opening *m* into and through which the fuel is sprayed from nozzle E, the wall of this opening *m* thus forming a tube, and the fuel may be sprayed against the hot wall of the tube to aid in vaporization or gasification. There are thus formed two bodies of air, one body of fuel-combining air below the partition which receives the fuel so as to form a cloud of vaporized or gasified fuel within and near the plug *e*, and a body of fuel-displacing air behind the fuel or in the outer part of the chamber. The relative amounts of air in the two bodies may be adjusted by piston 2 moving in cylinder 3 and adjustable by stem 4 operated by handle 5 outside the engine, so that adjustment may be made while the engine is running.

The construction shown in Fig. 2 is similar to that shown in Fig. 1, except that a separate tube *n* receives the fuel spray in the precombustion chamber, and the space within the chamber is divided by an adjustable partition *o* surrounding the tube, so that the two bodies of air above and below the partition may be adjusted by shifting the partition along the tube. The tube is shown as having the usual open lower end opposite the cartridge *e* and the series of openings 6 above the partition through which the expanding fuel-displacing air passes to the tube. In Fig. 2, adjustment of the amounts of air in the two bodies may be secured while the engine is running, by piston 7 having screw stem 8 which acts as a guide for the stem of valve *g*.

The construction shown in Fig. 3 secures to a partial extent the air division, but not so positively as the construction shown in Figs. 1 and 2. The fuel is largely segregated at and near the cartridge *e*, however, and the air above the tube *o* and in the portion of the chamber most removed from the cartridge, will secure the advantages of the construction in Figs. 1 and 2 to an important extent.

In the construction shown in Fig. 4, the fuel is segregated near the cartridge, and the air divided only by the elongated form of the chamber, the spray and cartridge being at one end, thus providing a considerable body of air which is not reached directly by the spray. The pressure equalizing connection *f* and valve *g* are preferably positioned as far as conveniently possible from the spray and cartridge so as to protect the valve from heating.

Figure 5 illustrates another form of fuel feed opening and equalizing connection without the air division. In this construction the fuel feed opening 9 is formed in a thin partition so that the walls of the opening are short and thus the action of a flow passage in a comparatively thin plate is secured. From this thin partition the walls taper outwardly for increased thickness, thus securing the desired strength and thermal conductivity, and the form preferably is of a nozzle coned on one or both sides of the opening so as to provide a nozzle producing a smooth uniform jet. The equalizing connection *s* in this case is formed by a series of ports arranged annularly about the plug *p* and closed by a light plate valve *t*.

The general operation of the construction shown in Figs. 1 and 2 is the same and as follows: The fuel is injected through the

nozzle E in a fine spray and is vaporized or gasified by contact with the hot compressed air, the action being aided by contact with the inner wall of the tube, and partial combustion follows within the tube and in that portion of the chamber next the plug *e*, the air in the precombustion chamber forced into the cylinder being then at high compression, the connection *f* with its open valve *g* assuring free passage of the air from the cylinder to the precombustion chamber during compression. Prompt ignition and combustion is thus started when or before the reverse flow from the cylinder begins on reversal of the piston and the increased pressure in the precombustion chamber closes the valve *g*. Upon reversal, therefore, there will be a flow of vapor and possibly liquid from the inner portion of the precombustion chamber through the openings 1 into the cylinder and the combustion in the precombustion chamber and expansion of the air above the partition *h* or *o* will sustain the pressure in the precombustion chamber during this outflow to maintain a vigorous flow until all the fuel has been fed to the cylinder and consumed.

Thus, instead of a violent explosion or sudden pressure rise in the precombustion chamber, there will be a slow rise of pressure if the injection occurs sufficiently before dead center, producing and maintaining a flow of fuel and expanding air from the precombustion chamber into the cylinder, thus securing the graduated fuel feed to the cylinder and air supply from the chamber that is desired for producing and maintaining combustion for a considerable time, in spite of the fact that the fuel pump may have injected all of the fuel into the chamber instantaneously. If the injection takes place later, there may be no rise of pressure in the precombustion chamber, but the required relative pressures between the precombustion chamber and the cylinder will be secured by the outward movement of the piston coacting with the combustion in the precombustion chamber acting to sustain the relative pressures therein and thus substantially the same results be secured as with a rise of pressure in the precombustion chamber on earlier injection. The construction will operate well with a timed pump and inaccuracies in the timing of the latter will be compensated for to such an extent that the use of a less delicate and troublesome pump apparatus is permitted than with many other forms of fuel feed, and at the same time suitable control of internal pressures of the engine is secured.

The general operation of the constructions shown in Figs. 3 and 4 is the same as above described, except that the air division is not so complete and positive in the construction shown in Figs. 3 and 4 and the fuel displacing and scavenging action of the air is less secured. The general operation of the engine, apart from the air division, is the same in connection with Fig. 5 as above described.

While the invention has been described in connection with solid injection of fuel and an especial object of the invention is to provide a satisfactory engine of this character, it will be understood that the invention is applicable also with compressed air spraying of fuel to the precombustion chamber and is thus claimed.

The invention is not to be limited to the specific form and construction of devices shown, but many modifications may be made therein by those skilled in the art while retaining the invention defined by the claims.

What is claimed is:

1. In an internal combustion engine, the combination with a precombustion chamber having a fuel feed opening to the cylinder and means for injecting fuel into the chamber during or about the end of compression to secure limited combustion and feed of fuel to the cylinder by the relative pressures in the chamber and cylinder, of a pressure equalizing connection between the chamber and cylinder open during compression, means for closing said connection during the feeding of fuel to the cylinder, and means for dividing the air compressed in the chamber into a body of fuel-combining air near the fuel feed opening and a body of fuel-displacing air behind the fuel.

2. In an internal combustion engine, the combination with a precombustion chamber having a fuel feed opening to the cylinder and means for injecting fuel into the chamber during or about the end of compression to secure limited combustion and feed of fuel to the cylinder by the relative pressures in the chamber and cylinder, of a pressure equalizing connection between the chamber and cylinder open during compression, means for closing said connection during the feeding of fuel to the cylinder, means for dividing the air compressed in the chamber into a body of fuel-combining air near the fuel feed opening and a body of fuel-displacing air behind the fuel, and means for adjusting the amounts of air in the bodies.

3. In an internal combustion engine, the combination with a precombustion chamber having a fuel feed opening to the cylinder and means for injecting fuel into the chamber during or about the end of compression to secure limited combustion and feed of fuel to the cylinder by the relative pressures in the chamber and cylinder, of a pressure equalizing connection between the chamber and cylinder open during compression, means for closing said connection during the feeding of fuel to the cylinder, means for dividing the air compressed in the chamber into a body of fuel-combining air near the fuel feed opening and a body of fuel-displac-

ing air behind the fuel, and means for adjusting the amounts of air in the bodies while the engine is running.

4. In an internal combustion engine, the combination with a precombustion chamber having a restricted fuel feed opening to the cylinder, of a fuel tube in the chamber, means for injecting fuel into the tube, and a partition surrounding the tube and dividing the air in the chamber into two bodies, one near the fuel feed opening and the other in the outer part of the chamber.

5. In an internal combustion engine, the combination with a precombustion chamber having a restricted fuel feed opening to the cylinder, of a fuel tube in the cylinder, means for injecting fuel into the tube, and a partition surrounding the tube and dividing the air in the chamber into two bodies, one near the fuel feed opening and the other in the outer part of the chamber said partition being adjustable to vary the amounts of air in the two bodies.

6. In an internal combustion engine, the combination with a precombustion chamber having a restricted fuel feed opening to the cylinder, of a fuel tube in the cylinder, means for injecting fuel into the tube. a partition surrounding the tube and dividing the air in the chamber into two bodies, one near the fuel feed opening and the other in the outer part of the chamber, a pressure equalizing connection between the chamber and cylinder, and a valve acting to close said connection during the feed of fuel to the cylinder.

7. In an internal combustion engine, the combination with a precombustion chamber having a fuel feed opening to the cylinder and means for injecting fuel into the chamber during or about the end of compression to secure limited combustion and feed of fuel to the cylinder by the relative pressures in the chamber and cylinder, of means for dividing the air compressed in the chamber into a body of fuel-combining air near the fuel feed opening and a body of fuel-displacing air behind the fuel, and means for adjusting the amounts of air in the bodies.

8. In an internal combustion engine, the combination with a precombustion chamber having a fuel feed opening to the cylinder and means for injecting fuel into the chamber during or about the end of compression to secure limited combustion and feed of fuel to the cylinder by the relative pressures in the chamber and cylinder, of means for dividing the air compressed in the chamber into a body of fuel-combining air near the fuel feed opening and a body of fuel-displacing air behind the fuel, and means for adjusting the amounts of air in the bodies while the engine is running.

9. In an internal combustion engine of that class having a precombustion chamber in communication with the cylinder and from which the fuel is fed to the cylinder by the relative pressures in the chamber and cylinder, the combination with the chamber, of fuel-injecting devices co-acting with the chamber to spray a charge of fuel into the compressed air near the cylinder opening, during or about the end of compression in such a manner as to secure partial combustion of the fuel in that part of the chamber near the opening with a body of fuel-displacing air in that part of the chamber remote from the opening, whereby the expansion of the fuel-displacing air behind the fuel secures the feed of all the fuel to the cylinder on the working stroke, a pressure equalizing connection between the chamber and cylinder open during compression, and means for closing said connection during the feeding of fuel to the cylinder.

In testimony whereof, I have hereunto set my hand.

CHARLES E. LUCKE.