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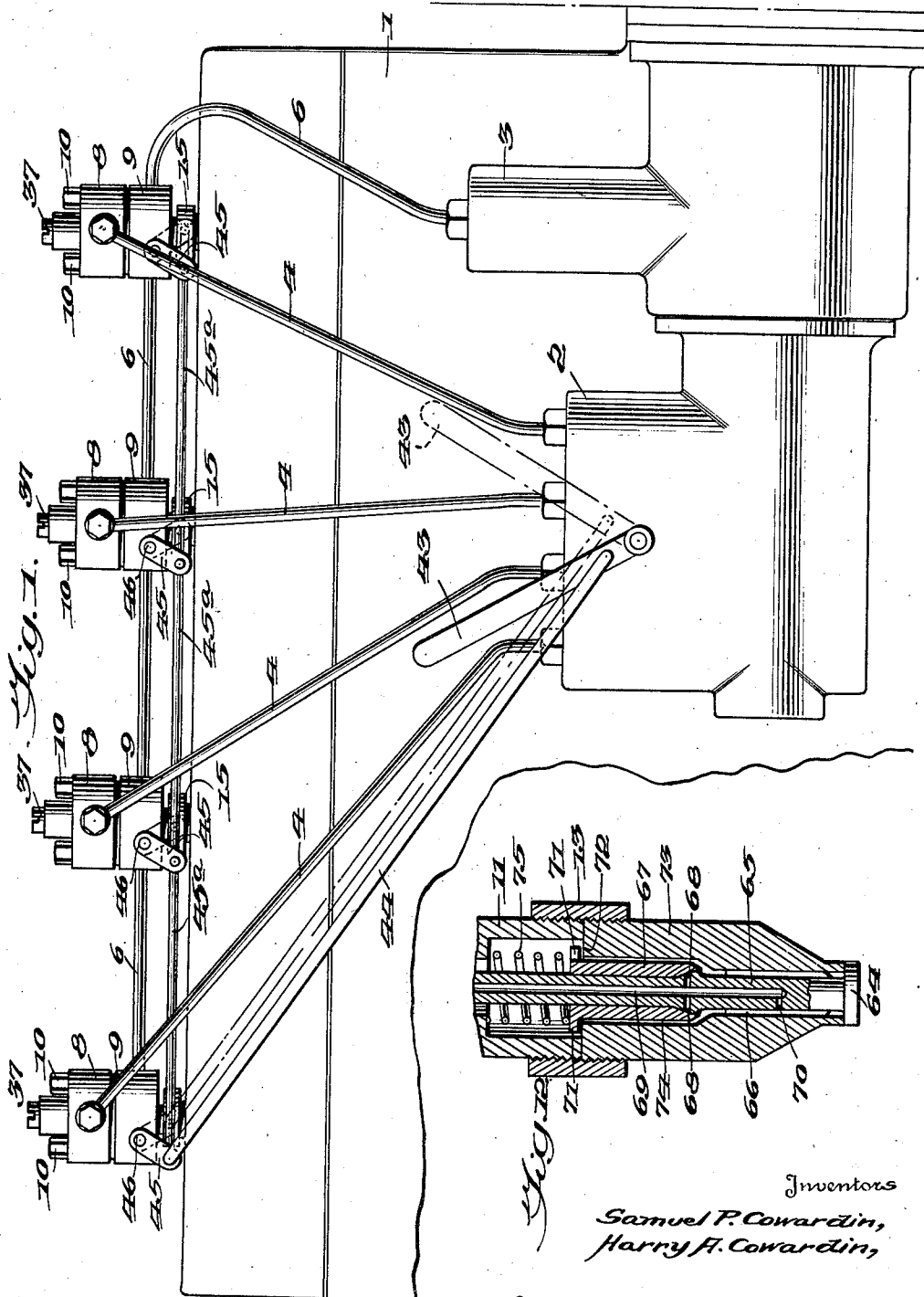
S. P. COWARDIN ET AL

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APPARATUS FOR INJECTING FUEL INTO INTERNAL COMBUSTION ENGINES

Filed Aug. 26, 1937

3 Sheets-Sheet 1



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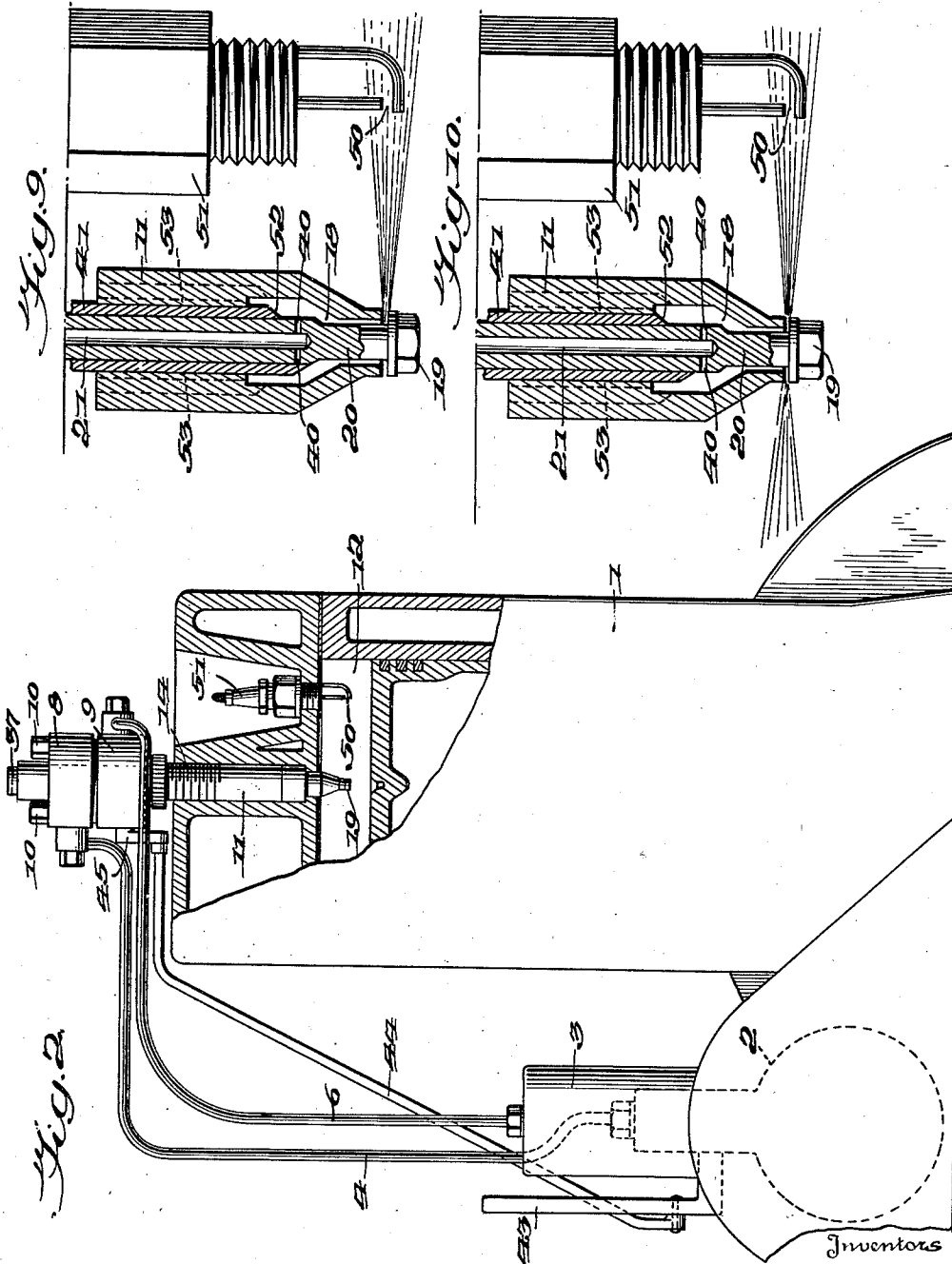
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3 Sheets-Sheet 2



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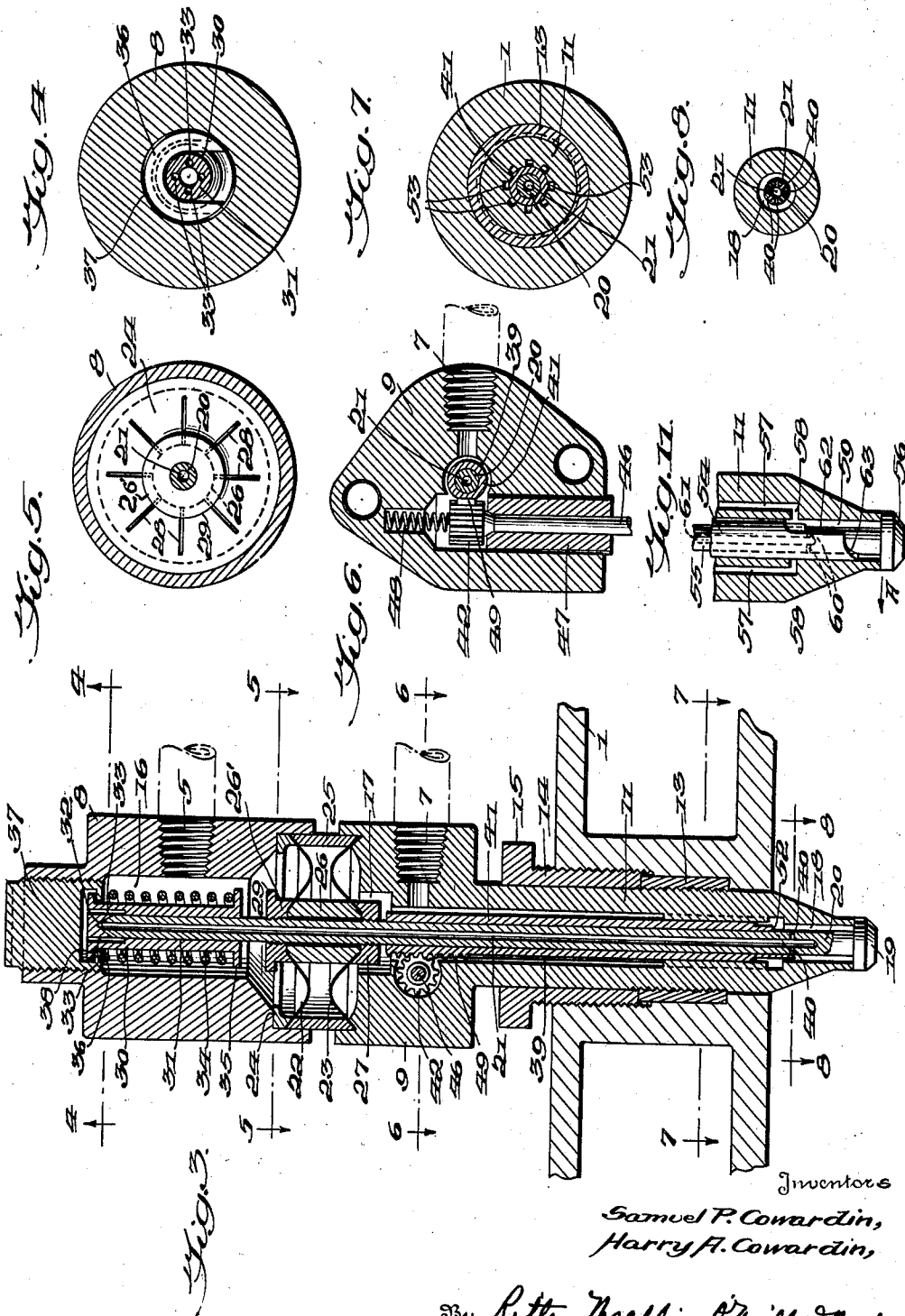
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3 Sheets-Sheet 3



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# UNITED STATES PATENT OFFICE

2,229,552

## APPARATUS FOR INJECTING FUEL INTO INTERNAL COMBUSTION ENGINES

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5 Claims. (Cl. 123-32)

Our invention relates to fuel injectors for internal combustion engines and to a method of injecting fuel into the engine.

A principal object of the invention is to insure complete combustion of the fuel injected into the engine whether the engine is under full load or part load or is merely idling.

Another object of the invention is to provide an injector of such construction that gases which may be trapped therein or in the fuel line will be carried through the injector and discharged into the combustion chamber of the engine so as to eliminate the necessity of employing bleeder valves or other mechanism for releasing the trapped gases.

A further object of the invention is to provide an injector which will effectively prevent the leakage of gas into the fuel line and the leakage of fuel into the air line.

Other objects of the invention are to seal the moving parts of the injector so as to prevent leakage of fuel or of injection air and to prevent carbonization of the fuel in the discharge end of the injector.

A primary feature of the invention consists in providing an injector with means responsive to variations in the amount of fuel supplied thereto for causing the fuel to be sprayed in a limited area toward the spark gap of a spark plug when the engine is idling and for spraying the fuel over a greater area when the engine is under load.

Another feature of the invention consists in providing an injector adapted to spray fuel in a restricted area in the vicinity of the spark gap of a spark plug when the engine is idling with means for causing the spray of fuel to spread progressively over greater areas as the load on the engine increases.

A further feature of the invention consists in providing the injector with means whereby air alone is discharged from the injector prior to the discharge of a mixture of air and oil.

A still further feature of the invention resides in providing an injector with a valve normally preventing the passage of fuel to a chamber in which the fuel is admixed with air and in further providing means controlling the discharge of the air and oil mixture which, upon being moved to open position, renders the valve inoperative so that oil is permitted to flow to the mixing chamber.

A still further feature of the invention consists in providing an injector with an oil chamber disposed above an air chamber which is provided

adjacent its lower end with a chamber in which the oil and air are mixed, the injector having a passageway the entrance to which is disposed adjacent the top of the oil chamber through which oil is adapted to flow to the mixing chamber.

Still another feature of the invention consists in providing an injector with means for feeding fuel into a rapidly moving stream of air which forms an insulating envelope or layer between the fuel and the surrounding portions of the discharge end or tip of the injector so as to prevent carbonization of fuel inside of the tip.

Other and more specific features of the invention, residing in advantageous forms, combinations and relations of parts, will hereinafter appear and be pointed out in the claims.

In the drawings, illustrating preferred embodiments of the invention,

Figure 1 is a side elevational view of a portion of an internal combustion engine provided with injectors embodying our invention.

Figure 2 is an end view of the engine, a portion thereof being broken away to illustrate the location of the injector.

Figure 3 is a vertical sectional view of an injector illustrating the preferred embodiment of the invention.

Figures 4, 5, 6, 7 and 8 are transverse sectional views taken on lines 4-4, 5-5, 6-6, 7-7 and 8-8, respectively of Figure 3.

Figure 9 is an enlarged detail sectional view of the lower or discharge end of the injector, the movable parts thereof being shown in the positions for restricting the fuel discharge therefrom to the vicinity of the spark gap of a spark plug, a portion of the plug being shown in elevation.

Figure 10 is a view similar to Figure 8, the movable parts of the injector being shown in the positions they occupy when fuel discharging therefrom is distributed in a substantially circular spray.

Figure 11 is a vertical sectional view of the lower end of an injector illustrating a modified form of the invention.

Figure 12 is a vertical sectional view of the lower end of an injector illustrating still another modification of the invention.

Referring more particularly to the drawings, 1 indicates an internal combustion engine of conventional construction, 2 a metering pump for liquid fuel, and 3 an air pump. As the engine chosen for purposes of illustrating the invention is of the four cylinder type, it is shown in Figure

1 as being provided with four injectors of identical construction, one for each cylinder. Fuel from the metering pump is supplied to the injectors through lines or pipes 4 which respectively communicate with ports 5 in the upper portions of the injectors and air is supplied to the injectors through a single line or pipe 6 having a plurality of branches which respectively communicate with ports 7.

The injectors are each preferably formed in two main sections, an upper section 8 and a lower section 9, which are rigidly connected by bolts 10. The lower section is provided with a tubular-like portion 11 which extends through an opening in the head of the cylinder with which it is associated so that the lower end thereof which forms the discharge end or tip of the injector projects into the combustion chamber 12 of the cylinder. The exterior of the tubular portion 9 is screw threaded to receive a sleeve 13 which rests upon a shoulder formed in the opening of the cylinder head and thus serves as an adjustable support for the injector. Threaded within the opening in the cylinder head is another sleeve 14 which is adapted to bear against the upper end of sleeve 13 and thus firmly secure the injector to the cylinder. Sleeve 14 may be advantageously formed at its upper end with a flange 15, the periphery of which is suitably shaped to receive a wrench or the like whereby it may be conveniently rotated.

The upper section 8 of the injector is provided with a fuel chamber 16 communicating with port 5 and the lower section 9 is provided in its upper portion with an air chamber 17 communicating with port 7 and in its lower portion with a chamber 18 in which the air and fuel are mixed preparatory to being discharged from the injector. The discharge of the air and fuel mixture from the injector is controlled by a valve 19 which is provided with an elongated stem 20 which extends upwardly to adjacent the top of the fuel chamber 16 and is formed with a longitudinally extending bore or passageway 21 through which fuel is adapted to flow from the oil chamber to the mixing chamber.

Secured to the stem intermediate its ends are two oppositely arranged diaphragms 22 and 23, respectively, which, together with a spring washer 24 for normally maintaining valve 19 in closed position, are clamped at their peripheries between the two sections 8 and 9 of the injector. Diaphragm 22 is constantly subject to the pressure of the fuel within chamber 16 and diaphragm 23 is similarly subject to the pressure of the air in chamber 17. The outer portions of the diaphragms are separated by an annular spacer 25 and their inner portions are separated by a spacer 26 to which they are clamped by nuts or the like 26' and 27 which have screw thread connection with the valve stem 20.

The portion of each diaphragm which is exposed to the pressure to which it is responsive is curved in the arc of a circle or other curve and the portions thereof which are clamped to the injector body and to the valve stem are respectively tangent to the circular arc or other curve at the point of clamping. For this reason, the surfaces of all the members having clamping engagement with the diaphragm are preferably conical. Diaphragms constructed and clamped in this manner are less flexible adjacent the portions thereof which are clamped than adjacent the central portions thereof which are exposed to pressure. Such diaphragms are, therefore, not

subjected to excessive bending in the region of the clamped surfaces which has been the principal cause of so many diaphragm failures in the past.

The spring washer 24 which is clamped at its outer periphery between section 8 of the injector and diaphragm 22 is provided with a plurality of preferably radial slots 28, as clearly shown in Figure 5, and its inner portion is disposed beneath a flange 29 which projects laterally from the upper end of nut 26' which is connected to the valve stem 20. Nut 26' is so arranged on the valve stem with respect to the spring washer that the latter normally serves to maintain valve 19 in closed position but the washer is of such resiliency as to enable the valve to open when the pressure in the oil chamber exceeds a predetermined value.

Fuel is normally prevented from flowing through passage 21 in the valve stem into the mixing chamber by a valve 30 which is mounted upon the upper end of the valve stem. This valve has an elongated body portion 31 having a central bore for receiving the upper end of the stem, the bore terminating in a conical portion 32 adapted to seat on the conical end of the valve stem. Extending downwardly from the upper end of the valve are a plurality of openings 33 which communicate with the bore of the valve just below the conical portion thereof, so that, when the valve stem moves downwardly relatively to the valve, fuel may pass from chamber 16 through openings 33 and thence downwardly through passage 21 in the valve stem.

Valve 30 is normally maintained in closed position by a helical spring 34 which is compressed between an annular flange 35 projecting laterally from the lower end of the valve and an inturned flange 36 formed on the lower end of an adjustable nut 37 threaded into the top of the upper section of the injector. The inturned flange 36, which for purposes of assembly only partially encircles the upper portion of valve 30, projects beneath an annular flange 38 at the top of the valve and serves as an abutment for inducing relative movement between valve 30 and valve stem 20 when the latter moves downwardly. Nut 37 is preferably adjusted so that a slight space will intervene between its inturned flange 36 and the flange 38. Valve 30 will, therefore, move downwardly with the valve stem a limited distance and accordingly valve 19 will open prior to the opening of valve 30. It will thus be appreciated that air will discharge from the injector before the discharge therefrom of the air and fuel mixture and the adjustability of nut 37 enables more or less injection air to be used as may be desired. It will also be appreciated that, as valve 30 seats independently of valve 19, the leakage of air into the fuel line or the fuel into the air line is effectively prevented and that, since the entrance to the fuel passageway 21 is disposed at the top of the fuel chamber, any gases which might be trapped in the fuel line or the injector will be carried through the latter by the fuel and discharged into the combustion chamber of the engine.

In the operation of the device, fuel from the metering pump 2 enters chamber 16 through port 5 and gradually fills the chamber. It is prevented from entering passage 21 of the valve stem, however, by valve 30 and valve 19 remains closed until the pressure of the oil within the chamber exceeds a predetermined value. Injection air enters chamber 17 through port 7 pressing

up against diaphragm 23 and passing down through passage 39 to mixing chamber 18. It is prevented from discharging from the mixing chamber into the combustion chamber of the engine by valve 19.

After chamber 16 is full of fuel, additional fuel entering it on a stroke of the metering pump subjects diaphragm 22 to sufficient pressure to overcome the resistance of the spring washer 24 and the air pressure acting upon diaphragm 23 and thus moves stem 20 downwardly and causes valve 19 to open. This opening of valve 19 allows injection air to pass from the injector to the combustion chamber of the engine. During the initial downward movement of valve stem 20, valve 30 is held closed by the expansion of spring 34 until the flange 38 on the top of the valve comes into contact with the inturned flange 36 of the adjusting nut 37. Further downward movement of the valve stem results in opening valve 30 and allows fuel to pass from the fuel chamber through openings 33 in valve 30 into the passageway 21 in the valve stem from which it discharges through a plurality of preferably radially arranged ducts 40 into the mixing chamber 18 where it is atomized and carried into the combustion chamber of the engine by the surrounding stream of injection air. The return stroke of the metering pump relieves the pressure in chamber 16 and valve 19 is returned to closed position by the upward pressure of spring washer 24 and the air pressure acting upon diaphragm 23.

The greatest difficulty heretofore encountered in the operation of oil engines, particularly low pressure types, is in idling. This is primarily due to the fact that, because so little fuel is injected, an injector which is designed to produce a good mixture of fuel and combustion air at full load will produce a mixture which, when the engine is idling, is too lean to burn properly. Failure of the fuel to burn properly or at all causes smoke, irregular burning and excessive dilution of the lubricating oil in the engine.

We have devised means of overcoming this difficulty by concentrating and directing the fuel discharging from the injector, when the engine is idling, in the vicinity of the spark gap of a spark plug so as to produce a localized mixture sufficiently rich to burn with perfect regularity and cleanness. This means is responsive to variations in the amount of fuel supplied to the engine so that, as the load on the engine increases, the spray of fuel issuing from the injector broadens to prevent too great a concentration of the fuel, until in the upper range of loading the spray is distributed substantially uniformly in the combustion chamber to produce intimate mixture of the fuel with all the injection air.

In the preferred embodiment of our invention, this means includes a vertically movable sleeve 41 which surrounds the lower portion of the valve stem 20 and it is adapted to be raised and lowered by a pinion 42 which is movable through suitable mechanism in accordance with movements of the fuel control lever or throttle 43 of the engine. Movement of the throttle may be advantageously transmitted to the pinion by a rod 44 which is pivotally connected to an arm 45 rigid with a shaft 46 on which a pinion is fixedly mounted. Motion transmitted to the arm 45 of one injector may be conveniently communicated to the arms of other injectors by suitable linkage indicated at 45a. Shaft 46 may be conveniently journaled in a bearing 47 mounted in the body of the injector and a spring 48 is prefer-

ably interposed between the inner end of the shaft and the injector body to restrain longitudinal movement of the shaft and thus maintain the pinion in operative engagement with the rack 49 formed on the sleeve.

When the engine is idling, sleeve 41 is disposed in its lowermost position and as the load on the motor increases and more fuel is, therefore, supplied to the injector, the sleeve is gradually raised until, when the engine is under full load, it is in its uppermost position. The lower end of the sleeve is so formed, considering the arrangement and relative disposition of the ducts 40 through which fuel passes into the combustion chamber, that, when it occupies its lowermost position, it prevents passage of fuel through all but one or two of the ducts which are so disposed that the fuel passing therethrough will discharge from the injector in a restricted area in the vicinity of the spark gap 50 of a spark plug 51. The lower end of the sleeve is also of such shape that, as the sleeve moves upwardly in response to movement of the throttle to admit more fuel to the injector, it will successively uncover others of the ducts 40 until it assumes its uppermost position, at which time all of the ducts will have been uncovered. In this manner, it will be perceived that the fuel issuing from the injector is sprayed progressively over greater areas in the combustion chamber as the load on the engine increases.

If the ducts 40 are radially arranged and their axes are disposed in a common plane perpendicular to the axis of valve stem 20, the successive uncovering of the ducts to cause the spray to progressively widen as the load on the engine increases may be conveniently accomplished by forming the lower end of the sleeve as indicated at 52, so that it will be disposed in a plane forming an angle with its longitudinal axis. The same result can, of course, be accomplished by a different arrangement of ducts and by making suitable changes in the formation of the lower end of the sleeve.

So that the injection air will pass rapidly across the discharge ends of the ducts 40 and thus thoroughly atomize the fuel issuing therefrom, the lower end of the air passage 39 is divided into a plurality of channels or the like 53 which are arranged in vertical alignment with the discharge ends of the ducts. Since the fuel is slowly fed from the center of the valve stem 20 through the laterally extending ducts 40 into rapidly moving streams of air, the air forms an insulating envelope or layer between the fuel and the hot inner surfaces of the surrounding portion of the injector and carbonization of the fuel in the discharge end of the injector is thus effectively prevented.

In Figure 11, illustrating a slightly modified form of the invention, the sleeve 54 and the stem 55 of valve 56 are operated in the same manner as the corresponding parts of the injector shown in Figures 1 to 10, inclusive. Instead of having the air pass down around the sleeve as in the preferred form, the injector of Figure 11 is provided with a plurality of longitudinally extending ducts 57, which respectively terminate in lateral passages 58 communicating with the mixing chamber 59. The ducts 60 through which fuel passes from passageway 61 in the valve stem to the combustion chamber are disposed below and in vertical alignment with the discharge ends of the air passageways 58.

The lower end of the sleeve 54 is cut away, 75

as indicated at 62, so that, when the sleeve is in its lowermost position, corresponding to the position occupied by the throttle when the engine is idling, all but one or two of the fuel ducts 60, as well as the lateral air passages 58, are closed. In other words, when the engine is idling, fuel discharges from only one or two of the ducts 60 and air discharges from only the one or two lateral air passages 58 respectively adjacent the uncovered fuel ducts. At the lower end of the cut away portion 62, the sleeve extends obliquely as indicated at 63, and, when the air discharging from the uncovered passages 58 entrains the fuel issuing from the ducts 60, it atomizes the fuel and drives it along the lower edge of the sleeve around the valve stem 55 and the fuel and air mixture, now fog, discharges as a jet through valve 56 in the direction indicated by the arrow A toward the spark gap of a spark plug, not shown. It will, of course, be appreciated that, as the sleeve is raised in response to opening movement of the throttle, the fuel ducts and air passages covered by the sleeve when the engine is idling will be uncovered, so that, when the engine is under part or full load, a substantially circular spray of fuel discharges from the injector.

In Figure 12, illustrating still another modification of the invention, the lower portion of an injector is shown having a valve 64 provided with a stem 65 which is operated in the same manner as valve 19 of the injector shown in Figures 1 to 10, inclusive. Instead of being provided at its upper end with a valve for controlling the passage of fuel to a mixing chamber 66, valve stem 65 is provided adjacent its lower portion with an encircling valve 67 which normally prevents fuel from passing into the combustion chamber from laterally extending ducts 68 which communicate with the main fuel passage 69 in the valve stem. Below the ducts 68, the stem is provided with a duct 70 which also communicates with passage 69. This additional duct is always in open communication with the mixing chamber and it is so arranged that the fuel passing therethrough will discharge from the injector in the vicinity of the spark gap of a spark plug.

The upper end of the valve 67 is provided with a plurality of laterally projecting lugs 71 which, when valve 64 is closed, are spaced slightly above a shoulder 72 formed by the upper end of the removable tip or nozzle 73 with which the injector of Figure 12 is provided. By disposing lugs 71 in spaced relation to shoulder 72, it will be perceived that when the valve stem is depressed only slightly, as when a small charge of fuel is delivered to the fuel chamber when the engine is idling, valve 67 remains closed but fuel issuing from duct 70 is atomized by the injection air flowing through passage 74 and is discharged from the injector toward the spark plug. When, however, the valve stem is depressed further by the action of a heavier charge of fuel, downward movement of the valve 67 is arrested by the lugs 71 thereof engaging the shoulder 72, whereby the valve is opened and fuel is permitted to flow from the ducts 68 into the mixing chamber from which it discharges as a circular spray into the combustion chamber of the engine. Valve 67 is caused to move downwardly with the valve stem 65 during the initial movement of the latter by a helical spring 67 which encircles the stem and bears upon the top of the valve. Various modifications in the details of the em-

bodiments illustrated and described may, of course, be made without departing from the spirit and scope of the invention as defined in the appended claims.

What we claim is:

1. The improvement in fuel feeding means for an internal combustion engine having spark ignition, said improvement comprising the combination of a regulable fuel feeding device, an injector for receiving fuel from said device and delivering it to a combustion chamber of the engine, said injector having movable means adapted to be disposed in one position when the engine is idling to cause the fuel discharged from the injector to be sprayed in a limited area towards the spark gap of a spark plug in said chamber and adapted to be disposed in another position when the engine is under load to cause the fuel discharged from the injector to be sprayed throughout an increased area of said chamber, and means operating to simultaneously control the quantity of fuel supplied by said device to the injector and the position of said movable means.

2. The improvement in fuel feeding means for an internal combustion engine having spark ignition, said improvement comprising the combination of a regulable fuel feeding device, an injector for receiving fuel from said device and delivering it to a combustion chamber of the engine, and means for controlling the quantity of fuel supplied by said device to the injector, said injector having means movable simultaneously with said controlling means for causing the fuel discharged from the injector when the fuel feeding device is adjusted for delivering an idling charge to be sprayed in a limited area toward the spark gap of a spark plug in said chamber and for causing the fuel discharged from the injector when the fuel feeding device is adjusted for delivering a load charge to be sprayed throughout an increased area of said chamber.

3. The improvement in fuel feeding means for an internal combustion engine having spark ignition, said improvement comprising the combination of a regulable fuel feeding device, an injector for receiving fuel from said device and delivering it to a combustion chamber of the engine, and means for controlling the quantity of fuel supplied by said device to the injector, the said injector having movable means operable coincidentally with said controlling means for causing the fuel discharge from the injector to be sprayed over a limited area in the vicinity of the spark gap of a spark plug when the fuel feeding device is adjusted for delivering an idling charge and for causing the spray of fuel to spread over progressively greater areas of the combustion chamber as the amount of fuel supplied to the injector increases beyond the quantity of fuel supplied to said injector during idling.

4. The improvement in fuel feeding means for an internal combustion engine having spark ignition, said improvement comprising the combination of a regulable fuel feeding device, an injector for receiving fuel from said device and delivering it to a combustion engine, said injector having a plurality of ducts through which fuel is adapted to be discharged, at least one of said ducts being arranged so as to cause the fuel passing therethrough to be discharged from the injector in a limited area towards the spark gap of a spark plug in said chamber, movable means preventing fuel from discharging from other of said ducts when the engine is idling, and means

for simultaneously controlling the quantity of fuel supplied by said device to the injector and for actuating said movable means to permit fuel to pass through a greater number of said ducts when the engine is under load and thus cause the fuel to be sprayed over a greater area of said chamber than when the engine is idling.

5. The improvement in fuel feeding means for an internal combustion engine having spark ignition, said improvement comprising the combination of a regulable fuel feeding device, an injector for receiving fuel from said device and delivering it to a combustion chamber of the engine, said injector including a stem having a longitudinally extending passageway for the fuel and also having a plurality of radially arranged ducts through which fuel is adapted to discharge

from said passageway, at least one of said ducts being arranged to cause the fuel passing there-through to discharge from the injector in a limited area towards the spark gap of a spark plug in said chamber, a sleeve encircling said stem preventing fuel from passing through other of said ducts when the engine is idling, and means for simultaneously controlling the quantity of fuel supplied by said device to the injector and for actuating said sleeve to permit fuel to pass through a greater number of said ducts when the engine is under load and thus cause the fuel to be sprayed over a greater area of said chamber than when the engine is idling.

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