

March 31, 1953

S. B. SMITH, JR

2,633,187

FUEL SYSTEM

Filed Sept. 18, 1948

3 Sheets-Sheet 1

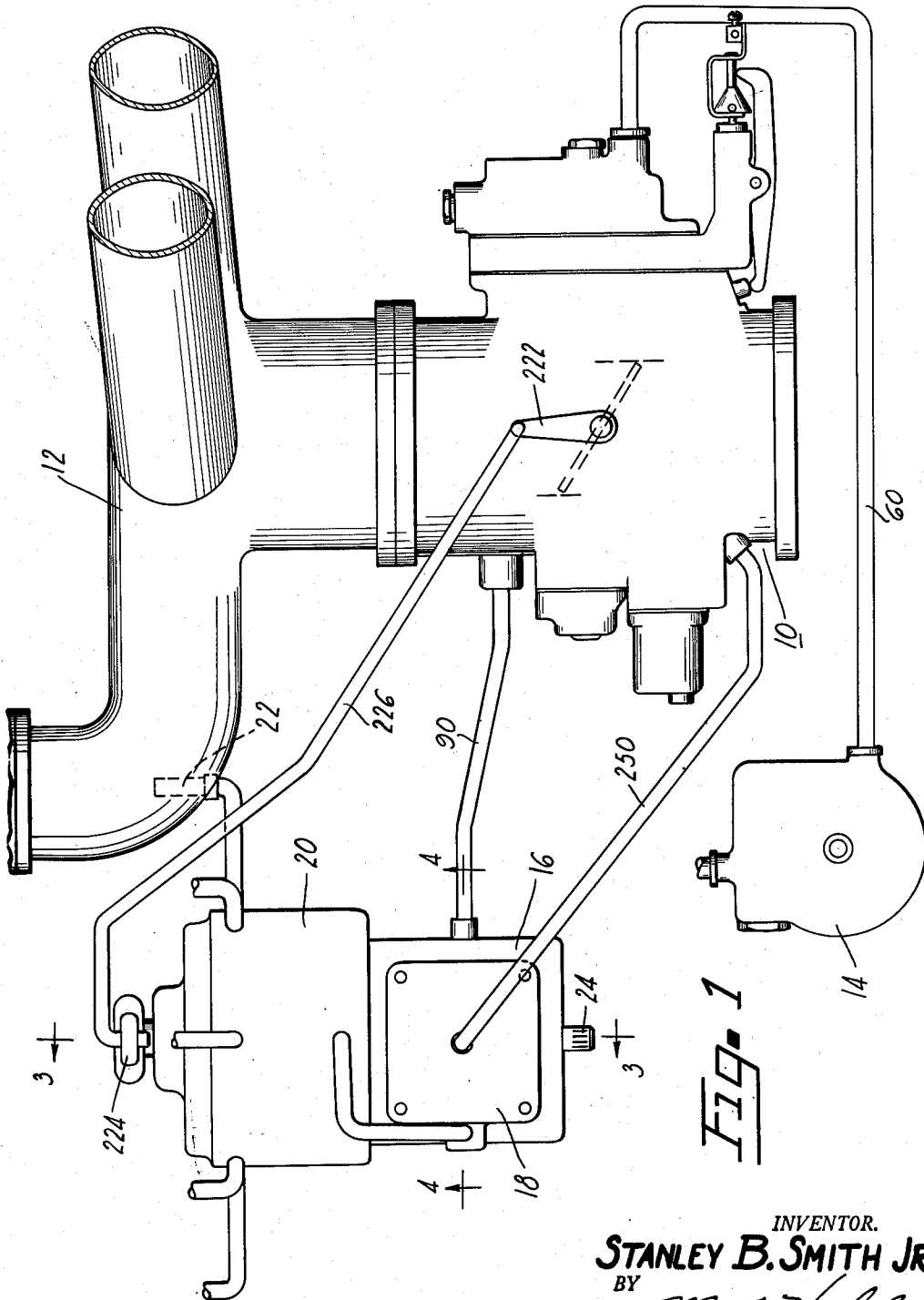


Fig. 1

INVENTOR.  
**STANLEY B. SMITH JR.**  
BY *M. A. Hobbs*  
ATTORNEY

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S. B. SMITH, JR

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3 Sheets-Sheet 2

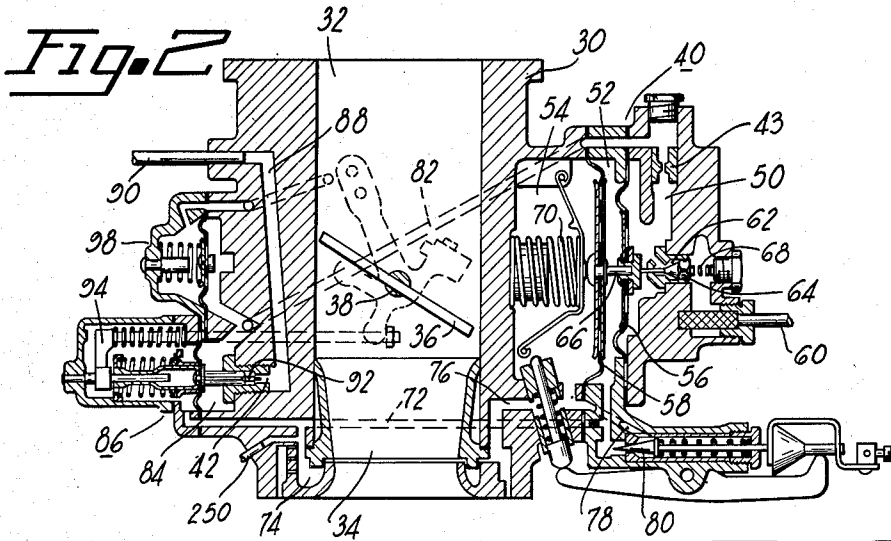
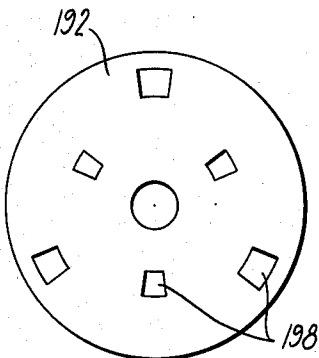
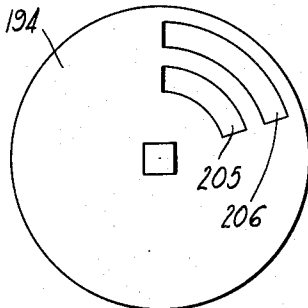
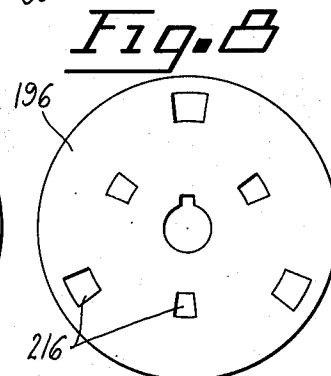
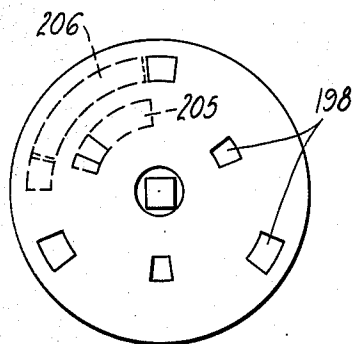
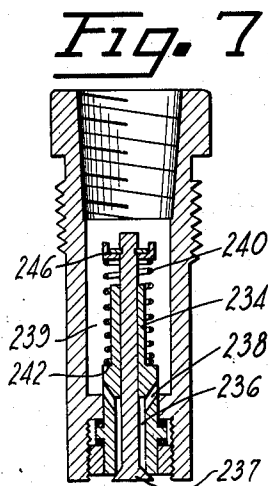
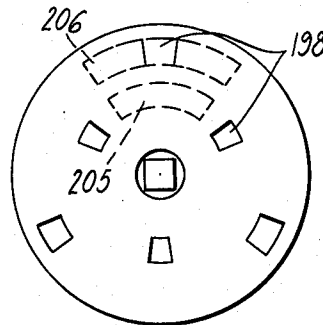


*Fig. 10*  
INVENTOR.  
**STANLEY B. SMITH JR**  
BY *M. A. Hobbs*  
ATTORNEY

**March 31, 1953**

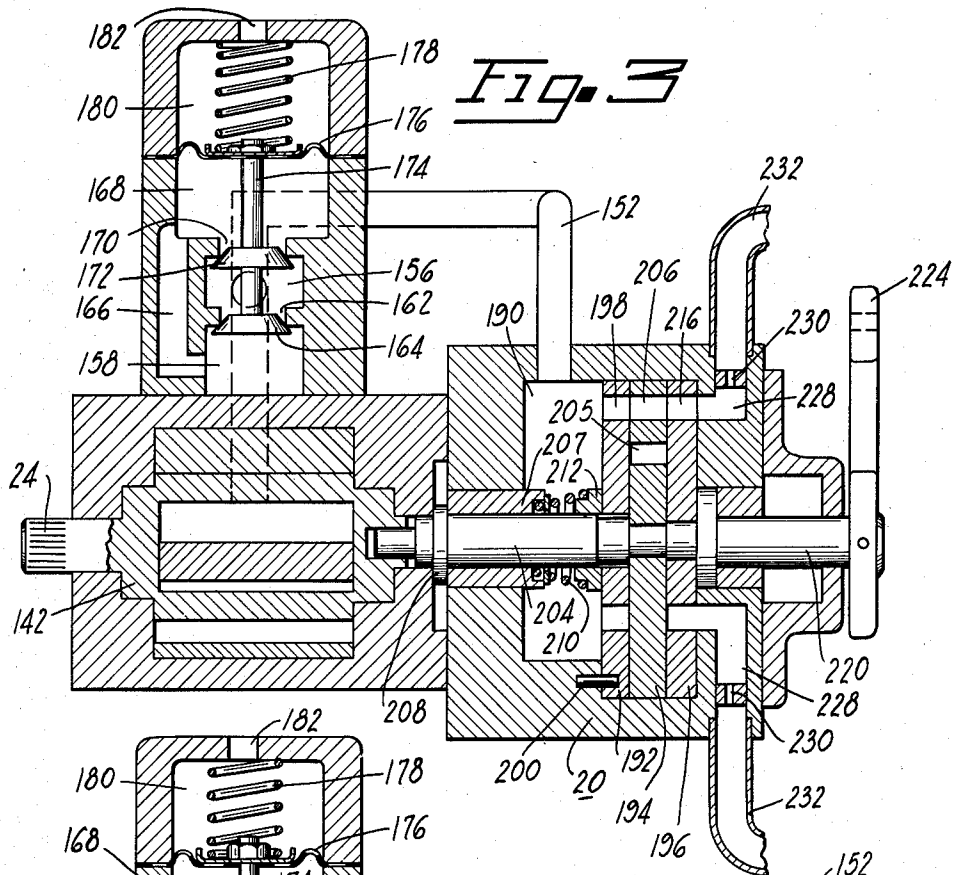
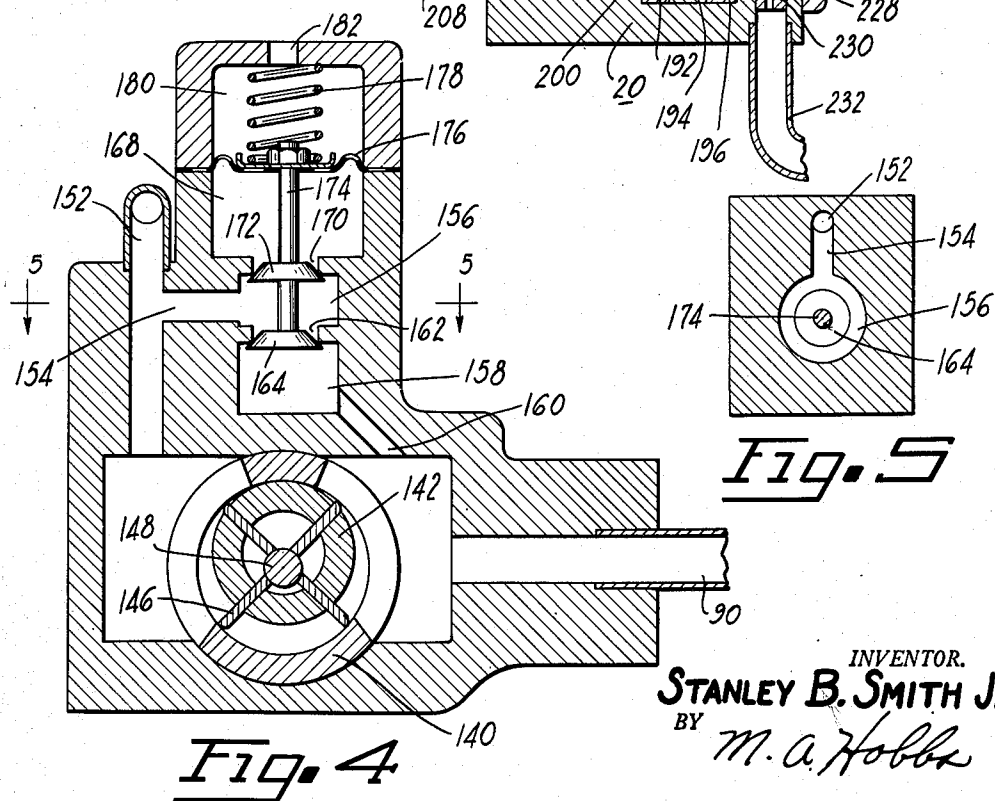
**S. B. SMITH, JR**

**2,633,187**

## FUEL SYSTEM

Filed Sept. 18, 1948

3 Sheets-Sheet 3



INVENTOR.  
**STANLEY B. SMITH JR.**  
BY *M. A. Hobbs*  
ATTORNEY

## UNITED STATES PATENT OFFICE

2,633,187

## FUEL SYSTEM

Stanley B. Smith, Jr., South Bend, Ind., assignor  
to Bendix Aviation Corporation, South Bend,  
Ind., a corporation of Delaware

Application September 18, 1948, Serial No. 49,967

5 Claims. (Cl. 158—36.3)

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The present invention relates to a charge forming device for an engine, and more particularly to a fuel system for an engine wherein the fuel is delivered under positive pressure to a plurality of discharge jets or nozzles.

In fuel supply systems for internal combustion engines and the like, it is usually desirable to meter the fuel at relatively low pressures in order to minimize line or joint failures and fuel leakage and to permit the use of comparatively light sections in the several elements comprising the system. However, in fuel systems in which the fuel is distributed to a plurality of discharge jets, the low pressure of the fuel coming from the metering device may permit substantial variations from one jet to another in the quantity of fuel delivered to the engine when the jets become impaired and restricted by foreign materials. It is, therefore, one of the principal objects of the present invention to provide a fuel system for an engine having a plurality of discharge jets or nozzles wherein equality of fuel distribution is maintained under all operating conditions regardless of minor impairments in the fuel jets or nozzles.

Another object of the invention is to provide a fuel supply system of the aforesaid type, wherein the fuel is metered at relatively low pressures and thereafter positively distributed equally to the several jets at relatively high pressures.

Another object of the invention is to provide a fuel metering system for an engine in which the metered fuel is maintained at a relatively low substantially constant pressure adjacent the downstream side of the metering orifice and is thereafter delivered at a substantially increased pressure.

Still another object of the invention is to provide a compact relatively lightweight fuel pump and distributor which can readily be adapted for use on most conventional fuel metering devices without substantially modifying the metering device or without materially affecting the metering characteristics of the device.

A further object of the invention is to provide a comparatively simple, compact and easily assembled fuel distributor which can readily be regulated to control the pressure of fuel therein in accordance with engine operating conditions.

In order to obtain the foregoing objects and other objects which will become apparent from the following description, the present fuel supply system for a multiple cylinder engine includes a full metering device in which the fuel is maintained under positive pressure, a pump for delivering the metered fuel at a substantially increased pressure, a by-pass unit for maintaining

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a constant pressure or a predetermined variable pressure at the inlet of the pump and thus at the outlet of the metering device, and a distributor for delivering the fuel to a plurality of discharge jets or nozzles in the intake manifold of the engine adjacent the inlet ports of the cylinders or in the cylinder head adjacent the combustion chambers of the cylinders. My invention may be more fully understood by reference to the accompanying drawings, wherein:

Figure 1 is a schematic view of a fuel supply system for an internal combustion engine, showing diagrammatically the several elements comprising the system;

Figure 2 is a cross-sectional view through a fuel metering device in which some of the elements thereof have been rearranged to more clearly show their operative relationship to one another;

Figure 3 is a cross-sectional view through a pressure control mechanism and fluid distributor taken on line 3—3 of Figure 1;

Figure 4 is a cross-sectional view through the pressure control mechanism taken on line 4—4 of Figure 1;

Figure 5 is a cross-sectional view through the pump by-pass taken on line 5—5 of Figure 4;

Figures 6, 7 and 8 are plan views of the plates of the distributor unit;

Figures 9 and 10 are plan views of the distributor plates showing them assembled in operative position; and

Figure 11 is a sectional view of the fuel discharge nozzle.

Referring more specifically to the drawings, wherein like numerals are used to designate like parts throughout the various figures, in Figure 1, numeral 10 designates a fuel metering device mounted on an intake manifold 12 of an aircraft internal combustion engine, numeral 14 a pump for supplying fuel to the fuel metering device, preferably at a substantially constant pressure, 16 a fuel pump for increasing the pressure of the metered fuel received from the fuel metering device 10, 18 a fuel by-pass unit for maintaining the pressure of the metered fuel on the inlet side of the pump at a substantially constant or an otherwise predetermined value, and 20 a fuel distributor for delivering fuel to a plurality of fuel discharge nozzles 22, only one of said nozzles being shown in the drawings, mounted in the intake manifold adjacent the inlet valves of the cylinders. Pump 16 is adapted to be driven by the engine through a suitable drive means connected to shaft 24 of the pump.

The fuel metering device 10 which is shown

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in detail in Figure 2 is one of several types suitable for use in the present fuel supply systems. The metering device shown is covered by U. S. Patent No. 2,445,846 to Barford et al., dated July 27, 1948, and contains a main body member 30 having an induction passage 32 with a venturi 34 positioned adjacent the air inlet end thereof and a manually actuated throttle valve 36 pivotally mounted on shaft 38 posterior to the venturi. The fuel flow is regulated or controlled by the combined operation of a control unit 40 on the upstream side of the fuel metering orifices 42 and 43 and the pump 16 and by-pass 18 on the downstream side of the metering orifices. The metering orifices may be either of a fixed or variable size type, the two shown illustrating both types.

The interior of the regulator unit 40 is divided into three chambers 50, 52 and 54 by diaphragms 56 and 58. Chamber 50 receives fuel from a source under pressure, such as pump 14, through a conduit 60 and an inlet port 62 controlled by a valve 64 operatively connected to diaphragms 56 and 58 by a linkage 66. A spring 68 urges the valve to the left, as shown in Figure 2, to its closed position and a spring 70 in chamber 54 urges the diaphragms in a direction to open the valve 64. The chamber 52 is connected to the venturi by means of a passage 72 and an annular chamber 74 and is thus subjected to a pressure primarily derived from the throat of the venturi 34, though this pressure may be modified by air inlet pressure transmitted through passages 76 and 78 and a manual mixture control valve 80. The chamber 54 is connected to the air inlet by passage 76 and is, therefore, subjected to a pressure primarily derived from the induction passage entrance or source of air pressure. Fuel entering the chamber 50 from the fuel inlet 62 flows through metering orifice 43 and a passage 82 to a chamber 84 of the fuel metering unit 86, and thence through orifice 42 to conduits 88 and 90 leading to pump 16. The effective area of orifice 42 is controlled in accordance with throttle position by a stepped valve 92 and a linkage 94, the valve being adapted to limit the fuel flow for idling and to provide a rich fuel-air mixture for high power output.

An acceleration pump, indicated generally at 98, an altitude mixture control, and an automatic power enrichment means (not shown) are preferably included in the metering device.

Referring to Figures 3 and 4, the pump 16 and by-pass unit 18 are shown in combination with the fuel distributor 20, said units being claimed in applications Serial Nos. 48,613, filed September 10, 1948, and 244,050, filed August 28, 1951. The pump, which is of the vane type, though any other suitable pump such as a centrifugal, gear or reciprocating piston type may be used, consists of a sleeve 140, and a rotor 142 having, as shown in the drawings, four vanes 146, abutting against a floating pin 148 and contacting the internal surface of the sleeve, said rotor being adapted to revolve in a clockwise direction in said sleeve.

The fuel is discharged from the pump through conduit 152 connecting the pump with the fuel distributor 20 and is divided into two portions, one portion of the fuel continuing through conduit 152 to distributor 20 and the other portion flowing through passage 154 to by-pass unit 18 and thence through chambers 156 and 158 and a passage 160 to the pump inlet. Chamber 156 is connected to chamber 158 by an orifice 162

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controlled by a valve 164. Communication between the two chambers is also established by a passage 166, chamber 168 and an orifice 170 controlled by a valve 172, said orifice and valve being provided primarily for the purpose of balancing valve 164. Valves 164 and 172 are mounted on an axially movable stem 174 which in turn is connected to a flexible diaphragm 176 subjected on one side to the pressure of the metered fuel transmitted from the metering device 10 through conduit 90 to the inlet of the pump, thence through passage 160, chamber 158, passage 166 to chamber 168 adjacent the underside of said diaphragm. The diaphragm is subjected on the other side to some preselected pressure, such as for example atmospheric pressure, and to the force of a calibrated spring 178 preferably provided with some adjustment means, such as an adjustment screw (not-shown), for regulating the tension of the spring. While the chamber 180 in which spring 178 is located is shown vented to the atmosphere through a port 182, it may be desirable to subject the diaphragm to a variable pressure to obtain certain fuel flow characteristics, particularly when the type of metering device shown in Figure 2 is included in the fuel system, as will be more fully explained hereinafter. Since valves 164 and 172 are the same size and are subjected to the same pressures, the operation of the valves is entirely controlled by diaphragm 176, and is otherwise unaffected by changes in pump inlet and outlet pressures transmitted to said valves.

The fuel in conduit 152 which is not diverted through the by-pass unit is delivered to the distributor unit 20, entering said unit at chamber 190 and thence flowing through the several ports of the distributor plates 192, 194 and 196, wherein separate charges are formed for each cylinder of a multiple cylinder engine. Plate 192 is a stationary element and, as shown in Figure 6, contains six ports 198, one for each cylinder of a six-cylinder engine. This plate is held in substantially fixed position in the distributor by a pin 200 extending through the plate into the distributor housing, the fit between the pin and hole for the pin in the plate preferably being such that slight axial movement of the plate is possible. While the ports in this distributor plate and also those in plate 196 are approximately frustoconical in shape, other shapes may be used satisfactorily or a combination of different shapes may be desirable under certain conditions to obtain special fuel delivery characteristics.

The rotatable distributor plate 194 is mounted on the end of shaft 204 for rotation therewith and, as shown in Figure 7, contains two arcuate ports 205 and 206 for registering with ports 198 of plate 192 for a fixed portion of each revolution, this being, in the plate shown, one-fifth of the time that the distributor is in operation. Shaft 204 is operatively connected to one end of pump rotor 142 and is journaled in bearing 207 and held against axial movement by a fixed collar 208 inserted in an annular space in the end of the pump housing. A spring 210 reacting between bearing 207 and a retainer ring 212 urges plate 192 into rather tight face-to-face contact with plate 194 and plate 194 into contact with plate 196. While, in the present embodiment, the pump rotor and distributor are driven in unison, the pump may be driven at any other speed so long as the capacity of the pump at the selected speed is at all times greater than the supply of metered fuel delivered to the pump inlet.

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Plate 196, as shown in Figure 8, is substantially the same as plate 192, i. e. it contains two circumferentially arranged rows of frustoconically-shaped fuel ports 216 which are adapted to register with the corresponding ports of plate 192 and with the two arcuate ports of rotatable plate 194, for a portion of each revolution of said latter plate. Plate 196, which is rigidly mounted on one end of shaft 220 axially aligned with shaft 204, though not operatively connected therewith, is adapted to be oscillated for a part revolution with each opening and closing movement of the throttle valve by a linkage consisting of a lever 222 mounted on the throttle valve shaft, a lever 224 mounted on the end of shaft 220 and a rod 226 pivotally connected to the free end of each lever. When the throttle valve is in closed position, the three plates occupy approximately the position in relation to one another shown in Figure 9, i. e. the ports of plate 192 and the corresponding ports of plate 196 are as far apart as possible and still in direct communication with one another through arcuate ports 205 and 206 during some portion of each revolution of plate 194. When the throttle valve has been moved to its fully opened position, the three plates occupy the position in relation to one another shown in Figure 10, i. e. the ports in plate 192 are in direct alignment with the ports of plate 196. It is thus seen that by oscillating plate 196 in relation to plate 192 it is possible to vary over a wide range the duration of direct communication between ports 198 of plate 192 and ports 216 of plate 196 and thus to vary the quantity of fuel discharged per each revolution of plate 194 for any given fuel pressure in chamber 190, or to vary the pressure required in chamber 190 to deliver a given amount of fuel in a given period of time. While in the embodiment shown the duration plate 196 is mechanically linked to the throttle valve actuating mechanism, it is contemplated that other arrangements for controlling plate 196 may be made. For example, lever 224 can be connected to a means actuated in response to variations in intake manifold pressure so that, for high manifold vacuum such as exists during idling, the duration of direct communication between ports 198 and 216 is relatively short and for low manifold vacuum such as exists during wide open throttle, the duration of communication between said ports is relatively long.

The fuel, on leaving the distributor, passes through conduits 228, restrictions 230 and conduits 232 to a plurality of discharge nozzles 22 located in the intake manifold in the proximity of the intake valves of the cylinders. The nozzle, shown in detail in Figure 11, includes a sleeve 234 having a central passage 236 through which the fuel is discharged into the manifold and in which a valve element 237 is adapted to move axially and seat over the discharge end of said passage, the central passage of said sleeve being connected with conduit 232 by a plurality of ports 238 and a chamber 239. The valve element is urged to its closed position by a spring 240 reacting between a shoulder 242 on sleeve 234 and a spring retainer 246 secured to the end of said element, said spring being calibrated to maintain a substantially constant pressure in conduit 232 immediately downstream from restriction 230.

In the operation of the present fuel supply system, fuel is delivered by pump 14 at a substantially constant superatmospheric pressure

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through conduit 60 to the fuel metering device 10 wherein the fuel is metered in accordance with air flow through the induction passage 32 to the engine. As the throttle valve is opened and the air flow increases, the decrease in pressure which occurs at the throat of the venturi is transmitted to chamber 52, causing diaphragms 56 and 58 to move to the right and urge valve 64 in the opening direction to admit a greater quantity of fuel into chamber 50. The increased fuel flow causes the pressure to rise in chamber 50, conduit 82 and chamber 84 and provides a greater differential in pressure across the metering orifices 42 and 43 and thus an increase in the flow of metered fuel through conduits 88 and 90 to pump 16. In the fuel metering device shown in Figure 2, the unmetered fuel in chamber 50 is controlled independently of the metered fuel in conduits 88 and 90; consequently, it is necessary to maintain accurately predetermined pressures in the fuel conduits both upstream and downstream from the metering orifices. The pressure of the metered fuel is controlled by pump 16 and by-pass unit 18, the spring 178 and fluid pressure in chamber 180 determining the pressure maintained by the metered fuel in conduit 90. If the pressure in chamber 180 is maintained substantially constant, for example at atmospheric pressure, the pressure of the metered fuel in conduit 90 will remain substantially constant. The pressure in chamber 180, however, may be varied according to some engine operating condition, such as Venturi suction, as will be more fully explained later.

Pump 16, which may be of any type having a capacity sufficiently large to pump, at all times, the entire quantity of metered fuel delivered by the metering device under all operating conditions, discharges the fuel through conduit 152 at a greatly increased pressure, a portion of said fuel, which is equal in quantity to the fuel delivered to the pump, passing through the distributor, and the other portion, which is in excess of that delivered to the pump, passing through conduit 154 and the by-pass unit back to the pump inlet. The quantity of fuel returned to the pump inlet is controlled by valves 164 and 172 actuated by diaphragm 176 in response to variations in pump inlet pressure. For example, if the pump inlet pressure increases in response to an increase in fuel delivery by the metering device, valves 164 and 172 are moved by the higher pressure on diaphragm 176 to a more nearly closed position so that the entire quantity of metered fuel will be delivered to the engine and the original inlet pressure re-established.

In the distributor, plate 194 is rotated at one-half engine speed and arcuate ports 205 and 206 permit one charge of fuel to be delivered through each distributor port for each revolution of plate 194 and thus provide one charge of fuel per cylinder for each intake stroke of a four-cycle engine. The oscillating or duration plate 196 has been included to limit the pressure range required to deliver the metered fuel to the engine and at the same time to maintain under all operating conditions a substantial differential across restrictions 230. A large differential across said restrictions is desirable to minimize the effect of unavoidable pressure changes in conduits 232 between said restrictions and the discharge nozzles. When the engine is operating with the throttle valve fully opened, duration plate 196 is so posi-

tioned in relation to plate 192 that the respective ports of each plate are in alignment to provide the greatest period of time of direct communication between said ports for each revolution of plate 194. When the throttle valve is returned to closed position, the quantity of metered fuel delivered to pump 16 is substantially decreased and a larger quantity of fuel is by-passed from the pump outlet to the inlet to maintain the predetermined pressure in conduits 88 and 90. This normally would cause a substantial decrease in the pressure between the pump and the distributor so that the differential of pressure across restrictions 230 would become relatively small and would be materially affected by the unavoidable changes in pressure in conduits 232. The duration plate prevents this by limiting the time during which the fuel is discharging through each restriction 230. As previously explained, the pump, together with the by-pass unit, operates to discharge all the metered fuel delivered to it. Consequently, when the period of time during which the fuel is discharged through each distributor port is substantially shortened by the duration plate, the pressure between the pump and the distributor immediately rises to the point required to discharge the entire quantity of fuel through said ports in the shortened period. When the throttle valve is again moved toward wide open position, the duration plate moves toward its non-limiting position to permit the larger quantity of fuel to be delivered through the distributor at relatively lower pressures. It is thus seen that the duration plate functions to limit the pressure range maintained between the pump and distributor and to maintain a relatively high minimum pressure for said range. The ports in the distributor plates are preferably of such size that, when there is direct communication between corresponding ports of plates 192 and 196, the pressure in the corresponding conduit 228 anterior to restriction 230 immediately becomes substantially equal to the pressure in chamber 190 anterior to the distributor plates, thus immediately establishing the desired high differential in pressure across restriction 230 for the delivery of a fuel charge to the engine.

As previously pointed out, chamber 180 above diaphragm 176 may be vented to some pressure other than atmospheric pressure. For example, in the present fuel system, said chamber may be connected by a conduit 250 as shown in Figures 1 and 2 with the venturi in the fuel metering device so that with a decrease in Venturi pressure on an increase in air flow to the engine, the pressure in chamber 180 causes diaphragm 176 to move in the direction to close valves 164 and 172. With these valves in a more nearly closed position, less fuel is by-passed back to the pump inlet, thus resulting in a greater delivery of fuel to the engine and in a slightly lower metered fuel pressure in conduits 88 and 90. With this condition prevailing, a greater differential across the metering orifice and thus a greater flow through the system are established for high power output.

Various modifications and arrangements may be made in the present fuel supply system and elements thereof. For example, the fuel metering device shown in the drawings may be replaced by a speed density fuel metering device such as the one shown in U. S. patent application Serial No. 600,756 filed on June 21, 1945, by Frederik Barfod, now Patent No. 2,489,214, issued November 22, 1949.

Further, the plates of the fuel distributor may be replaced by cylinders, i. e. a stationary cylinder, a rotatable cylinder around said stationary cylinder, and an oscillating cylinder around said rotatable cylinder, each of said cylinders containing ports operatively arranged in the same relationship as those of the corresponding plates of the distributor shown in the drawings. Many other modifications may be made in the present fuel supply system to suit requirements.

I claim:

1. A fuel supply system for an engine, comprising a conduit adapted to connect a source of fuel supply to the engine, a metering restriction in said conduit, a means for varying the fuel pressure in said conduit anterior to said metering restriction in response to variations in engine fuel requirements, a pressure creating means in said conduit posterior to said metering restriction, and a pressure regulating means communicating with the inlet and outlet passages of said pressure creating means for maintaining a substantially constant pressure in the conduit between said metering restriction and said pressure creating means.

2. A fuel supply system for an engine, comprising a conduit adapted to connect a source of fuel supply to the engine, a metering restriction in said conduit, a means for varying the fuel pressure in said conduit anterior to said metering restriction in response to variations in engine fuel requirements, a pressure creating means in said conduit posterior to said metering restriction, and a pressure regulating means for maintaining a substantially constant pressure in the conduit between said metering restriction and said pressure creating means.

3. A fuel supply system for an engine, comprising a conduit adapted to connect a source of fuel supply to the engine, a metering means in said conduit, a means for varying the fuel pressure in said conduit anterior to said metering means in response to variations in engine fuel requirements, a pressure creating means in said conduit posterior to said metering means, a pressure regulating means communicating with the inlet and outlet passages of said pressure creating means for maintaining a substantially constant pressure in the conduit between said metering means and said pressure creating means, and a fuel distributor in said conduit posterior to said pressure creating means.

4. A fuel supply system for an engine, comprising a conduit adapted to connect a source of fuel supply to the engine, a metering means in said conduit, a means for varying the fuel pressure in said conduit anterior to said metering means in response to variations in engine fuel requirements, a pressure creating means in said conduit posterior to said metering means, and a pressure regulating means communicating with the inlet and outlet passages of said pressure creating means for maintaining a predetermined pressure in the conduit between said metering means and said pressure creating means.

5. A fuel supply system for an engine, comprising a conduit adapted to connect a source of fuel supply to the engine, a metering means in said conduit, a means for varying the fuel pressure in said conduit anterior to said metering means in response to variations in engine fuel requirements, a pressure creating means in said conduit posterior to said metering means, and a pressure regulating means for maintaining a pre-

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determined pressure in the conduit between said  
metering means and said pressure creating means.

STANLEY B. SMITH, JR.

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