June 12, 1956 N. M. REINERS 2,749,897

FUEL APPARATUS FOR AN INTERNAL COMBUSTION ENGINE

Filed Jan. 9, 1952 6 Sheets-Sheet 1

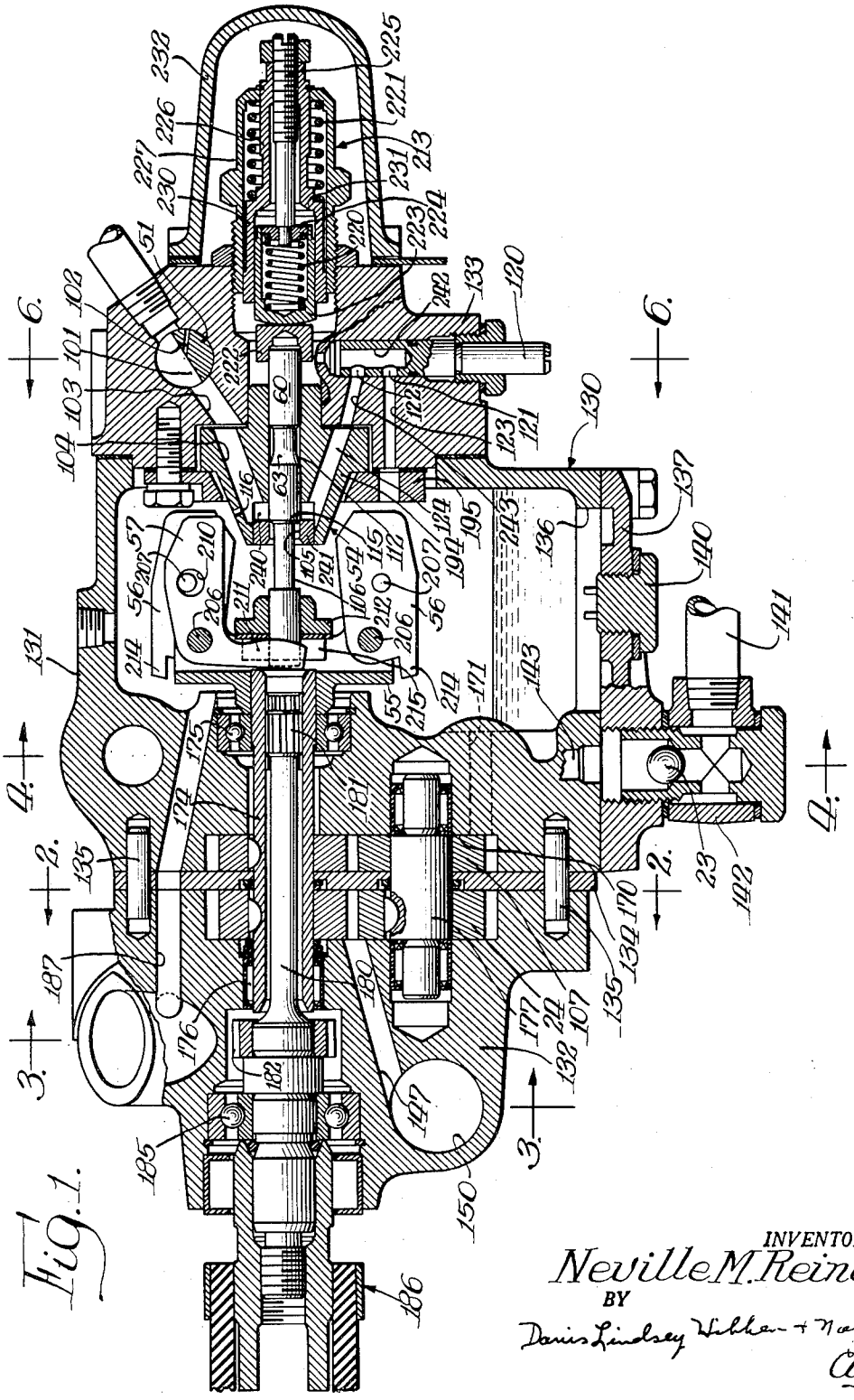


Fig. 1.

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Fig. 4.

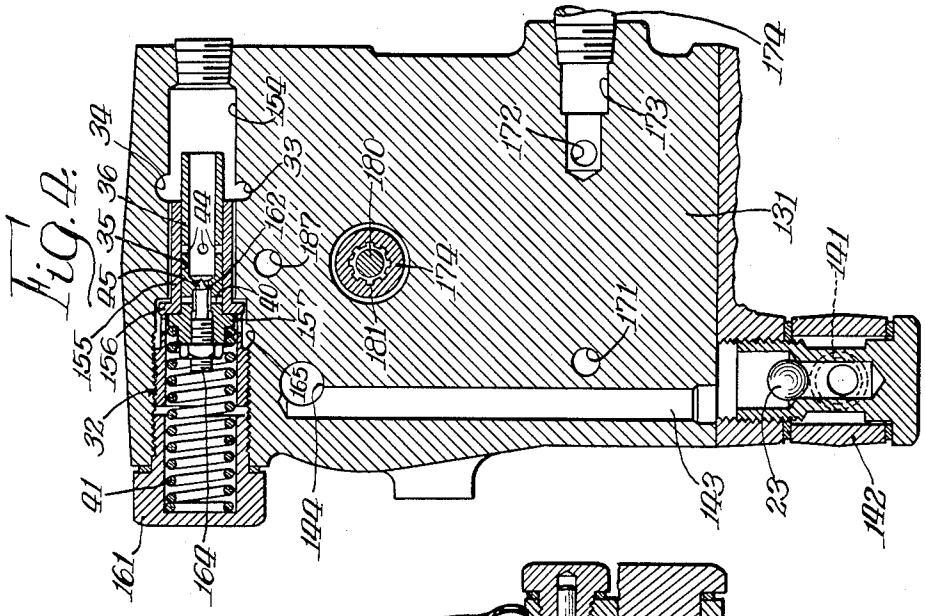


Fig. 3.

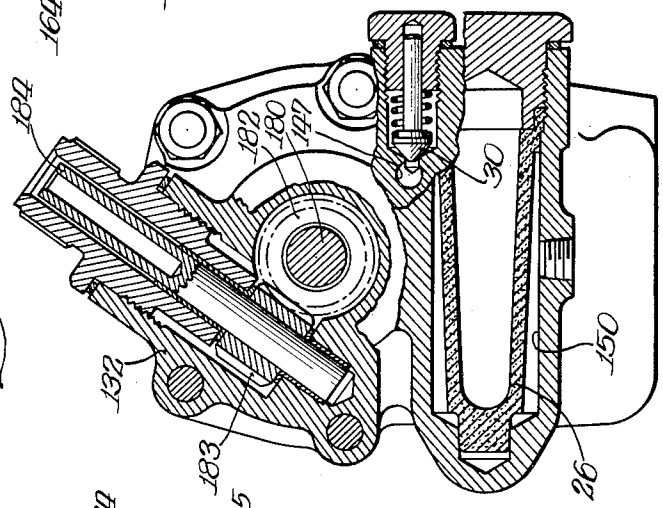
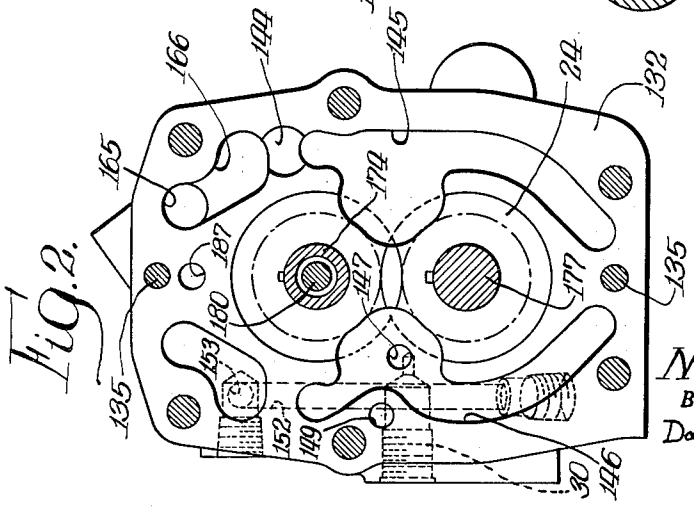


Fig. 2.



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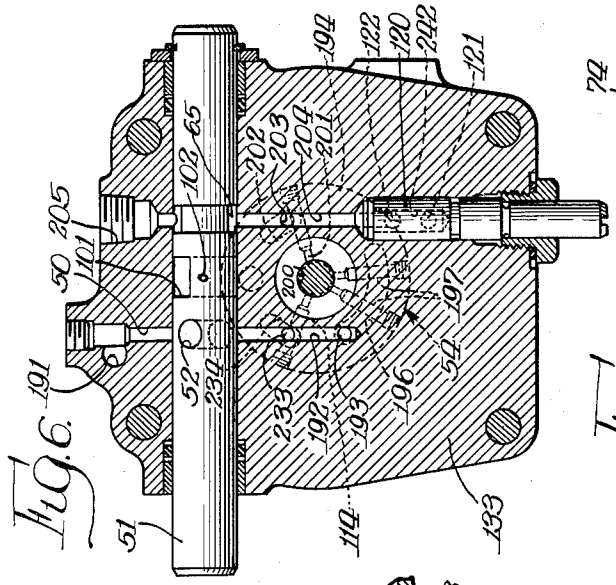


Fig. 6.

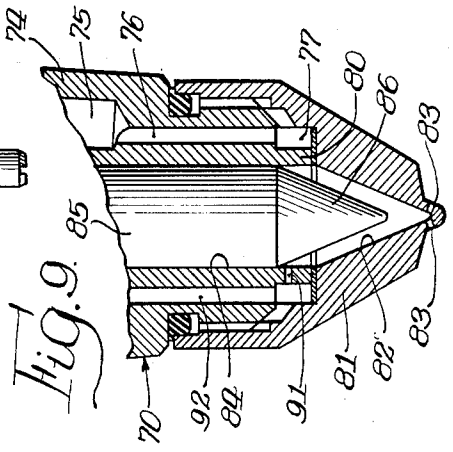


Fig. 9.

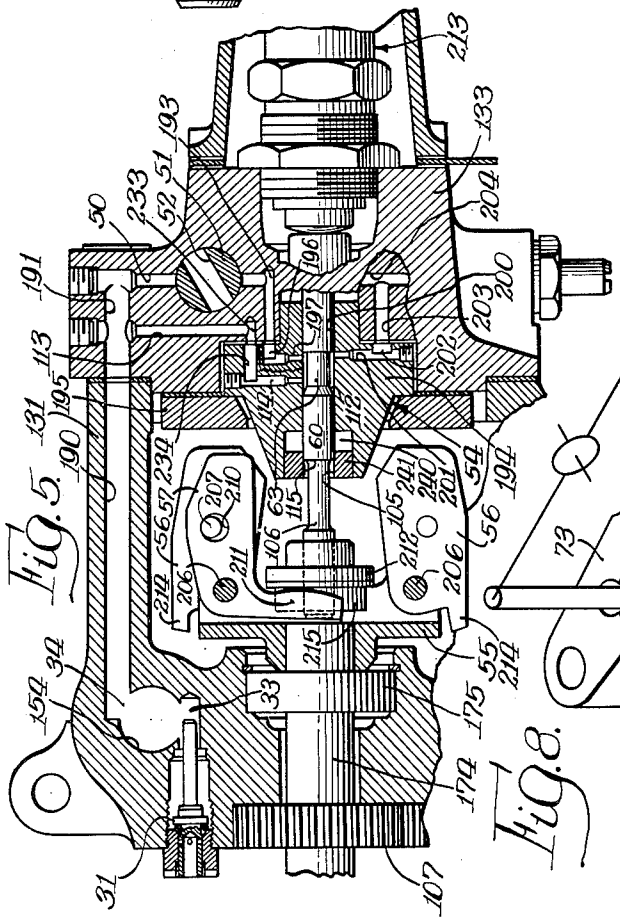


Fig. 5.

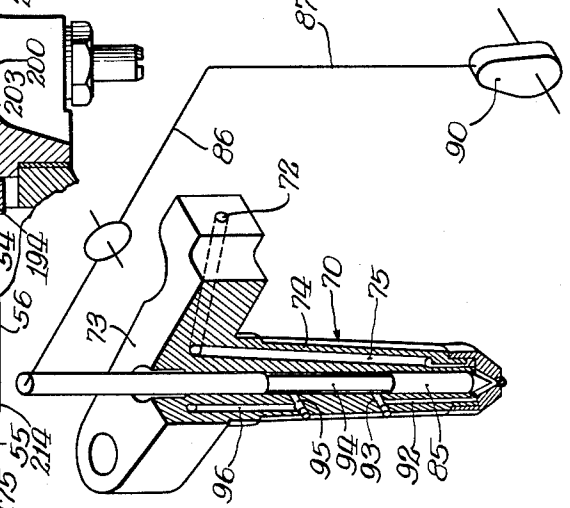


Fig. 8.

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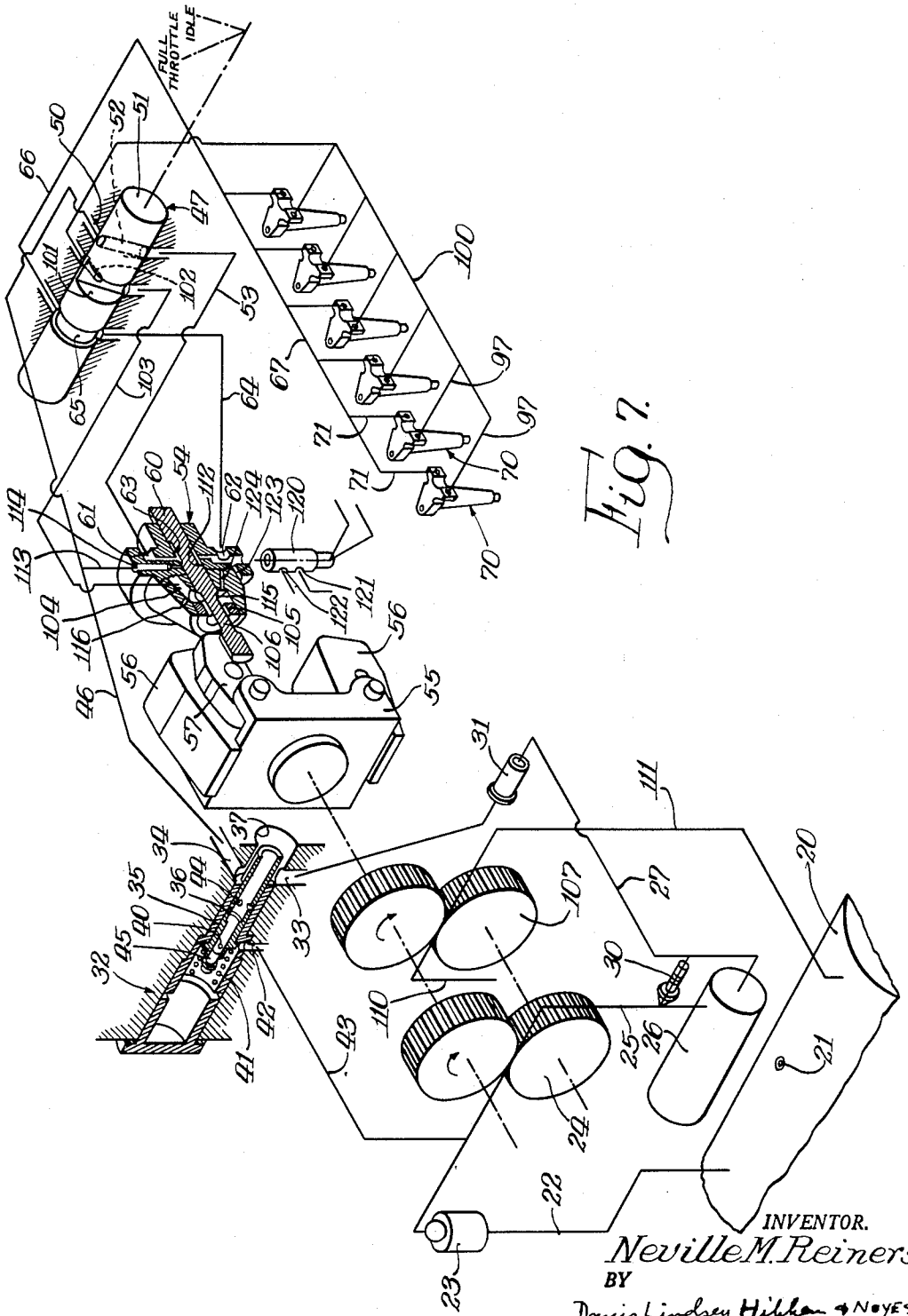


Fig. 7.

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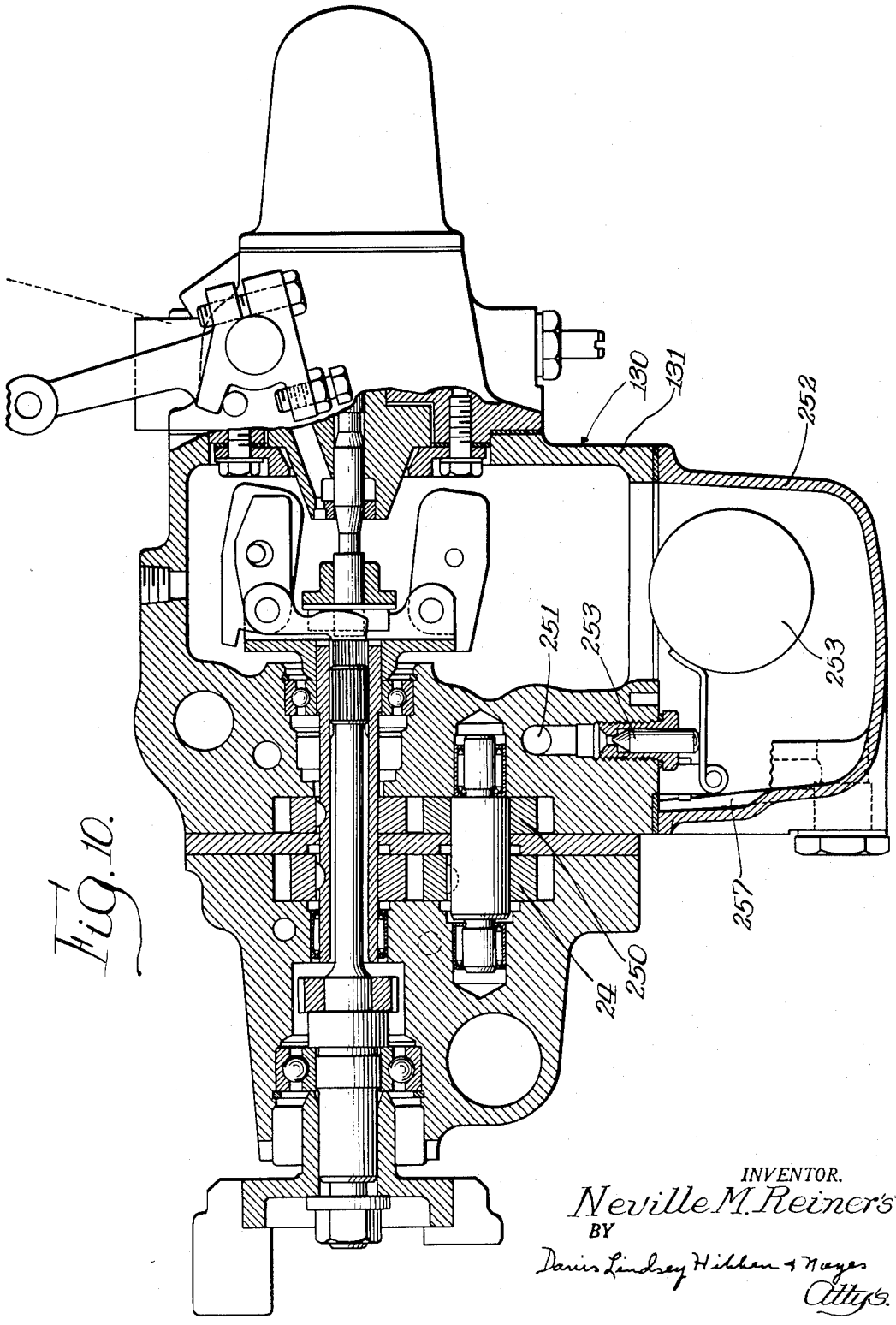


Fig. 10.

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FUEL APPARATUS FOR AN INTERNAL COMBUSTION ENGINE

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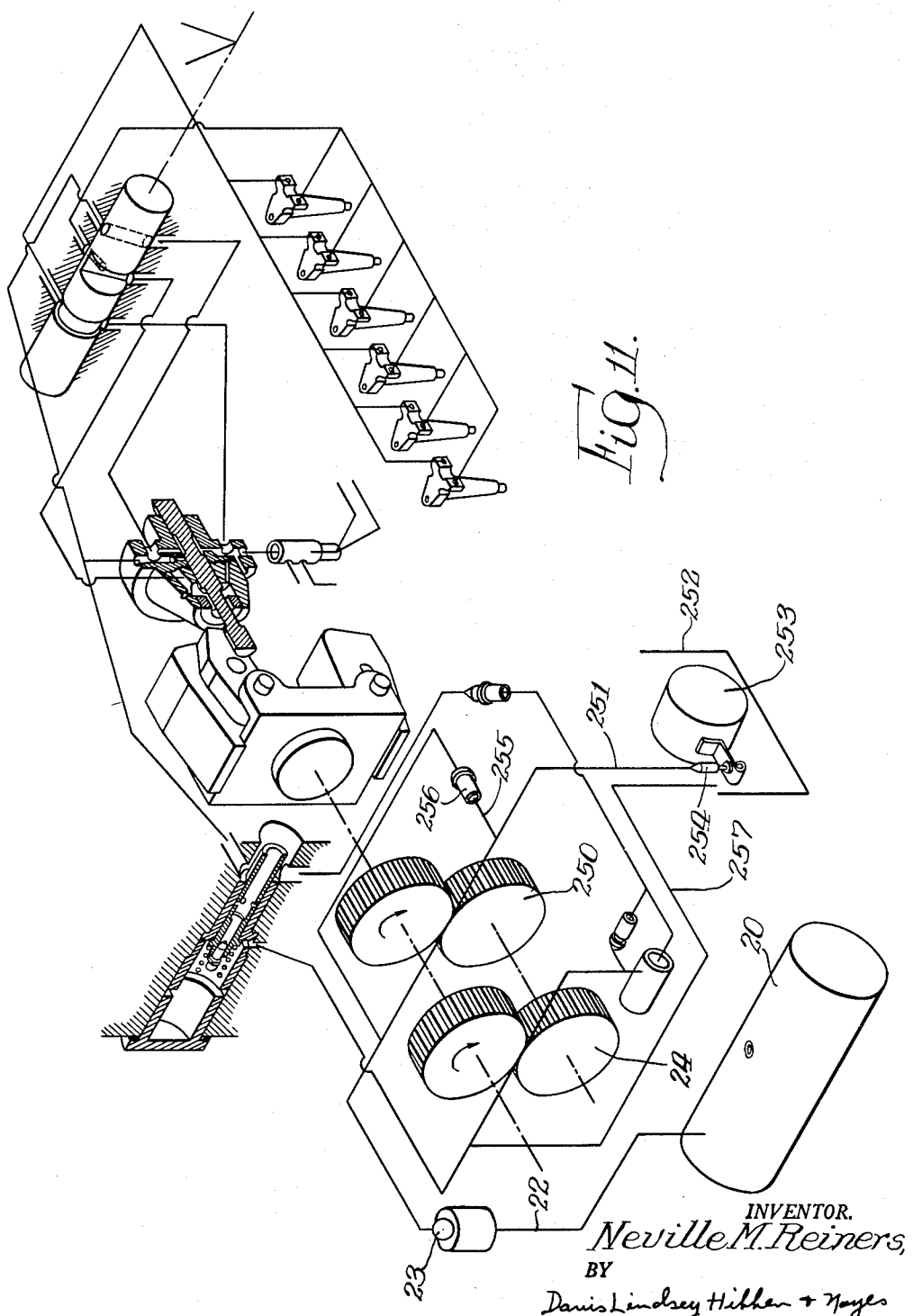


Fig. 11.

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United States Patent Office 2,749,897 Patented June 12, 1956

2,749,897

FUEL APPARATUS FOR AN INTERNAL COMBUSTION ENGINE

Neville M. Reiners, Columbus, Ind., assignor to Cummins Engine Company, Inc., Columbus, Ind., a corporation of Indiana

Application January 9, 1952, Serial No. 265,698

28 Claims. (Cl. 123—140)

The invention relates generally to fuel supply apparatus for internal combustion engines and more particularly to a fuel supply apparatus for a multi-cylinder engine of the diesel type.

The general object of the invention is to provide a novel fuel supply apparatus for delivering accurately metered quantities of fuel to the respective cylinders of the engine under varying load and speed conditions.

Another object is to provide a novel fuel supply apparatus of the foregoing character, in which the delivery of fuel to the cylinders is promptly responsive to adjustment of the manually operable throttle.

More specifically, it is an object to provide a novel fuel supply apparatus which eliminates any difficulty due to air in the fuel by constantly purging the system of air.

Still another object is to provide a novel fuel supply apparatus by which a desired torque curve for the engine may be obtained.

A still further object is to provide a fuel supply apparatus in which the metering of the fuel is dependent upon the pressure of the fuel at a certain point in the apparatus, with novel means for controlling such pressure as well as the flow to such point.

Other objects and advantages will become apparent from the following description taken in connection with the accompanying drawings, in which:

Figure 1 is a longitudinal sectional view of the main unit of a fuel supply apparatus embodying the features of the invention.

Figure 2 is a transverse sectional view taken on the line 2—2 of Figure 1.

Figure 3 is a transverse sectional view taken on the line 3—3 of Figure 1.

Figure 4 is a transverse sectional view taken on the line 4—4 of Figure 1.

Figure 5 is a fragmentary longitudinal sectional view taken in a different plane from that of Figure 1.

Figure 6 is a transverse sectional view taken on the line 6—6 of Figure 1.

Figure 7 is a diagrammatic view of the complete apparatus, including parts of the main unit shown in Figure 1, as well as the injectors utilized therewith.

Figure 8 is a perspective view, partially in section, of one of the injectors.

Figure 9 is an enlarged fragmentary longitudinal sectional view of one of the injectors.

Figure 10 is a longitudinal sectional view of a modified form of the main unit.

Figure 11 is a diagrammatic view of a complete fuel supply apparatus utilizing the main unit shown in Figure 10.

Control of a multi-cylinder internal combustion engine of the diesel type is obtained by controlling the quantity of fuel which is supplied to the cylinders. It is therefore essential that the fuel be accurately metered, so as to exercise the proper degree of control over the engine, and that the fuel be injected into the respective cylinders in equal amounts so that each cylinder will

carry its proper proportion of the load. With an engine which operates at fairly constant speed and constant load, the problem of supplying accurately metered quantities of fuel is not too difficult. However, in the case where the engine is subjected to wide variations in speed and load, provision must be made for accurately metering the fuel under all variations in the speed and load. Particularly in the case where an engine of this type is utilized as the prime mover for an automobile, truck or tractor, or the like, where the speed and load vary over a wide range, not only must the fuel be accurately metered under all conditions, but the engine must respond quickly to adjustments of the manual controls for the engine.

The fuel apparatus shown in the present application is adapted to meet the requirements of an engine of the afore-mentioned type where there is a wide variation both in speed and load. Fundamentally, the present apparatus utilizes the principle of metering the fuel by controlling the pressure applied to cause flow through a fixed orifice, in conjunction with the period of time that the orifice is open for flow therethrough. The time that such orifice is open is more or less determined by the mechanical characteristics of the injector and, while it varies with changes in the speed of the engine, it cannot be readily altered to meet varying load conditions. However, the pressure of the fuel applied to the orifice can be controlled so that proper metering under all conditions will result.

The fuel apparatus disclosed herein comprises generally a plurality of injectors, one for each cylinder, and each provided with a permanently open passage through which fuel is circulated. Extending from an intermediate point in this passage is an orifice through which a portion of the fuel flowing through the passage is diverted for injection into the associated cylinder. The orifice is adapted to be opened and closed by a plunger in the injector which is operated by the engine so that the time that the orifice is open thus varies with the speed of the engine. The quantity of fuel metered to the cylinder is therefore dependent upon the pressure of the fuel in the above-mentioned passage. Control of the metering may thus be obtained by controlling the pressure of the fuel in the passages of the respective injectors and, since the fuel is to be injected into the respective cylinders in a predetermined order under the control of the plungers of the injectors, all the injectors may be supplied from a common supply rail or line. Moreover, since fuel is constantly circulated through the passages in the injectors, they all are connected to a common return rail or line to carry away the fuel in excess of that diverted through the respective orifices.

The control of the pressure of the fuel in the injector passages is obtained by a pressure regulator which varies the pressure obtainable by the pump supplying the fuel, so that a predetermined pressure curve covering the speed range of the engine is provided to obtain a predetermined torque curve for the engine. Control of the pressure in the injector passages is also obtained by means for restricting the flow through the return rail, such restriction cooperating with the effect of the pressure regulator to provide the desired range of pressure in the injector passages. The pressure regulator is of a type which bleeds off a portion of the fuel supplied by the pump with the result that a desired increase in fuel pressure with increase in speed of the engine can be obtained. The means for restricting the flow through the return rail is adjustable so as to provide an increased restriction to increase engine speed or load or both.

To meet all conditions of operations, the present fuel apparatus may also include a manually operable throttle as well as a governor-operated means controlling the flow of fuel from the pump to the common supply rail. The

manually operable throttle is arranged to control the flow of fuel only when the engine is operating above idling speed and provides for gradually increased flow to increase the speed or load or both. Since it is desired to vary by the throttle, the restriction to flow from the return rail only above idling speeds, the throttle and the flow restricting means are interconnected by being formed on a single manually movable member.

The governor-operated means is arranged to control the flow of fuel at idling speed and also to limit the flow for maximum engine speed. It also has a drain passage to receive the flow returning from the injector passages and, should the speed of the engine fall below a desired idling speed, the governor-operated means provides for a restriction of the drain passage to increase the pressure in the injector passages and thus supply more fuel to the engine cylinders to bring the speed of the engine back up to the desired idling speed.

The present fuel apparatus also includes a novel shut-off valve which provides for drainage of the injector passages so that any injector which is left open at the time the engine is stopped will not be flooded with fuel from its passage.

One embodiment of the invention is shown in detail in Figs. 1 to 6, 8 and 9, and is shown diagrammatically in Fig. 7. In order to give a clear understanding of the invention, particularly as to its broad aspects, it will be described first from the diagrammatic disclosure of Fig. 7.

In this figure, the supply of fuel is shown as being carried in a fuel tank 20 provided with an air vent 21. Fuel is withdrawn therefrom through a line 22 provided with a check valve 23 by means of a pump 24 which is preferably a gear pump. This pump is the one that has heretofore been referred to as supplying fuel under pressure to the various injectors.

From the pump 24, fuel preferably passes through a line 25 to a filter 26 and thence to a line 27. In case the filter should become seriously clogged so that too great a head of fuel is required to force fuel therethrough, a check valve 30 is provided which permits bypassing of the filter 26 so that fuel may flow directly from the line 25 to the line 27. The line 27 is also provided with a check valve 31 which prevents fuel from passing therebeyond until the pressure built up by the pump exceeds a predetermined value. The purpose of the check valve 31 is to prevent the apparatus being flooded by fuel from the tank 20 when the engine is stopped, in case the tank is carried at an elevation above the engine. The check valve 31 is of the spring-pressed type and its spring is such as to withstand any pressures that might result from elevation of the tank 20, but the check valve 31 is adapted to open when the pressure in the line 27 is built up by the pump 24.

As heretofore mentioned, the pressure of the fuel delivered by the pump is adapted to be controlled by a pressure regulator, indicated generally in Fig. 7 by the numeral 32. The line 27 extending from the pump 24 is connected to an inlet 33 in the pressure regulator and fuel is permitted to flow from the latter through an outlet 34 to the rest of the apparatus. The pressure regulator 32 is provided with a bore 35 in which is slidably mounted a tubular member 36. The bore 35 at one end is enlarged as at 37 and the inlet 33 and outlet 34 open into this enlarged portion 37. The end of the tubular member 36 also opens into the enlarged portion 37 so that fuel flowing from the inlet 33 to the outlet 34 may enter the tubular member 36.

The tubular member is closed at its left end, as shown in Fig. 7, and is provided with lateral bleed passages 40 adjacent its left end. The tubular member 36 is urged to the right by a spring 41 and when in its extreme right-hand position, the bleed passages 40 lie within the bore 35 so that they are closed. Upon building up of pressure within the pressure regulator by the pump 24, the tubular member 36 will compress the spring 41 by movement

to the left so that the bleed passage 40 will move to a position beyond the end of the bore 35 and thus be open for flow. A portion of the fuel supplied through the line 27 by the pump 24 will thus be bled off. The fuel thus by-passed may flow from the pressure regulator through an outlet 42 connected by a line 43 to the intake side of the pump 24. When the pressure of the fuel supplied by the pump reaches a predetermined maximum, the tubular member 36 is moved far enough to open additional and larger bleed passages 44 so as to dump a large amount of fuel and thus provide a limit to the pressure attainable by the pump.

It will be seen from this construction that as soon as pressure is built up by the pump 24, the bleed passages 40 will be opened to bleed off some of the fuel delivered by the pump and thus control the pressure attainable by the pump is adapted to be driven by the engine so that its delivery is proportional to engine speed. Thus, with an increase in engine speed, the delivered pressure will tend to rise, moving the tubular member 36 farther to the left against the pressure of the spring 41. The bleed passages 40, in the present instance, are adapted to bleed off sufficient fuel to maintain a desired rise of pressure in the fuel supplied by the pump, a greater rate of flow occurring through the bleed passages 40 as the pressure increases. While the bleed passages 40, shown as simple round holes in the present instance, are found to yield the desired pressure for the present apparatus, it is contemplated that the bleed passages may in some instances provide for an increasing area of the bleed opening to attain the desired range of pressure. The pressure regulator also may include means, indicated at 45, for varying the effective size of the bleed passage to compensate for factors inherent in other parts of the apparatus, said means being described in more detail hereinafter.

The outlet 34 of the pressure regulator is connected by a line 46 to a manually operable throttle, indicated generally at 47, having a passage 50 to which the line 46 is connected. The manually operable throttle in this instance is shown as a rotatable member 51 having a transverse bore 52 therethrough and adapted by rotation of the member 51 to be moved into registry with the passage 50. Such movement also connects the bore 52 with a line 53 connected to governor-operated means indicated generally at 54.

The governor in this instance as illustrated as comprising a carrier member 55 adapted to be driven by the engine. To this end, the carrier 55 is preferably mounted on the same shaft as drives the pump 24. The carrier 55 pivotally supports a pair of relatively large low-speed weights 56 and a pair of smaller high-speed weights 57. As will hereafter be more fully described, the two sets of weights together act to move a control plunger 60 in the governor-operated means 54 to control the flow of fuel at idling speed, while movement of larger weights 56 is prevented at speeds above idling and the smaller weights 57 alone act to move the plunger 60 to limit the flow of fuel to the engine when a predetermined maximum speed is attained.

The governor-operated means 54 includes an inlet duct 61 connected to the line 53 extending from the manually operable throttle 51, and an outlet duct 62. Flow of fuel from the inlet duct 61 to the outlet duct 62 passes around a reduced portion 63 formed on the plunger 60. From the outlet duct 62 fuel flows through a line 64 which is herein shown as connected to a groove 65 formed in the manually operable throttle member 51 and thence to a line 66 connected to a common supply rail 67 for supplying fuel to the injectors. The supply rail 67 together with the lines and passages extending from the pump as heretofore described constitute a first conduit as recited in certain of the claims.

Each injector is herein indicated generally at 70 and it is to be understood, of course, that there is one injector for each of the engine cylinders, the injectors be-

ing mounted in the heads of the cylinders for injecting fuel into the respective cylinders.

As hereinbefore generally stated, each injector is provided with a fuel passage extending therethrough from which fuel is diverted for injection into the associated cylinder, the pressure of the fuel in such passage determining the amount of fuel that is injected for each charge into the cylinder. The construction of the injectors is shown in Figs. 8 and 9. The common supply rail **67** is connected to each injector by a branch line **71** (see Fig. 7), and the latter is connected to a passage **72** (see Fig. 8) in the head **73** of the injector. The injector is provided with a main body **74** extending downwardly from the head **73** and has a longitudinal bore **75** therein which connects at its upper end to the passage **72**. At its lower end, the passage **75** is reduced as at **76** (see Fig. 9) and opens into an annular chamber **77** formed between a reduced portion **80** on the lower end of the injector body **74** and an injector cup **81** secured thereon.

Cup **81** is provided with a tapered interior **82** forming a fuel chamber and has restricted nozzle openings **83** through which fuel is adapted to be forced from the fuel chamber into the cylinder for combustion therein. Aligned with the tapered interior **82** of the injector cup **81** is an internal bore **84** in the body **74** of the injector and reciprocably mounted in this bore is an injector plunger **85** having a tapered lower end **86** adapted to move downwardly into the tapered interior **82** to force fuel therefrom through the nozzle openings **83**. The plunger **85** is adapted to be reciprocated in timed relation to the operation of the engine and in Fig. 8 I have shown diagrammatically means for effecting this result. Thus, each plunger **85** is actuated by a rocker arm **86** moved by a push rod **87** actuated by an engine driven cam **90**.

To supply fuel to the injector cup, the reduced lower end **80** of the injector body is provided with a lateral orifice or inlet port **91** extending from the annular space **77** to the bore **84**. The orifice **91** is positioned so that it is adapted to be opened and closed by reciprocation of the plunger **85**. Thus, when the plunger **85** is raised, the pressure of the fuel in the annular chamber **77** causes flow of fuel through the orifice **91** into the interior of the injector cup **81**, the orifice **91** being closed when the plunger **85** moves downwardly to prevent flow through the orifice.

With this construction, the quantity of fuel diverted from the annular chamber **77** through the orifice **91** into the injector cup depends upon the pressure of the fuel in the chamber **77**, the size of the orifice **91**, and the length of time that the orifice remains open by virtue of the reciprocation of the plunger **85**. The size of the orifice **91** is fixed, and the length of time that it is open is determined by the shape of the cam **90** and the speed of the engine. Control of the quantity of fuel metered through the orifice each time that it is opened is therefore obtained by controlling the pressure of the fuel circulated through the annular chamber **77**.

To maintain circulation of fuel in the chamber **77**, the injector is provided with a continuation of the passage **75** beyond the orifice **91**. Thus, the chamber **77** connects with a return passage **92** extending upwardly in the injector body on the opposite side from the passage **75**. Midway of the length of the injector body, the passage **92** extends inwardly, as at **93** (see Fig. 8), and opens into the bore **84** at a point where the plunger **85** is reduced in diameter, as shown at **94**. Thus, any leakage of fuel along the plunger from the lower end thereof is picked up by the return portion of the injector passages. Near the upper end of the reduced portion **94** of the plunger, there is a lateral passage **95** connecting with a vertical passage **96** extending to the head of the injector. In the head, the passage **96** connects with a lateral passage (not shown) which in turn is connected to a branch line **97** (see Fig. 7), there being one branch line **97** for each injector. The branch lines **97** are all connected to common return rail **100**.

One means for controlling the pressure of the fuel passing through the injector passages formed by the longitudinal passages **75** and **92** and the annular chamber **77** comprises means for restricting the flow from the return rail **100**. The restriction offered by such means is adjustable so that there may be increased restriction for increased engine speed, or load or both, thus increasing the pressure of the fuel in the chambers **77** of the injectors so as to increase the quantity of flow through the orifices **91** each time they are opened. Consequently, more fuel will be injected into the cylinders to increase the engine speed or load or both.

In the present instance, a predetermined restriction is provided for idling speed and as the throttle **51** is shifted to increase the engine speed, the restriction becomes greater. For this reason the restricting means is interconnected with the throttle **51** and comprises restricted passages formed in the throttle **51**. Thus, the throttle **51** is provided with a transverse notch **101** through which the flow returning from the common return rail **100** passes when the throttle **51** is set for idling speed. The notch **101** provides for fairly free flow through the return rail **100**. As the throttle is shifted away from its idle speed position, the notch **101** moves away from its connection with the rail **100** and a transverse aperture **102** formed in the throttle **51** moves into registry with the line connected to the return rail **100**. The transverse aperture **102** opens into the notch **101** and fuel returned from the injectors either directly through the notch **101** or through the aperture **102** and the notch then flows through a line **103**. The return rail **100** together with the line connecting it with the throttle **51** and the line **103** constitute a second conduit for conducting fuel away from the injector passages.

The line **103** is connected to a drain duct **104** formed in the governor-operated means **54** and flow therethrough under certain conditions is controlled by the plunger **60**. Thus, the drain duct **104** communicates with a bore **105** at one end of the governor-operated means **54** and the governor-operated plunger **60** is provided with a reduced portion **106** which, when the engine is operating at speeds above a predetermined minimum somewhat below idling speed, registers with the bore **105** so that the fuel return to the drain duct **104** from the common return rail **100** may be discharged through the bore **105**.

The pump **24**, the pressure regulator **32**, the throttle **51**, the governor, and the governor-operated means **54** are all preferably mounted in a single housing, which is not shown in the diagrammatic view of Fig. 7 but is illustrated in the other views showing this embodiment. The fuel returned from the injectors and draining through the bore **105** is discharged into the housing. A second pump **107** is mounted in the housing is provided with an intake **110** for picking up the fuel collecting in the housing and such fuel is discharged through a line **111** and returned to the main fuel tank **20**. In addition to the fuel discharged through bore **105**, any leakage into the housing will also be picked up by the pump **107** for return to the fuel tank **20**. Any air carried by the fuel returned to tank may separate from the fuel when it reaches the tank and the vent **21** prevents pressure being built up in the tank.

For operation of the engine at speeds above idling, the fuel from the pump **24** passes through the pressure regulator **32** where a portion of the fuel is bled off, and then to the throttle **51** where it passes through the transverse bore **52**. From there, the fuel flows through the inlet duct **61** in the governor-operated means **54** around the plunger **60** and from the outlet duct **62** to the common supply rail **67** to supply the injectors. The fuel circulated through the injectors in excess of that diverted for injection into the cylinders returns to the return rail **100**,

thence through the aperture 102 in the throttle 51 to the drain duct 104 in the governor-operated means 54. From the drain duct 104 the fuel flows into the housing to be picked up by the pump 107 for return to the fuel tank 20.

Rotative adjustment of the throttle 51, of course, determines the degree to which the transverse bore 52 is opened and consequently controls the flow of fuel to the injectors. At full throttle, the transverse bore 52 is fully opened. If the throttle is moved to its fully opened position and there is no load on the engine, the speed would tend to exceed a desired maximum. To prevent this, the reduced portion 63 of the plunger 60 in the governor-operated means 54 provides a shoulder 112 which preferably is tapered and which, by the action of the governor, moves to close communication between the inlet duct 61 and the outlet duct 62. Thus, the flow of fuel to the common supply rail 67 of the injectors will be shut-off when the speed of the engine exceeds a predetermined maximum and the speed will consequently be limited, the governor opening the communication between the inlet duct 61 and the outlet duct 62 when the speed falls below such predetermined maximum. Actuation of the plunger 60 to attain this result is obtained by movement of the high speed governor weights 57.

For operating the engine at idling speed, the hand throttle 51 is turned to its extreme position at which the transverse bore 52 is out of registry with the passage 50 so that no fuel can flow therethrough to the governor-operated means 54 to supply the injectors. Fuel is supplied, however, through a branch line 113 extending from the line 46 to a second inlet duct 114 formed in the governor-operated means 54. The second inlet duct 114 extends to the bore in which the plunger 60 operates, and when the speed is reduced to idling, the reduced portion 63 of the plunger provides space for communication between the second inlet duct 114 and the outlet duct 62 so that fuel may flow therethrough to supply the injectors. To prevent the engine from exceeding a predetermined speed for idling, the tapered shoulder 112 on the plunger 60 moves to close the second inlet duct 114 when the speed exceeds such predetermined speed.

When the fuel is supplied to the injectors through the branch line 113 and the second inlet duct 114 to operate the engine at idling speed, the fuel flows through the injector passages and the excess over that required for operation of the engine returns through the common return rail 100. Such return flow is conducted to the throttle valve and the latter, when in idling speed position, has the notch 101 shifted to directly receive the fuel flowing from the common return rail 100. Because of the relatively large size of the notch 101, very little restriction is encountered by the return flow so that the pressure in the injector passages and particularly in the annular chambers 77 is relatively low. Thus, the amount of fuel passing through the orifices 91 is small and is only sufficient to maintain the engine at idling speed.

If there is some load on the engine when the hand throttle is turned to idling position, the speed of the engine will be thereby reduced. Through the governor weights, this reduction causes the plunger 60 of the governor-operated means 54 to be moved to the left, as illustrated in Fig. 7, so that the reduced portion 63 of the plunger aligns with both the second inlet duct 114 and the discharge duct 62 to give the maximum freedom for flow of fuel therethrough under idling conditions. However, if the load on the engine is of such size that it tends to reduce the speed still farther below idling speed, then the shoulder, indicated at 115, formed by the reduced portion 106, tends to close the bore 105 and thus provides restriction to the free return of fuel from the return rail 100. The pressure is thereby increased in the annular chambers 77 in the injectors to increase the flow of fuel through the orifices 91, and thus bring the speed of the engine up to that desired for idling.

When the engine is stopped, the plunger 60 of the governor-operated means 54 has been moved to a position where it completely closes the bore 105 from the drain duct 104. The drain, however, is provided with a small vent 116. On starting the engine, the fuel delivered by the pump 24 will purge the system of air, particularly the passages in the injectors, and the air can escape through the vent 116. However, as soon as the air is discharged, the vent 116 is small enough to greatly restrict the flow of fuel from the drain duct 104, and consequently, the pressure in the annular chambes 77 of the injectors will be rapidly built up to force fuel through the orifices 91 for injection into the cylinders. After the engine attains a speed somewhat less than idling speed, the shoulder 115 on the plunger 60 will move beyond the bore 105 to permit discharge of fuel through the bore and the engine then functions at idling speed, as heretofore described.

Since the hand throttle 51 merely controls the engine between idling speed and maximum speed, a separate shut-off valve is provided for stopping the engine. Such shut-off, in the present instance, cooperates with the various ducts in the governor-operated means 54, and comprises a tubular member 120 mounted so that its interior communicates with the outlet duct 62 of the governor operated means. The valve member 120 is also provided with a pair of radial holes 121 and 122 opening from the interior thereof. The lower of the two holes 121 is positioned so that it may be rotatably moved into registry with a discharge passage 123. The hand throttle 51 is normally first turned to idling speed position so that no fuel can flow to the injectors from the pump 24 through the transverse bore 52. Rotation of the shut-off valve 120 to bring the hole 121 in registry with the discharge passage 123 permits the fuel flowing through the idle speed branch 113 to be discharged. Moreover, the shut-off valve permits fuel from the common supply rail 67, as well as the injector passages connected thereto, to drain backwardly through the shut-off valve 120 for discharge into the housing.

At the same time that the radial hole 121 is aligned with the discharge passage 123, the second radial hole 122 also aligns with a passage 124 extending from the drain duct 104. Thus, fuel may also drain to the discharge passage 123 from the return rail 100 and the injector passages. Both ends of each injector passage are thus connected to the discharge 123 in the governor-operated means so that fuel may be completely drained therefrom.

As the engine slows down and no fuel is supplied thereto, the air compressed in the cylinders will pass into the injector cups 81, and thence outwardly through the orifices 91 to force the fuel in the injector passages through both rails to the discharge passage 123. Moreover, the fuel supply apparatus is positioned so that the discharge passage 123 is located below the injectors, when the fuel supply apparatus is mounted on an engine, and the air entering the injector passages from the cylinders will permit a siphoning of the fuel therein back to the discharge passage 123 both through the supply rail 67 and the return rail 100.

The foregoing description relates to the construction as disclosed in the diagrammatic showing of Fig. 7, and indicates how the present fuel apparatus functions. A detailed description of the actual construction of the apparatus is hereinafter given, but it, of course, conforms to the diagrammatic showing. The various connecting lines referred to in the diagrammatic showing are, in many instances, in the form of passages provided in the structure of the actual apparatus as will more fully hereinafter appear.

The various parts of the present fuel apparatus with the exception, of course, of the injectors 70 and the supply and return rails 67 and 100, are enclosed within a housing indicated generally at 130 in Fig. 1. The hous-

ing comprises a main section 131 a pump section 132 and a control section 133. Between the main section 131 and the pump section 132 there is a separator plate 134 (see Fig. 1) and the two sections 131 and 132 and the separator plate 134 are held in properly aligned relation by dowel pins 135 and bolts. The main section 131 is open at its bottom face as shown at 136 and a cover plate 137 is mounted over the opening, the cover plate 137 being provided with a drain plug 140 which permits drainage of all fuel discharged into the housing.

Fuel is supplied to the apparatus from a tank such as the tank 20 shown in Fig. 7, and a pipe 141 constitutes the line 22. The pipe 141 is threaded into fitting 142 (see Figs. 1 and 4) which is threaded into the cover plate 137. The fitting 142 includes the check valve 23.

Fuel is supplied to the pump 24 from the check valve 23 by a vertical passage 143 formed in the main housing section 131. At its upper end, the vertical passage 143 opens into a longitudinally extending passage 144 (see Fig. 4) which extends through the separator plate 134 and into the pump section 132 (see Fig. 2). In the latter, the longitudinally extending passage 144 communicates with an intake chamber 145 for the fuel supply pump 24 which is mounted in a cavity in the pump section 132, the cavity being closed by the separator plate 134. Fuel delivered by the pump 24 is discharged into a delivery chamber 146 provided in the pump section 132.

Extending from the delivery chamber 146 is a passage 147 which slants downwardly and extends to a filter chamber 150 (see Figs. 1 and 3). Within the chamber 150 is mounted the filter element 26. Fuel flowing into the chamber 150 from the passage 147 passes inwardly through the filter element 26 and then flows therefrom through a vertical passage 152 (see Fig. 2) formed in the pump section 132. The by-pass valve 30 is also mounted in the pump section 132 and when open provides communication directly from the passage 147 through a short passage 149 to the passage 152. As heretofore described, when the filter becomes clogged to such an extent that too great a head of fuel is required to force fuel therethrough, the pressure of the fuel will cause the check valve 30 to open so that the fuel by-passes the filter element 26.

At its upper end, the passage 152 communicates with a longitudinally extending passage 153 (see Fig. 2) which extends to the check valve 31 (see Fig. 5) mounted in the main section 131 of the housing. The check valve 31 is adapted to open when the pump 24 develops sufficient pressure in the fuel delivered thereby and the check valve 31 remains closed until such time so that, should the fuel tank 20 be in an elevated position, the pressure due to such position will not cause flow of fuel to the engine.

From the check valve 31, the fuel flows to the intake 33 of the pressure regulator 32 which is mounted in a cavity 154 formed in the main section 131 as shown in Figs. 4 and 5. Fuel supplied by the pump 24 and entering the pressure regulator through the inlet 33 is permitted to flow from the latter through the outlet 34 as heretofore described.

The pressure regulator 32 comprises a sleeve 155 mounted in the cavity 154 and having a flanged end 156 seated against a shoulder formed by an enlargement of the cavity 154. The sleeve 155 provides the bore 35 in which the tubular member 36 is mounted. The tubular member 36 as heretofore described is open at its right-hand end, as shown in Fig. 4, so that fuel entering the cavity 154 is permitted to flow into the interior of the tubular member 36. The left-hand end of the tubular member 36 is closed and is provided with a plurality of bleed passages 40 extending radially from the interior thereof. The tubular member 36, at its left-hand end, is also provided with a flange 157 and, when no pressure is applied to the tubular member, the spring 41 holds the flange 157 against the flanged end 156 of the sleeve 155. The bleed passages 40 are so positioned that under such condition they lie within the bore 35 of the sleeve 155 and are closed. The spring 41 is carried in a plug 161 which is threaded in the enlarged portion of the cavity 154.

When the pump 24 builds up pressure in the cavity 154, the tubular member 36 is moved to the left, as shown in Fig. 4, against the pressure of the spring 41, and when the bleed passages 40 move beyond the flanged end 156 of the sleeve 155, fuel is by-passed through the tubular member 36 out through the bleed passages 40 and into the enlarged portion of the cavity 154. To adjust the flow of fuel through the bleed passages to the proper amounts at the various operating pressures to provide a desired metering of fuel at the injectors, the interior of the tubular member 36 is provided with a valve seat 162 and the needle valve 45 heretofore mentioned cooperates therewith to regulate the area through which the fuel may flow from the interior of the tubular member 36 to the bleed passages 40. The needle valve 45 is formed on the end of a screw 164 threaded into the left-hand end of the tubular member 36. The needle valve 45 thus varies the effective size of the bleed passages 40 to compensate for various factors inherent in other parts of the apparatus. Thus, the effective area of the bleed passages 40 may be varied to obtain proper pressures of the fuel flowing to the injectors.

The fuel by-passed through the pressure regulator 32 is returned to the intake side of the pump 24. To this end, the enlarged portion of the cavity 154 communicates with a longitudinally extending passage 165 formed in the main housing section 131. The passage 165 extends through the separator plate 134, and into the pump section 132 to communicate with a branch 166 of the pump intake cavity 145, as shown in Fig. 2. Thus, the fuel by-passed by the pressure regulator is returned to the pump 24.

As the speed of the engine increases, the effective area of the bleed passages remains constant but the increased speed of operation of the pump increases the quantity of fuel delivered thereby and hence the delivery pressure increases. The quantity of fuel by-passed will thus increase, thereby providing the desired increase in the pressure of the fuel supplied to the engine to obtain a predetermined torque curve. Determination of such torque curve may thus be obtained by the design of the pressure regulator.

As mentioned in the description heretofore given, the present apparatus also includes a pump 107 for removing the fuel discharged into the housing 130 and for returning it to the fuel tank 20. The pump 107 is mounted in a cavity 170 (see Fig. 1) provided in the main housing section 131 and closed by the separator plate 134. Thus, the fuel pump 24 is on one side of the separator plate while the pump 170 is on the opposite side thereof. To remove the fuel collecting in the housing, the main section 131 thereof is provided with a passage 171 (see Fig. 4) adjacent the lower portion of the main section and extending from the interior thereof to the intake side of the pump cavity 170. The delivery side of the pump cavity 170 has extending therefrom a passage 172 leading to a threaded bore 173 extending to the adjacent side face of the main section 131. In the outer end of the bore 173, a return pipe 174 constituting the line 111 may be connected for conducting fuel to the tank 20.

The two pumps 24 and 107 are preferably of the gear type, and one gear of each pump is shown as being keyed to a tubular shaft 174 (see Fig. 1) located in a suitable bore in the main section 131 and the pump section 132 of the housing. At its inner end, the tubular shaft 174 is shown as being mounted in a ball bearing 175 seated in the main section 131, and at its outer end, the tubular shaft 174 is shown as being mounted in a roller bearing 176 located in the pump section 132. The other gear of each of the two pumps is mounted on a stub shaft 177

having its ends journaled in roller bearings respectively mounted in the main section 131 and the pump section 132. Preferably only one of the lower pump gears is keyed to the stub shaft 177 while the corresponding gear of the other pump is mounted loosely thereon. Both gears, however, rotate together, since both are driven from the upper gears mounted on the tubular shaft 174, and consequently, there will be no rotation between the stub shaft 177 and the gear which is loosely mounted thereon.

To drive the tubular shaft 174, a main shaft 180 extends therethrough, the main shaft being of smaller diameter than the interior of the tubular shaft 174 and having a splined portion 181 on its inner end cooperating with splines formed on the interior of the inner end of the tubular shaft 174. The main shaft extends outwardly beyond the tubular shaft 174 and adjacent the end of the latter carries a gear 182 adapted to drive a gear 183 (see Fig. 3) mounted on a tachometer drive shaft 184. In this instance the tachometer itself is not shown. Beyond the gear 182, the main shaft 180 is journaled in a ball bearing 185 mounted in the outer end of the pump section 132. Beyond the pump section the main shaft is provided with coupling means indicated generally at 186, for connecting the shaft to the engine so that it may be driven thereby. Any leakage of fuel from the pump 24 through the bearing 176 and into the mounting for the tachometer drive shaft 184 is adapted to be drained back to the main housing section through a passage 187 (see Fig. 1) formed in the pump section 132 and extending through the separator plate 134 and the adjacent wall of the main section 137 to the interior of the latter, so that such fuel may be picked up by the pump 107 and returned to the fuel tank.

The fuel delivered by the pump 24, after passing through the pressure regulator 32, flows through the outlet 34 of the latter and thence through a longitudinal passage 190 provided in the upper part of the main section 131 of the housing. From the passage 190 the fuel flows into an extension thereof, indicated at 191, in the control section 133. The passage 190 and its extension 191 constitute the line 46 referred to in connection with the diagrammatic view of Fig. 7.

The throttle valve 51 is mounted in the control section 133 of the housing, as shown in Figs. 5 and 6, and comprises a rotatable shaft journaled in the control section and having passages cooperating with passages in the control section to control the flow of fuel. Thus, the throttle valve 51 is provided with the transverse bore 52 adapted to be moved into and out of registry, by rotation of the throttle valve, with the passage 50 communicating with the passage 191. When the throttle 51 is rotated to bring the bore 52 into registry with the passage 50, fuel may flow therethrough to a longitudinally extending passage 193 constituting a portion of the line 53 referred to in the diagramamtic disclosure. The latter conducts fuel to the governor-operated means 54 shown in longitudinal section in Figs. 1 and 5 and indicated by dotted lines in Fig. 6.

The governor-operated means 54 comprises a conical member 194 seated in a cavity formed in the control section 133 of the housing and held in place therein by a clamping plate 195 bolted to the interior face of the control section 133. The passage 193 communicates with an arcuate passage 196 formed in the conical member 194 and constituting a portion of the inlet duct 61. Extending from the arcuate passage 196 are one or more radial passages 197 formed in the conical member 194. The radial passages 197 communicate with a central bore 200 extending through the conical member 194. Slidably mounted in the bore 200 is the governor-operated control plunger 60. The outlet duct 62 comprises one or more radial passages 201 formed in the conical member 194 and a short arcuate passage 202. The arcuate passage 202 communicates through the face of the conical member 194 with a longitudinal passage 203 formed in the central section 133 of the housing. The latter in turn leads to a vertical passage 204 extending upwardly to the bore in which the throttle valve 51 is located. The passages 203 and 204 constitute the line 64 referred to in the diagrammatic view. The passage 204 communicates with the annular groove 65, shown in Fig. 6 and formed in the throttle valve 51, and the fuel may flow beyond the throttle valve to the injectors 70 by the line 66 which is adapted to be connected into the threaded hole 204 communicating with the annular groove 65 of the throttle valve.

As heretofore stated, the plunger 60 is adatped to be operated by the governor which in turn is driven by the engine. The governor comprises the carrier member 55 (see Figs. 1 and 5) which is mounted on the inner end of the tubular drive shaft 174 driving the two pumps 24 and 107. The carrier member 55 supports, on pivot pins 206, the low speed weights 56 and the high speed weights 57. The low speed weights 56 are connected to the high speed weights 57 by means of pins 207 projecting from the sides of the low speed weights into enlarged apertures 210. At lower speeds, the larger low speed weights 56 move outwardly and the high speed weights move along with them, the high speed weights being provided with arms 211 engaging a collar 212 secured to the adjacent end of the plunger 60. Movement of the plunger by the weights is resisted by a spring means indicated generally at 213 in Figs. 1 and 5, such spring means engaging the opposite end of the plunger 60. Thus while the outward movement of the high speed weights 57 is resisted by the spring means 213, the low speed weights assist in overcoming the action of the spring means, under certain circumstances, by pulling the high speed weights 57 outwardly through the pins 207. When the engine reaches a predetermined speed proper for idling, further outward movement of the low speed weights 56 is prevented by fingers 214 provided on the ends of the low speed weights and adapted to engage the carrier member 55.

As heretofore described, the governor plunger 60 is provided with a reduced portion 63 which permits flow from the inlet duct 61 comprising passages 196 and 197 to the outlet duct 62 comprising passages 201 and 202. In order to limit the speed of the engine to a predetermined maximum, the reduced portion 63 is provided with the tapered shoulder 112 which, upon movement of the plunger 60 to the right as shown in Figs. 1 and 5, gradually shuts off flow of fuel from the inlet duct to the outlet duct and completely stops such flow when the predetermined maximum speed is reached. In order to prevent the plunger 60 from sticking in the conical member 194 and resisting the movement thereof by the governor weights, the plunger is constantly rotated so as to break any adherence between the plunger and the conical member. Such rotation of the plunger is effected by providing a straight sided boss 215 on the collar 212 so that the arms 211 of the high speed weights 57 engage the straight sides of such boss and cause the collar together with the plunger 60, to rotate. Thus, the plunger 60 is constantly being moved within the bore in the conical member 194 so that it is quickly responsive to the force exerted by the governor weights to move it longitudinally.

The spring means 213, which resists outward movement of the governor weights, is provided with two springs, one which is indicated at 220 being a relatively light spring and resisting movement of both low and high speed weights to control the idling speed of the engine, and the other, which is indicated at 221, being a relatively stiff spring and resisting movement only of the high speed weights 57 to determine maximum speed of the engine. The right hand end of the governor plunger 60, as viewed in Fig. 1, is provided with a head 222 engaging a cup shaped member 223 within which the spring 220 is seated. The spring 220 at one end bears against the end of the cup member 223 and at its other end against a spring seat 224 rigidly secured to an end of an adjusting screw 225. The cup member 223 is adapted to telescope over

the spring seat **224** in compressing the spring **220**. The adjusting screw **225** is threaded in a tubular member **226** and the latter is slidably mounted in a retainer **227** threaded in the control section **133** of the housing. The tubular member **226** has an enlarged inner end portion **230** in which the cup member **223** slides. The tubular member is also provided with an internal shoulder **231** which is adapted to be engaged by the cup member **223** when the spring member **220** is compressed to the desired extent. The screw **225** thus adjusts the resistance offered by the spring **220** to the outward movement of the two sets of centrifugal weights when the engine is operating at idling speed so that movement of the governor plunger **60** can cut off the flow of fuel to limit the idling speed as has been described in connection with the diagrammatic view of Fig. 7 and will be more fully described hereinafter.

The high speed spring **221** is located between the tubular member **226** and the retainer **227** and is adapted to be compressed by movement of the high speed weights **57** alone. Thus, when the maximum speed for the engine is approached, the high speed weights **57** begin to move outwardly independently of the low speed weights and compress the spring **221**, the enlarged apertures **210** in the high speed weights permitting such independent movement. At a predetermined speed, the tapered shoulder **112** on the governor plunger **60** shuts off all flow of fuel from the inlet duct **61** to the outlet duct **62**. More specifically, flow of fuel from the radial passages **197**, as illustrated in Figs. 5 and 6, to the radial passage **201** is prevented. The spring means **213** is preferably enclosed by a cover **232** secured to the housing.

When the governor plunger **60** cuts off all flow of fuel from the inlet duct to the outlet duct at the maximum engine speed so that no fuel can flow to the engine, the pump, of course, is still operating to deliver fuel. Such fuel must be by-passed but the bleed passages **40** in the pressure regulator **32** are insufficient to carry off this quantity of fuel without producing excessively high pressures in the system. For this reason, the tubular member **36** of the pressure regulator is provided with the additional and larger bleed passages **44** (see Fig. 4) and the pressure of the fuel forces the member **36** outwardly so that the passages **44** are beyond the flanged end **156** of the sleeve **155** and a large amount of fuel thus may be dumped to return to the intake side of the pump **24**.

The fuel flowing to the injectors through the line **66** connected into the threaded hole **205** flows to the common supply rail **67** and thence into the injectors, as heretofore described in connection with the diagrammatic showing of Fig. 7. The pressure of the fuel within the injectors, which determines the metering by the orifices **91** is thus controlled partially by the pressure regulator **32**. The throttle valve **51** controls the flow between idling speed and the maximum, the throttle valve preventing flow by closing communication between the passage **50** and the passage **193** in the control section of the housing at idling speed. As the throttle **51** is rotated, its transverse bore **52** moves into registry with the passage **50** to gradually increase the area through which fuel may flow to the passage **193**, thus gradually increasing the flow to the engine through the injectors. The transverse bore **52** is adapted to be fully in registry with the passage **50** at full throttle and the throttle member **51** thus may be employed to control the flow of fuel to the engine between idling speed and maximum. The governor, as heretofore described, controls the speed at idling and limits the speed of the engine to a predetermined maximum when the throttle is fully open.

As previously described, the throttle **51** is moved so that the transverse bore **52** is out of registry with the passage **60** for operating the engine at idling speed. However, a small quantity of fuel is required for such operation and as mentioned in describing the diagrammatic showing, fuel is supplied to the engine through a branch line **113** (see Fig. 5). The branch line **113** which is provided by a passage in the control section **133**, connects with the extension **191** carrying fuel from the pump and communicates with a short longitudinal passage **233** extending to the face of the conical member **194** of the governor-operated means **54**. The passage **233** opens into a short arcuate passage **234** formed in the conical member **194**, and the passage **114** extends from the arcuate passage **234** radially to the bore in which the plunger **60** is mounted.

With the foregoing arrangement, when the throttle valve **51** shuts off flow of fuel therethrough to the governor-operated means, fuel may flow through the passages **113**, **233**, **234**, and **114**. With the engine operating at idling speed, the reduced portion **63** of the plunger **60** will be moved to the left, as shown in Fig. 5, far enough to bring it opposite the radial passage **144**. In such position the outlet duct comprising the radial passage **201** is also open and the fuel thus may flow therethrough to the arcuate passage **202**, the passages **203** and **204** to the grooves **65** in the throttle valve **51** and thence to the injectors.

If the speed of the engine tends to exceed the desired idling speed, the governor plunger **60** moves to the right, thus first bringing the tapered portion **112** in line with the radial passage **114** to reduce the flow therethrough. If the speed of the engine is still greater, the plunger moves the tapered portion **112** still farther and thereby completely shuts off flow of fuel through the radial passage **114**. Thus, no fuel will be conducted to the injectors. As the speed of the engine decreases, the radial passage **114** is opened to permit flow therethrough.

As mentioned in the description of the diagrammatic disclosure of Fig. 7, the fuel flowing through the groove **65** in the throttle member **51**, whether the engine is operating at speeds above idling or at idling speed, is conducted through the line **66** to the common supply rail **67**. The fuel then enters the injector passages and the fuel in excess of that flowing through the orifices **91** is returned through the return rail **100** to the throttle member **51** where it flows either through the notch **101** or through the transverse aperture **102** formed in the throttle member **51**. The notch **101** and the transverse aperture **102** are shown in Figs. 1 and 6 and it is evident from their difference in cross-sectional area that the aperture **102** offers a much greater restriction to the flow of fuel than the notch **101**. The line **103** extending therefrom, in the present instance is formed in the control section **133** (see Fig. 1) and extends to the face of the conical member **194** of the governor-operated means. Within the latter is the drain duct **104** which opens into a central chamber **240** provided therein. The adjacent end of the conical member **194** is provided with a plug **241** having the central bore **105** formed therein, through which the governor plunger **60** extends, as shown in Figs. 1 and 5.

When the engine is operating at idling speed, the shoulder **115** on the governor plunger is clear of the bore **105** so that fuel may flow from the chamber **240** through the central bore **105** around the reduced portion **106** of the governor plunger **60** which forms the shoulder **115**. Under this condition of operation, the throttle member **51** is positioned so that fuel may flow from the return rail **100** directly through the notch **101** in the throttle member, the passages **103** and **104** to the chamber **240** and thence out through the bore **105** for discharge into the interior of the main section **131** of the housing. The fuel thus discharged into the housing is returned by the pump **107** to the fuel tank **20** as heretofore described.

For operation of the engine at speeds above idling, the throttle valve **51** is turned so that not only is the passage **52** gradually opened but the return flow from the injectors is gradually shifted from passage directly through the notch **101** to passage through the transverse aperture **102** and then through the notch. Thus, the restriction in the return from the injector passages is

gradually increased to increase the pressure in the injector passages. Control of the quantity of fuel metered by the orifices is thus obtained by such increase in restriction. In one particular arrangement, turning of the throttle valve 51 first reduces the area of the portion of the notch 101 which is in registry with the passage connected to the return rail 100 and at approximately 60 per cent of full throttle, the transverse aperture 102 begins to open, with the notch being completely closed when the valve 51 has been moved to its full throttle position. The area through which the return flow passes is thus gradually reduced with the consequent increase in restriction. The invention is, however, not limited to this specific arrangement of the notch and bore, since other arrangements by which the restriction to the return flow may be varied are clearly within the scope of the invention.

When the engine is idling and if there is some load placed on the engine, the tendency will be to reduce the engine speed below the normal idling speed. Such reduction in speed causes the governor-operated plunger 60 to move to the left, and if the reduction in speed is of sufficient extent, the shoulder 115 on the plunger 60 moves to close the central bore 105 extending from the chamber 240. Such action restricts the flow of fuel from the injectors and thus tends to build up the pressure in the injector passages and particularly in the annular chambers 77 thereof so that an increased quantity of fuel will flow through the orifices 91 to increase the speed of the engine. Such increase in flow, however, is terminated as soon as the speed of the engine causes the shoulder 115 on the governor plunger 60 to move away from the central bore 105.

When the engine is stopped, the governor plunger 60 is in such position that the shoulder 115 thereon is completely within the central bore 105 so that no fuel can be discharged therethrough. On starting the engine, the air in the fuel passages in the injectors and in the lines leading thereto must be purged before fuel can enter through the orifices 91. For this reason, the drain duct 104 is provided with the vent 116 (see Fig. 1) so that such air can escape. The on-rushing fuel supplied to the various lines and passages, on starting, forces the air therein ahead of it and ultimately such air reaches the drain duct 104 to escape through the vent 116.

After the air is purged from the system, fuel eventually reaches the drain duct 104 and, of course, some of it will escape through the vent 116 to the interior of the housing. The size of the vent 116, however, is so small that considerable restriction to the flow is effected thereby and the pressure of the fuel in the injector passages will rapidly build up to cause flow of fuel through the orifices 91 for injection into the engine. As soon as the speed of the engine attains a predetermined value somewhat lower than idling speed, the shoulder 115 on the governor plunger 60 moves out of the central bore 105 and permits free escape of fuel therethrough from the drain duct 104. The engine then operates at idling speed as heretofore described.

In a previous portion of this description, the shut-off valve 120 was described in connection with the diagrammatic showing in Fig. 7. The function of this valve is to permit complete drainage of the lines leading both to and from the injectors, when the engine is stopped, so that no fuel can enter the injectors through the orifices 91 to collect in the injector chambers prior to starting the engine. The valve member 120 is tubular for at least a portion of its length, the internal bore being indicated in Figs. 1 and 6 at 242. The upper end of the bore 242 is open and communicates with passage 204 in the control section 133, through which fuel is conducted to the groove 65 in the throttle member 51. Thus, the interior of the tubular valve member 120 is open to the line through which fuel is conducted to the injectors.

Intermediate the ends of the valve member 120 is the radial hole 121 opening outwardly from the central bore 242. The radial hole 121, when the valve member 120 is properly rotated, is adapted to register with the passage 123, which in this instance is formed in the control section 133 and has an extension through the clamping plate 195 holding the governor-operated means 54 in place. Thus, communication is provided from the passage 204, through which fuel is supplied to the engine, and the interior of the housing, by rotating the valve member 120 to bring the radial hole 121 into registry with the passage 123.

Before the valve member 120 is so rotated, the throttle valve 51 is normally turned to idling position so that no fuel can flow through the transverse bore 52 to the governor-operated means. The fuel delivered by the pump 24 through the idling passages flows through the shut-off valve 120 and thus will not be supplied to the engine.

The shut-off valve 120 also provides for discharging fuel from the return rail 100 when the valve is rotated to the above-mentioned position. As the engine slows down, the central bore 105 extending from the chamber 240 and the drain duct 104, of course, becomes closed on lowering of the engine speed. To drain the fuel therefrom, the conical member 194 is provided with the passage 124 which connects with a passage 243 formed in the control section 133. The passage 243 leads to the second radial hole 122 provided in the shut-off valve 120 so that the fuel in the drain duct 104 may flow through the shut-off valve and thence through the passage 123 for discharge into the housing.

With the foregoing arrangement, it will be apparent that both the supply rail 67 and the return rail 100 are connected through the shut-off valve 120 with the passage 123 for discharge of the fuel therein to the housing. The first effect of opening the shut-off valve 120 is to release the pressure in the two rails leading to and from the injectors. As the engine slows down, the air compressed in the cylinders passes through the nozzle openings 83 and into the injector chambers so that, when the injector plungers 85 are raised, the pressure forces air outwardly through the orifices 91 and into the annular chambers 77 of the injectors. The fuel in the injector passages will thus be forced back to the shut-off valve both through the supply rail 67 and the return rail 100 so that such fuel will be discharged into the housing and the lines will be cleared of fuel as the engine slows down. Moreover, the air entering the annular chambers 77 in the injectors permits a siphoning action on the fuel to cause it to flow back to the shut-off valve since the injectors are positioned at a higher level than the shut-off valve.

The form of fuel apparatus shown in Figs. 10 and 11 is substantially the same as that shown in Figs. 1 to 9 inclusive, particularly as to the control of the pressure of the fuel circulated through the injectors. The chief difference lies in the manner in which the fuel is pumped to the apparatus. Thus, fuel is drawn from a tank 20 through a line 22 provided with the check valve 23. Such fuel is pumped by means of a pump 250 and is discharged through a passage 251 into a float tank 252 secured to the opening in the bottom of the main housing section 131 in place of the cover plate 137.

The fuel circulated through the injectors and discharged into the housing also may flow into the float tank 252 and the level of fuel in the float tank is controlled by a float 253 operating a valve 254 provided in the passage 251. Thus, when the float 253 indicates that a certain level of fuel has been reached in the float tank 252, the valve 254 is closed to prevent the pump 250 from dumping further fuel therein. The pump 250, however, continues to deliver fuel to the line 251 and a by-pass 255 extending from the line 251 carries the fuel delivered by the pump through a check valve 256 back to the intake side of the pump 250. The pump

24 in this instance draws its fuel from the float tank through a passage 257, instead of directly from the tank 20. The flow of fuel delivered by the pump 24 is exactly the same as in the first described form.

From the foregoing description, it will be apparent that with the present fuel apparatus a continuous flow of fuel under pressure is provided through the injectors, when the engine is operating. From such circulation of fuel in the injector passages, a quantity of fuel will be diverted through the orifices 91 for injection into the engine, such quantity being dependant upon the pressure of the fuel in the annular chambers 77 and the length of time that the orifices remain open by virtue of the movement of the injector plunger 85. In actual practice, the orifices 91 are opened by the plungers 85 at times the pressure of the air in the fuel chambers of the injectors is lower than the fuel pressure in the annular chamber 77 so that fuel is forced through the orifices 91. The pressure due to compression of the air in the cylinder rises above the fuel pressure causing flow through the orifices 91 before the plungers 85 close such orifices. Thus, the termination of flow through the orifices may be effected by the pressure existing in the fuel chambers of the injectors. However, a metered quantity of fuel has by that time been diverted through the orifices 91 for injection into the cylinders.

Since the quantity of fuel diverted through the orifices 91 depends upon the pressure in the annular chambers 77 of the injectors, control of the pressure of the fuel in the annular chambers thus determines the metering of the fuel to the cylinders, and by such control of the pressure a predetermined torque curve may be obtained for the engine. Control of the pressure in the present instance is obtained both by controlling the pressure of the fuel delivered by the pump as determined by the pressure regulator and by controlling the restriction to flow away from the injectors by means of slot 101 and the transverse aperture 102 in the throttle valve 51. While pressure of the fuel is thus controlled by the two means in the present instance in the broader aspects of the invention, the pressure can be controlled either by the pressure regulator alone with a restricting orifices on the return line of fixed size, or by omitting the control of the delivery pressure of the pump by the pressure regulator and controlling the pressure in the injectors solely by variation of the restriction to flow away from the injectors.

I claim:

1. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising an engine driven fuel pump, a pressure regulator for controlling the pressure of the fuel delivered by the pump, a supply rail connected to receive fuel from said pump, a return rail, a plurality of injectors, one for each cylinder and each having a permanently open passage therethrough connecting the two rails and also having means connected to said passage for injecting fuel into the associated cylinder, a throttle connected between said pump and said supply rail and controlling the flow of fuel from said pump to said supply rail, and means permitting a continuous but controlled flow of fuel through said return rail.

2. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising an engine driven fuel pump, a plurality of injectors connected to receive fuel from said pump, one for each cylinder and each having a permanently open passage through which fuel is continuously circulated and from which a quantity of fuel dependent upon the pressure of the fuel in said passage is diverted for injection into the associated cylinder, and means for controlling the pressure of the fuel flowing through said injector passages comprising a pressure regulator responsive to the pressure of the fuel delivered by said pump for varying such pressure to provide a predetermined pressure change as the speed of the engine varies, and means for restricting the flow of fuel from said injector passages.

3. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a plurality of injectors, one for each cylinder and each having a permanently open passage therethrough and also having means for injecting fuel into the associated cylinder including an inlet port connected to said passage, an engine driven pump for supplying fuel to said injector passages, a first conduit for conducting fuel from said pump to said injectors, a second conduit for conducting fuel away from said passages, means for controlling the pressure of the fuel flowing through said passages to determine the amount of fuel passing through said inlet ports for injection into the cylinders, said means comprising a pressure regulator connected to said first conduit, and means for controlling the flow of fuel through said second conduit, and governor operated means controlling the flow of fuel through said first conduit.

4. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a plurality of injectors, one for each cylinder and each having a permanently open passage therethrough and also having means for injecting fuel into the associated cylinder including an inlet port connected to said passage, an engine driven pump for supplying fuel to said injector passages, a first conduit for conducting fuel from said pump to said injectors, a second conduit for conducting fuel away from said passages, and means for controlling the pressure of the fuel flowing through said passages to determine the amount of fuel passing through said inlet ports for injection into the cylinders, said means comprising a pressure regulator connected to said first conduit and having a by-pass valve responsive to the pressure of the fuel delivered by the pump and maintaining a predetermined increasing pressure with increase in engine speed, and means for restricting the flow of fuel through said second conduit.

5. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a plurality of injectors, one for each cylinder and each having a permanently open passage therethrough and also having means for injecting fuel into the associated cylinder including an inlet port connected to said passage, an engine driven pump for supplying fuel to said injector passages, a first conduit for conducting fuel from said pump to said injectors, a second conduit for conducting fuel away from said passages, and means for controlling the pressure of the fuel flowing through said passages to determine the amount of fuel passing through said inlet ports for injection into the cylinders, said means comprising a pressure regulator connected to said first conduit and comprising a movable valve member having a bleed opening for bleeding fuel from said first conduit at a rate varying with the pressure of the fuel and thereby controlling the pressure of the fuel in said first conduit throughout the range of engine speed, and means for restricting the flow of fuel through said second conduit.

6. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a plurality of injectors, one for each cylinder and each having a permanently open passage therethrough and also having means for injecting fuel into the associated cylinder including an inlet port connected to said passage, an engine driven pump, a first conduit extending from said pump to said injectors, a pressure regulator for controlling the pressure of the fuel in said conduit, a throttle valve in said conduit for controlling the flow of fuel therethrough, a governor-operated valve in said conduit for limiting the flow of fuel therethrough when the engine reaches a predetermined maximum speed, a second conduit for conducting fuel away from injection passages, and means in said second conduit for restricting the flow therethrough.

7. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a plurality of injectors, one for each cylinder and each having a permanently open passage therethrough and also having means for injecting fuel into the associated cylinder including an inlet port connected to said passage, an engine driven pump,

governor-operated valve means, a first conduit connecting said pump with said valve means and connecting said valve means with the injector passages for supplying fuel thereto, a second conduit connecting said injector passages with said valve means for conducting fuel away from said passages, and means in said second conduit for restricting the flow therethrough.

8. In a fuel supply apparatus for a multi-cylinder internal combustion engine comprising an engine-driven fuel pump and a plurality of injectors, one for each cylinder and each having a permanently open passage through which fuel is constantly circulated and from which fuel is withdrawn for injection into the associated cylinder, the combination therewith of a throttle valve, a first conduit connecting said throttle valve with said pump, governor-operated valve means having a pair of inlet ducts and an outlet duct, one of said inlet ducts being connected to receive fuel from said throttle valve when the engine is operating above idling speed, the other of said inlet ducts being connected to said first conduit for receiving fuel therefrom during operation of the engine at idling speed, and said outlet duct being connected to the injector passages, said valve means also having a drain duct, a second conduit for conducting fuel to said drain duct from said injector passages, and means in said second conduit for restricting flow therethrough.

9. In a fuel supply apparatus for multi-cylinder internal combustion engine comprising an engine-driven fuel pump and a plurality of injectors, one for each cylinder and each having a permanently open passage through which fuel is constantly circulated and from which fuel is withdrawn for injection into the associated cylinder, the combination therewith of means for controlling the flow of fuel from said pump to said injector passages and comprising a throttle valve adapted to be open for flow therethrough when the engine is operating above idling speed, and governor-operated valve means having a pair of inlet ducts, an outlet duct connected to said injector passages, a drain duct, and a movable valve member responsive to engine speed for controlling connection between said inlet ducts and said outlet duct, one of said inlet ducts being connected to said throttle valve with said valve member permitting flow from said pump through said throttle valve, said one inlet duct and said outlet duct to said injector passages when the engine is operating above idling speed, the other of said inlet ducts being comnected to said pump with said valve member permitting flow through said other inlet duct and through said outlet duct to said injector passages when the engine is operating at idling speed, said injector passages being connected to said drain duct, and means for restricting the flow from said injector passages to said drain duct.

10. In a fuel supply apparatus for a multi-cylinder internal combustion engine comprising an engine-driven fuel pump and a plurality of injectors, one for each cylinder and each having a permanently open passage through which fuel is constantly circulated and from which fuel is withdrawn for injection into the associated cylinder, the combination therewith of means for controlling the flow of fuel from said pump to said injector passages and comprising a throttle valve adapted to be open for flow therethrough when the engine is operating above idling speed, and governor-operated valve means connected to receive fuel from said throttle valve and direct from said pump and connected to said injector passages, said valve means having a valve member movable in response to the engine speed for selectively controlling the flow of fuel through said throttle valve and direct from said pump to said injector passages, and means for controlling the flow of fuel from said injector passages.

11. In a fuel supply apparatus for a multi-cylinder internal combustion engine comprising an engine-driven fuel pump, and a plurality of injectors, one for each cylinder and each having a permanently open passage through which fuel is constantly circulated and from which fuel is withdrawn for injection into the associated cylinder, the combination therewith of means for controlling the flow of fuel from said pump to said injector passages and comprising a throttle valve adapted to be open for flow therethrough when the engine is operating above idling speed, and governor-operated valve means connected to receive fuel from said throttel valve and direct from said pump and connected to said injector passages, said valve means having a valve member movable in response to the engine speed for controlling the flow of fuel from said throttle valve to said injector passages when the engine is operating above idling speed and for controlling the flow of fuel direct from said pump to said injector passages when said throttle valve is closed and the engine is operating at idling speed, and means for restricting the flow of fuel from said injector passages to a predetermined degree when the engine is operating at idling speed and for restricting said flow to a greater degree when the engine is operating above idling speed.

12. In a fuel supply apparatus for a multicylinder internal combustion engine comprising an engine-driven fuel pump and a plurality of injectors, one for each cylinder and each having a permanently open passage through which fuel is constantly circulated and from which fuel is withdrawn for injection into the associated cylinder, the combination therewith of means for controlling the flow of fuel through said injector passages when the engine is operating at idling speed comprising governor-operated valve means having a duct through which fuel flows from said pump to said injector passages and a drain to receive fuel flowing from said injector passages, said valve means having a valve member movable in response to engine speed for controlling the flow of fuel to said injector passages to limit the speed of the engine to idling speed, and means for restricting the flow of fuel from said injector passages to said drain, said valve member tending to close said drain to increase the restriction to flow from said injector passages when the speed of the engine falls below idling speed.

13. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising an engine-driven fuel pump, a plurality of injectors connected to receive fuel from said pump, one for each cylinder and each having a permanently open passage through which fuel is constantly circulated and from which fuel is withdrawn for injection into the associated cylinder, a pressure regulator for bleeding off fuel delivered by the pump and having a pressure responsive member controlling the bleeding off of fuel to provide a predetermined increase in fuel pressure of increase in engine speed, means connected to said injector passages for restricting the flow therefrom, and a governor-operated valve means having a valve member movable in response to engine speed for limiting the flow from said pump to said injector passages for maximum speed, said pressure responsive member being movable to increase the amount of fuel bled off when said valve member limits said flow.

14. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising an engine-driven fuel pump, a plurality of injectors connected to receive fuel from said pump, one for each cylinder and each having a permanently open passage through which fuel is constantly circulated and from which fuel is withdrawn for injection into the associated cylinder, and governor-operated valve means having a duct through which fuel flows from said pump to said injector passages and a drain to receive fuel flowing from said injector passages, said valve means having a valve member movable in response to engine speed and movable from a position closing said drain when the engine is stopped to gradually open said drain whereby on starting the engine the flow of fuel from said injector passages is greatly restricted

to assist in quickly increasing the pressure of the fuel in said injector passages, said valve member also being movable to limit the flow of fuel to said injector passages when the engine reaches idling speed.

15. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising an engine-driven fuel pump, a plurality of injectors connected to receive fuel from said pump, one for each cylinder and each having a permanently open passage through which fuel is constantly circulated and from which fuel is withdrawn for injection into the associated cylinder, and means for controlling the flow of fuel to and from said injector passages comprising valve means having a single movable valve member provided with two portions, one for controlling the flow of fuel to said injector passages and the other for controlling the flow of fuel from said injector passages.

16. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising an engine-driven fuel pump, a plurality of injectors connected to receive fuel from said pump, one for each cylinder and each having a permanently open passage through which fuel is constantly circulated and from which fuel is withdrawn for injection into the associated cylinder, and means for controlling the flow of fuel to and from said injector passages comprising valve means having a single movable valve member provided with two portions, one of said portions being arranged for controlling the flow of fuel to said injector passage and being movable from a closed position to a maximum open position and the other portion being arranged for controlling the flow of fuel from said injector passages and being movable from a position providing a predetermined restriction to flow from said injector passages for idling to a position providing greater restrction to such flow when the first portion is at its maximum open position.

17. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising an engine-driven fuel pump, a plurality of injectors connected to receive fuel from said pump, one for each cylinder and each having a permanently open passage through which fuel is circulated and from which fuel is withdrawn for injection into the associated cylinder, and means for controlling the flow of fuel to and from said injector passages comprising valve means having a rotatable valve member having a transverse bore therethrough for the flow of fuel to said injector passages and movable from a position where said bore is closed for idling to a position where said bore is fully open for maximum flow, said rotatable valve member also having a transverse notch and a second bore of smaller cross-sectional area than said notch, the fuel from said injector passages flowing through said notch when the first bore is closed and flowing through said second bore when the first bore is open.

18. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising an engine-driven fuel pump, a plurality of injectors connected to receive fuel from said pump, one for each cylinder and each having a permanently open passage through which fuel is circulated and from which fuel is withdrawn for injection into the associated cylinder, each of said passages having an inlet and an outlet and means for controlling the flow of fuel to and from said injector passages comprising a pair of valve elements interconnected for simultaneous movement, one connected to said inlets for controlling the flow of fuel to said injector passages and the other connected to said outlets for controlling the flow of fuel from said injector passages.

19. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising an engine-driven fuel pump, a plurality of injectors connected to receive fuel from said pump, one for each cylinder and each having a permanently open passage through which fuel is circulated and from which fuel is withdrawn for injection into the associated cylinder, means for controlling the flow of fuel to said injector passages for operating the engine at idling speed, a throttle valve for controlling the flow of fuel to said injector passages for operating the engine above idling, and means providing a predetermined restriction to flow of fuel from said injector passages when the engine is idling and a greater restriction to such flow when the engine is operating above idling, the pressure of the fuel flowing through said injector passages being adapted to be reduced to decelerate the engine both by reducing the flow through said throttle valve and by reducing the restriction provided by said last-mentioned means.

20. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising an engine-driven fuel pump, a plurality of injectors connected to receive fuel from said pump, one for each cylinder and each having a permanently open passage through which fuel is circulated and from which fuel is withdrawn for injection into the associated cylinder, and governor-operated means for controlling the flow of fuel to said injector passages when the engine is idling, said means having a drain connected to said injector passages to receive fuel therefrom and having a movable valve member adapted to close said drain when the engine is stopped, said drain having a restricted orifice for venting air therefrom and thereafter to restrict the flow of fuel therefrom when the engine is starting whereby air in said injector passages is rapidly purged therefrom and fuel pressure is rapidly built up.

21. Fuel supply apparatus for a multicylinder internal combustion engine, comprising an engine-driven fuel pump, a plurality of injectors connected to receive fuel from said pump, one for each cylinder and each having a permanently open passage through which fuel is circulated and from which fuel is withdrawn for injection into the associated cylinder, and governor-operated means for controlling the flow of fuel to said injector passages when the engine is idling, said means having a drain connected to receive fuel from said injector passages and being adapted to close said drain when the engine is stopped, said drain being vented to purge said injector passages of air when the engine is starting but restricting the flow of fuel therefrom to rapidly build up pressure in said injector passages before said drain is opened.

22. Fuel supply apparatus for a multicylinder internal combustion engine, comprising an engine-diven fuel pump, a plurality of injectors connected to receive fuel from said pump, one for each cylinder and each having a permanently open passage through which fuel is constantly circulated and from which fuel is withdrawn for injection into the associated cylinder, and means providing a drain connected to receive fuel from said injector passages and having a member movable in response to the speed of the engine for closing said drain when the engine is stopped and adapted to open said drain when the engine reaches a predetermined speed, said drain being vented to permit the flow of fuel to said injector passages to purge the latter of air when the engine is starting but restricting the flow of fuel therefrom to rapidly build up pressure in said injector passages before said drain is opened.

23. Fuel supply apparatus for a multicylinder internal combustion engine comprising an engine-driven fuel pump, a plurality of injectors connected to receive fuel from said pump, one for each cylinder and each having a permanently open passage through which fuel is circulated and from which fuel is withdrawn for injection into the associated cylinder, and governor-operated means having supply ducts for the flow of fuel to said injector passages and a drain duct for receiving fuel from said injector passages, said means including a member movable in response to engine speed having one portion for controlling the flow through said supply ducts and another portion for controlling the flow through said drain duct.

24. Fuel supply apparatus for a multicylinder internal combustion engine, comprising an engine-driven fuel pump, a plurality of injectors connected to receive fuel from, said pump, one for each cylinder and each having

a permanently open passage through which fuel is constantly circulated and from which fuel is withdrawn for injection into the associated cylinder, and governor-operated means having a pair of supply ducts, one for the flow of fuel to said injector passages during idling and the other for the flow of fuel thereto above idling, said means also having a drain duct for receiving fuel from said injector passages, said means including a member movable in response to engine speed and having one portion cooperating with said one supply duct to control the flow of fuel during idling and with said other supply duct to limit the flow of fuel to a predetermined maximum, and said member having another portion for controlling the flow of fuel through said drain duct.

25. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising an engine-driven pump, a plurality of injectors, one for each cylinder and each having a permanently open passage through which fuel is circulated and from which fuel is withdrawn for injection into the associated cylinder, a first conduit for supplying fuel from the pump to said injector passages, a second conduit connected to said injector passages to receive fuel therefrom, governor-operated means in said first conduit for controlling the flow of fuel to said injector passages and having a drain connected to said second conduit and adapted to be closed when the engine stops, and a shut-off valve mounted in said means and adapted to release fuel from both of said conduits to drain both of said conduits and said injector passages and thereby stop the supply of fuel to the engine.

26. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising an engine-driven pump, a plurality of injectors, one for each cylinder and each having a permanently open passage through which fuel is circulated and from which fuel is withdrawn for injection into the associated cylinder, means having a duct connected to the inlet side of said injector passages through which fuel flows to the latter and having a second duct connected to the outlet side of said injector passages through which fuel flows from the latter, and a shut-off valve mounted in said means, and having a drain passage connectible with both of said ducts to release fuel from both of said ducts to prevent fuel flowing to and to drain said injector passages.

27. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising an engine-driven pump, a plurality of injectors, one for each cylinder and each having a permanently open passage through which fuel is circulated and from which fuel is withdrawn for injection into the associated cylinder, means having a duct connected to the inlet side of said injector passages through which fuel flows to the latter and having a second duct connected to the outlet side of said injector passages through which fuel flows from the latter, and a shut-off valve mounted in said means and adapted to release fuel from both of said ducts to prevent fuel flowing to and to drain said injector passages, said means being located below said injectors whereby air compressed in the cylinders during slowing down of the engine tends to force fuel out of said injector passages and supplies air to said injector passages for siphoning the fuel therefrom back through said ducts.

28. Fuel supply apparatus for a multi-cylinder internal combustion engine, comprising an engine-driven pump, a plurality of injectors, one for each cylinder and each having a permanently open passage through which fuel is circulated and from which fuel is withdrawn for injection into the associated cylinder, means having a supply duct connected to the inlet side of said injector passages for the flow of fuel thereto from said pump, a drain duct connected to the outlet side of said injector passages for the flow of fuel therefrom, and a discharge passage, and a shut-off valve mounted in said means for preventing flow of fuel to and for draining said injector passages, said shut-off valve comprising a rotatable valve member having axial and radial bores communicating with each other for connecting both of said ducts with said discharge passage.

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