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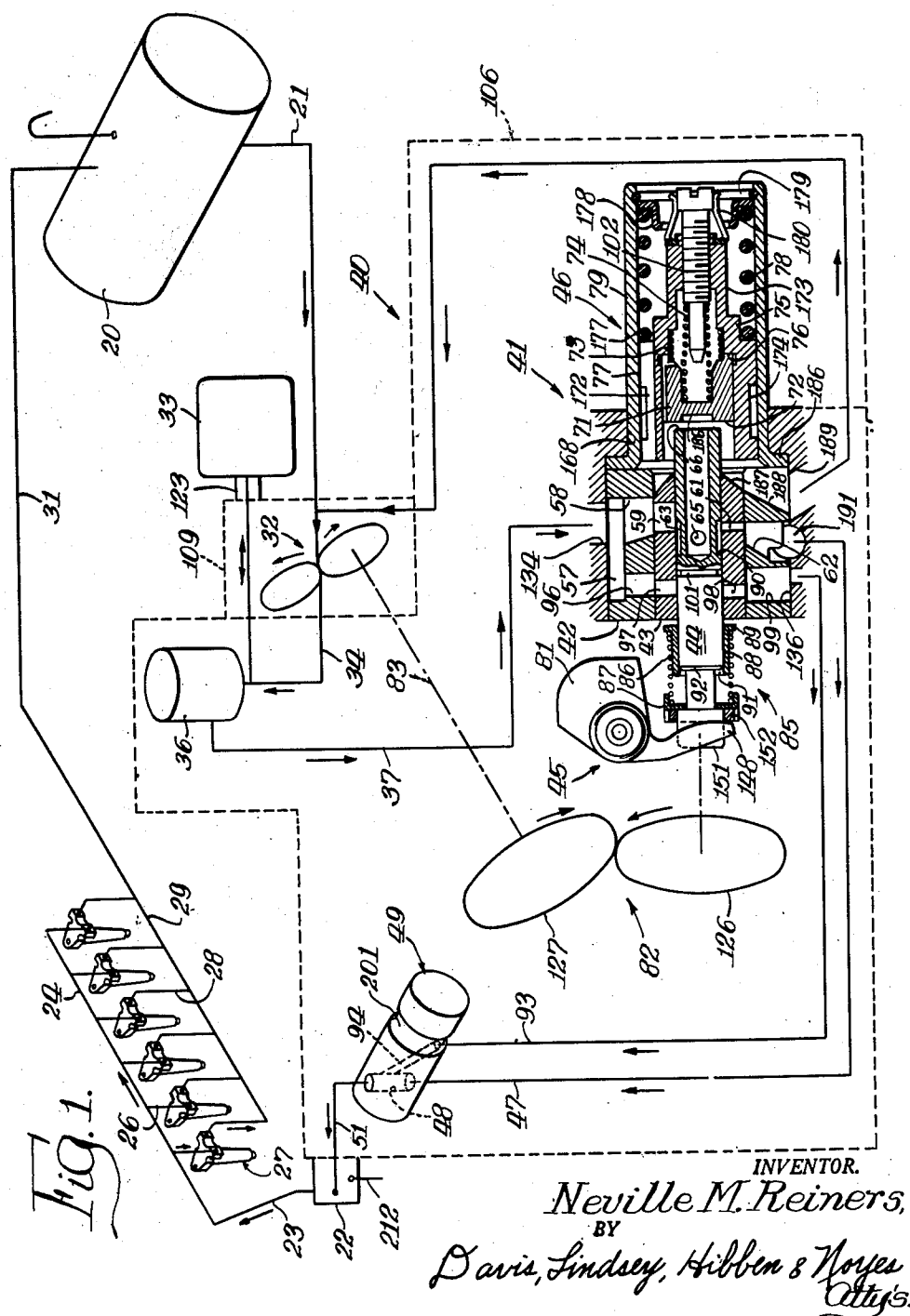
N. M. REINERS

3,159,152

FUEL SUPPLY APPARATUS FOR AN INTERNAL COMBUSTION ENGINE

Filed Nov. 29, 1960

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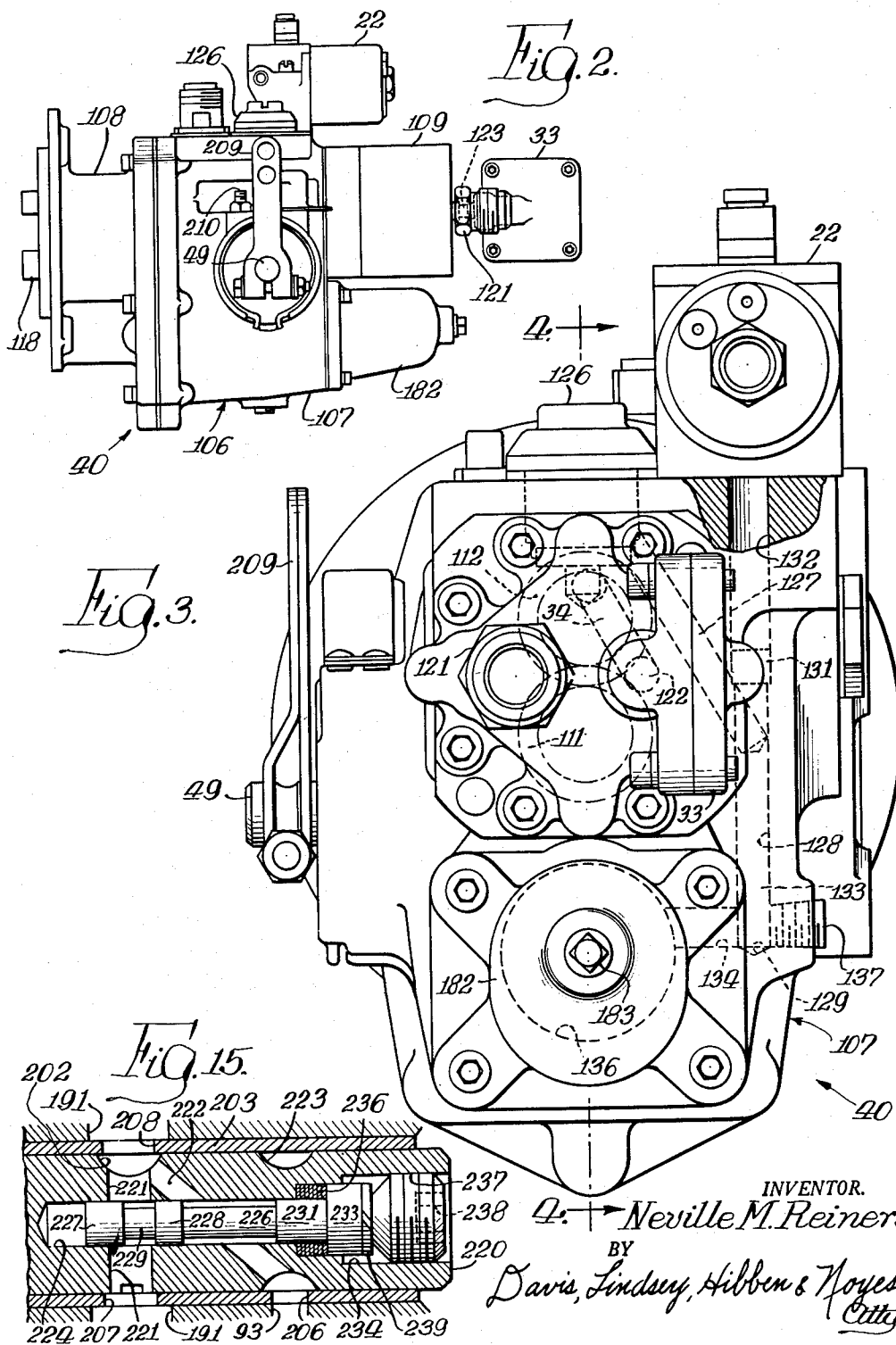
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5 Sheets-Sheet 2



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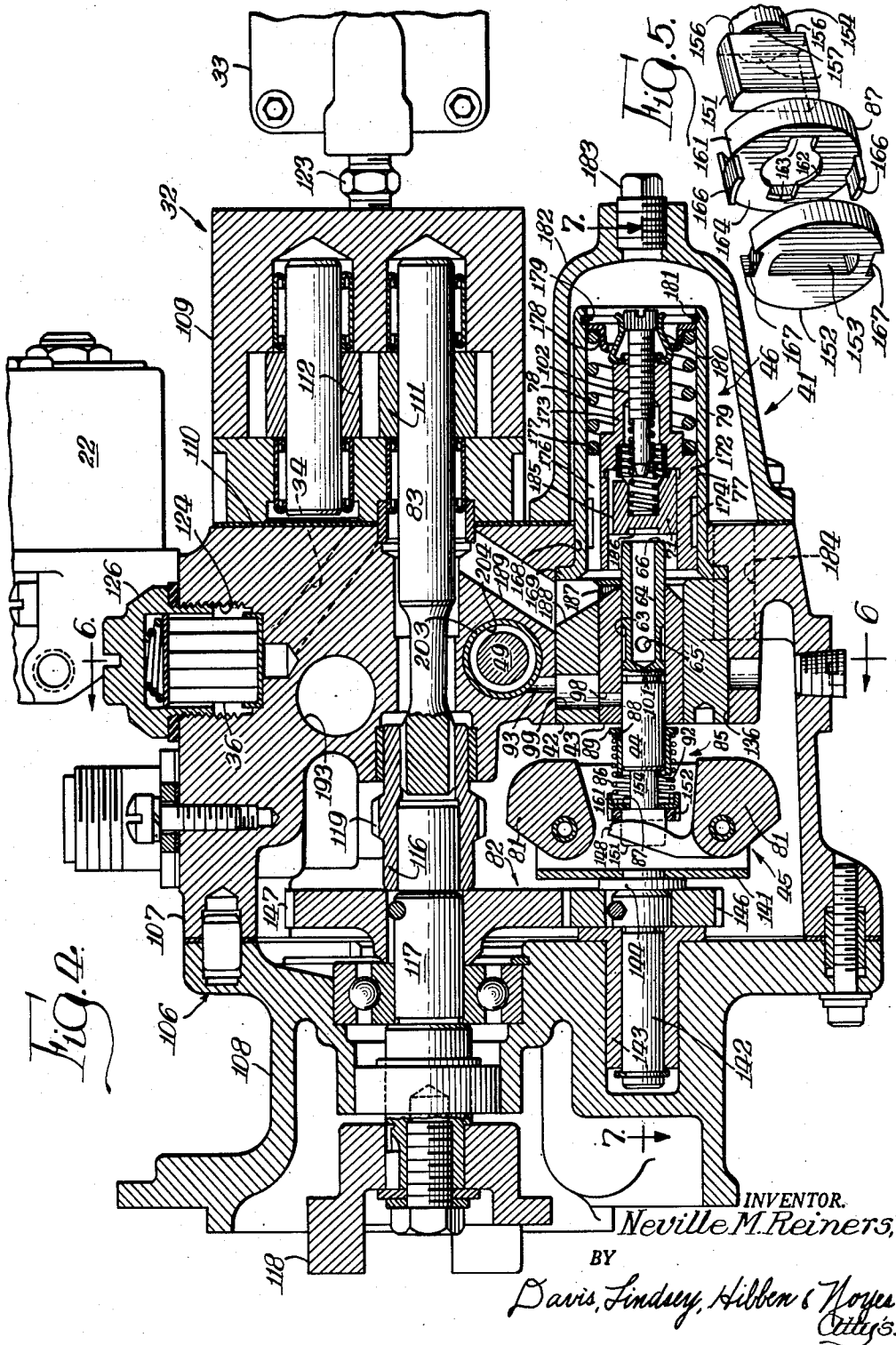
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FUEL SUPPLY APPARATUS FOR AN INTERNAL COMBUSTION ENGINE

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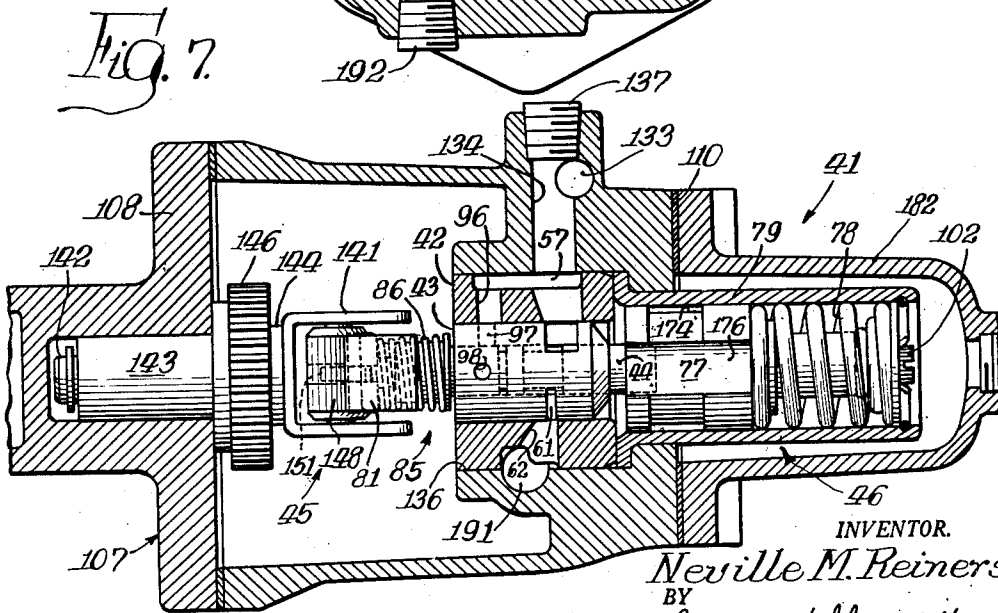
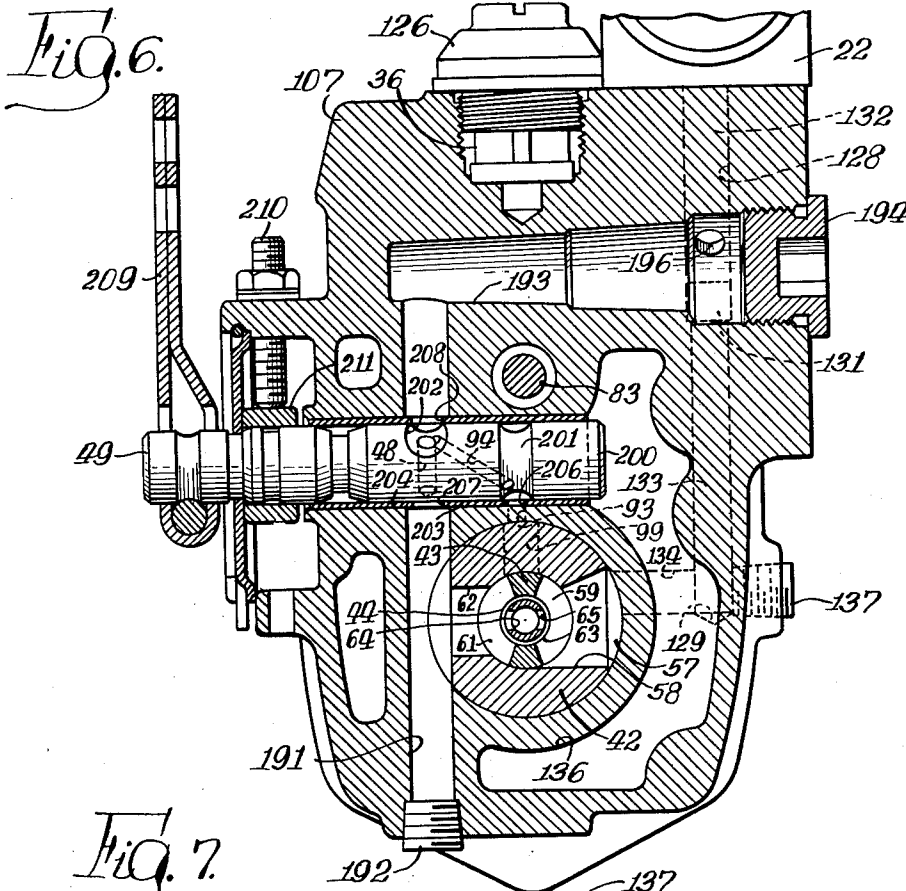
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FUEL SUPPLY APPARATUS FOR AN INTERNAL COMBUSTION ENGINE

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5 Sheets-Sheet 4



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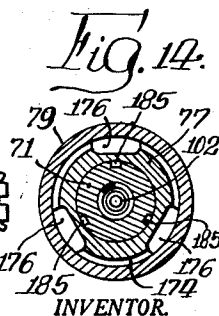
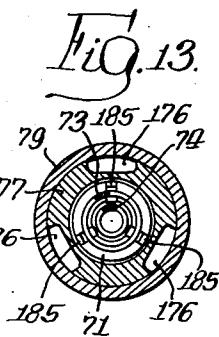
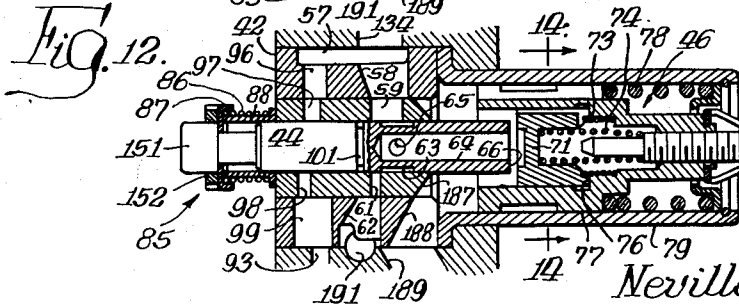
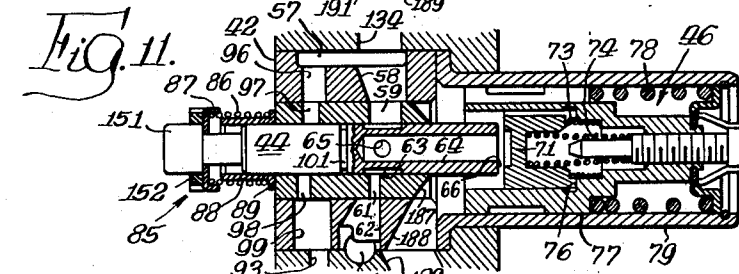
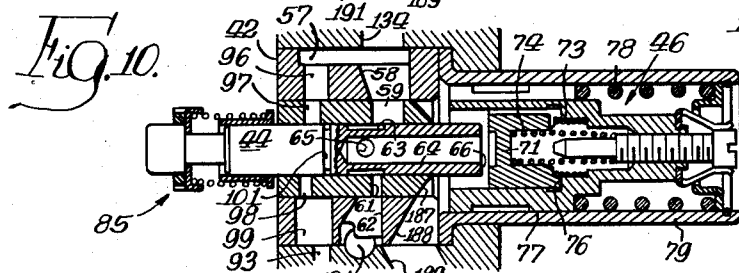
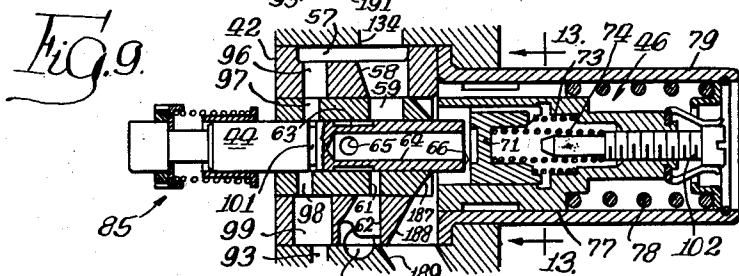
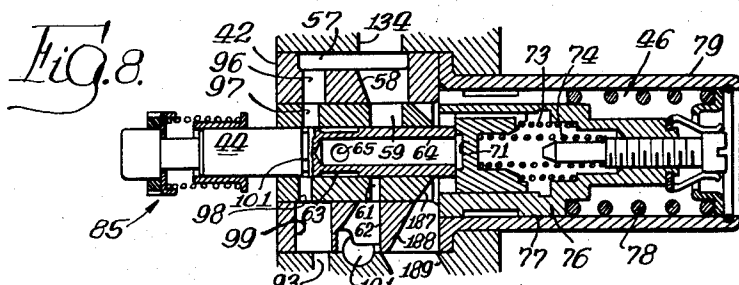
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FUEL SUPPLY APPARATUS FOR AN INTERNAL COMBUSTION ENGINE

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5 Sheets-Sheet 5



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FUEL SUPPLY APPARATUS FOR AN INTERNAL COMBUSTION ENGINE

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Filed Nov. 29, 1960, Ser. No. 72,440

29 Claims. (Cl. 123—140)

This 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 an internal combustion engine under varying load and speed conditions.

A more specific object is to provide a novel fuel supply apparatus for delivering accurately metered quantities of fuel to the cylinders of an internal combustion engine, in which an engine driven centrifugal means functions as a governor to control the flow of fuel to the cylinders of the engine at idle and maximum speeds and to regulate the fuel pressure by a by-pass flow of the fuel at engine speeds between idle and maximum.

A further object is to provide a fuel supply apparatus of the foregoing character, having novel means for controlling the torque curve of the engine.

Another object is to provide a novel fuel supply apparatus having a positive displacement pump as the fuel pressurizing source and which automatically compensates for changes in the output of the pump due to wear.

Still another object is to provide a fuel supply apparatus of the foregoing type in which the full pump pressure at engine cranking speed is utilized to supply fuel to the injectors of the engine, regardless of the position of the throttle thereof.

A further object of the invention is to provide a novel manually-controlled throttle for a fuel supply apparatus of the foregoing character, which compensates for variations in the fuel flow for a given throttle setting, due to temperature changes of the fuel.

Another object is to provide a fuel supply apparatus having a plurality of fuel injectors for delivering accurately metered quantities of fuel to the cylinders of the engine, and a throttle for controlling the flow of fuel to said injectors, the throttle when moved to idle position providing a leakage flow to the injectors to maintain a predetermined minimum fuel flow through the injectors to purge air and gases therefrom and to lubricate moving parts thereof.

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

FIGURE 1 is a diagrammatic view of a fuel supply apparatus embodying the features of the invention;

FIG. 2 is a reduced side elevational view of a fuel supply unit constituting a portion of the apparatus shown in FIG. 1;

FIG. 3 is an end elevational view of the right-hand end of the unit shown in FIG. 2;

FIG. 4 is a vertical sectional view taken generally on the line 4—4 of FIG. 3;

FIG. 5 is an exploded perspective view of parts of the fuel supply unit of FIG. 4;

FIG. 6 is a vertical sectional view taken generally on the line 6—6 of FIG. 4;

FIG. 7 is a horizontal sectional view taken along the line 7—7 of FIG. 4;

FIGS. 8 to 12, inclusive, are a series of fragmentary

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sectional views of a portion of the unit shown in FIG. 4 and showing the positions of the parts thereof under varying operating conditions;

FIG. 13 is a sectional view taken along the line 13—13 of FIG. 9;

FIG. 14 is a sectional view taken along the line 14—14 of FIG. 12; and

FIG. 15 is a fragmentary sectional view of a modified throttle construction adapted for use with the unit shown in FIG. 2.

The fuel supply apparatus disclosed herein is similar in some respects to the apparatus disclosed in my prior Patent No. 2,727,498, issued December 20, 1955, in that the primary purpose of both structures is to deliver accurately metered quantities of fuel to the respective cylinders of a Diesel-type internal combustion engine under varying load and speed conditions. Both systems effect the foregoing by controlling the pressure of the fuel at the injectors of the engine to provide a desired torque curve.

The present apparatus includes an engine-driven centrifugal means which is operable as a governor for idle and maximum speeds of the engine and functions to control by-passing of fuel throughout the entire operating range of the engine, including idle speed, to thereby control the pressure of the fuel at the injectors. With the present apparatus, a precise control of the pressure of the fuel at the injectors is achieved, and the apparatus is self-compensating for reduction in the output of the pump due to wear. The necessity for periodic calibration and adjustment of the fuel supply unit is thus eliminated. The present apparatus may also include a pulsation damper to eliminate pressure peaks in the output of the pump, which might otherwise adversely effect the control and operation of the by-pass system, and a novel throttle construction which compensates for the effect of changes in temperature of the fuel in the system.

Before proceeding with the detailed description of the parts of the apparatus, a general description of the apparatus and the various components thereof will be given. Thus, in FIG. 1, which is a diagrammatic representation of the apparatus, a fuel tank or reservoir 20 is shown, and a line 21 connects the tank 20 with a fuel supply unit which is indicated generally at 40 and represented in FIG. 1 by the enclosed dotted line area. A controlled fuel flow from the fuel supply unit 40 passes through an electrically controlled shutoff valve 22 and thence by a line 23 to a common supply rail or header 24 connected by a plurality of branch lines 26 to the supply passages in a plurality of fuel injectors 27 mounted in the respective cylinders of the engine. Each injector may be of the character shown in my prior patent and includes a supply passage, a metering orifice communicating with the supply passage for directing a flow of fuel to a fuel chamber adjacent the nozzle of the injector, and a return passage. The line 23, supply rail 24, branch lines 26 and the injectors 27 comprise delivery means for supplying metered quantities of fuel to the respective cylinders of the engine. A plurality of branch lines 28 are connected to the return passages in the injectors 27 and to a common return rail 29 which is connected by a line 31 to the tank 20 to return excess amounts of fuel thereto. Such excess flow is effective to maintain the supply and return passages in the injectors purged of undesired air or gases and to lubricate plungers in the injectors. A more detailed explanation of the construction and operation of the injectors 27 will be found in my prior patent.

Fuel is drawn into the unit 40 through the line 21 by a positive displacement pump 32 which is herein shown as being of the gear type. The pump 32 is adapted to be driven by the engine and thus has a rate of delivery vary-

ing with the speed of the engine. A pulsation damper 33 is provided, which communicates with the high-pressure side of the pump 32 to eliminate high-pressure peaks in the output flow therefrom. Fuel from the high-pressure side of the pump 32 flows through a passage 34 to a fuel strainer 36 which is preferably of the magnetic and filter screen type. Upon leaving the strainer 36, the entire fuel flow is directed through a series of interconnected passages 37 to an engine-driven centrifugal control mechanism, indicated generally at 41. The mechanism 41 comprises a barrel 42 with a sleeve 43 mounted therein, and a movable member in the form of a plunger 44 mounted in the bore of the sleeve 43. An engine-driven centrifugal device 45 is located at the left end of the plunger 44, as shown in FIGS. 1 and 10, and tends to move the plunger 44 to the right, while a spring pack 46 is located at the right end of the plunger 44 and tends to move the latter in the opposite direction. The barrel 42, sleeve 43 and plunger 44 are provided with cooperating passages providing two paths through the mechanism 41, and, depending upon the operating condition of the engine, such as starting, idle, normal running, or maximum speed, fuel entering the mechanism 41 through the passages 37 may take one or the other of the two paths.

Thus, the mechanism 41 includes a main or primary fuel path which is operable during the normal speed range of the engine including speeds above idle and up to maximum to direct a flow of fuel to an interconnected passage, indicated generally at 47 in FIG. 1, extending to a main fuel passage 48 in a manually operable throttle 49. The passage 48 is connected with the shutoff valve 22 by a passage 51. The passages 37, the main path through the mechanism 41 and the passage 47, thus form a main flow branch for the fuel flow through the unit 40.

The main flow path through the mechanism 41 comprises a passage 57 formed by a flattened portion on one side of the barrel 42, to which the passages 37 are connected. Extending inwardly from the flattened portion 57 are passages 58 and 59 in the barrel 42 and sleeve 43, respectively, opening into the bore in the sleeve in which the plunger 44 is mounted. A second pair of passages 61 and 62 in the sleeve 43 and barrel 42, respectively, extend from the bore in the sleeve and communicate with the passages 47. The plunger 44 includes a portion 63 of reduced diameter adapted to be moved into registry with the passages 59 and 61 in the sleeve 43 at engine speeds above idle and up to maximum to complete the main flow path through the mechanism 41.

To control the quantity of fuel supplied to the engine cylinders, the pressure of the fuel flowing to the injectors 27 is controlled by the mechanism 41. To this end, the mechanism 41 includes means for discharging or by-passing from the main branch a portion of the fuel flow therein throughout the operating range of the engine. The structure for accomplishing this comprises a duct 64 formed in and extending longitudinally of the plunger 44. The duct 64 communicates at its inner end with the reduced diameter portion 63 by a pair of transverse holes 65 and extends to and opens at 66 at the right-hand end of the plunger. Cooperating with the open end 66 of the plunger 44 is a closure 71 in the form of a cup having its end wall 72 adapted to abut the open end 66.

The closure 71 constitutes part of the spring pack 46 and is utilized to vary the by-pass flow through the duct 64 under control of the centrifugal device 45, the spring pack 46 and the pressure of the fuel in the duct 64. The spring pack 46 tends to urge the closure 71 into abutment with the open end 66 of the plunger 44, while the centrifugal device 45 tends to move both the plunger 44 and closure 71 toward the right against the action of the spring pack 46. The pressure of the fuel in the duct 64, when of sufficiently high value, tends to separate the open end 66 of the plunger 44 and the closure 71 to permit discharge of fuel therefrom, such discharged fuel being conducted back to the intake side of the pump 32.

The closure 71 is urged toward the open end 66 of the plunger by a pair of springs 73 and 74 which function to urge the closure against the open end 66 when the engine is operating at idle speed. When the engine attains a speed above idle, the force exerted by the centrifugal device 45 on the plunger 44 and the pressure of the fuel in the duct 64 cause the closure 71 to seat against a shoulder 76 formed in a guide member 77. The guide member 77 is urged to the left, to urge the closure 71 toward the open end 66 of the plunger, by a larger spring 78 which functions when the engine is operating at speeds above idle, the spring 78 holding the guide member 77 seated against the barrel 42 at idle speed. The idle springs 73 and 74 are seated against the guide member 77 while the larger spring 78 is seated in a tubular member 79 secured in the unit 40.

The centrifugal device 45 includes pivotally mounted centrifugal weights 81 which, when rotated, swing outwardly and force the plunger 44 to the right against the pressure exerted by the spring pack 46 and the pressure of the fuel in the duct 64. The centrifugal device 45 is driven from gearing 82 connected to a shaft 83 for driving the gear pump 32, the shaft 83 being driven from the crankshaft of the engine.

From the foregoing structure it will be evident that fuel flows to the injectors 27 from the pump 32 through the centrifugal control mechanism 41, and that the pressure of the fuel supplied to the injectors at engine speeds above idle is controlled by the centrifugal mechanism 41 which regulates the by-passing or discharge of fuel through the duct 64. Thus, because the output of the pump 32 is at all times greater than the requirements of the injectors 27, the force exerted by the centrifugal device 45 tending to move the plunger 44 to the right and the opposing force of the spring pack 46 result in a pressure in the duct 64, which causes the plunger 44 and closure 71 to separate and discharge fuel therefrom. The pressure in the duct 64 is, of course, substantially the pressure of the fuel flowing to the injectors. The by-passing or discharge of the fuel through the duct 64 and the pressure of the fuel supplied to the injectors is therefore determined by the centrifugal control mechanism 41.

According to present invention, the centrifugal device 45 includes means for modifying the torque curve of the engine. Such means function by adding resistance to the action of the centrifugal device 45 and is effective throughout the intermediate to maximum speed range. In the present instance, as shown in FIGS. 1 and 11, such means comprises an auxiliary spring assembly 85 mounted on the plunger 44 adjacent the centrifugal device 45. The auxiliary spring assembly 85 includes an auxiliary spring 86 having one end seated against a retainer 87 mounted on the outer or left end of the plunger 44, and its other end seated against a slidable member 88 also mounted on the plunger 44 inwardly of the retainer 87. The member 88 preferably pre-loads the spring 86 and thus has a radially outwardly extending flange 89 at its inner end, which forms a seat for the right end of the spring 86, and a radially inwardly extending flange 91 at its outer end which is adapted to engage a shoulder 92 on the plunger 44. Inward movement of the member 88 on the plunger 44 and expansion of the spring 86 is thus limited by the shoulder 92. The auxiliary spring assembly 85 becomes effective when the engine attains a speed sufficient to bring the flange 89 into engagement with the sleeve 43. At speeds above such speed, the spring 86 will be compressed, thus adding resistance to the action of the centrifugal device 45.

The auxiliary spring assembly 85 is effective to modify the torque curve of the engine by causing a proportionate reduction in the amount of fuel by-passed through the bore 64 at a particular engine speed so that a proportionately greater fuel pressure is obtained at the injectors. A greater amount of fuel is thus injected and a higher torque developed. Generally speaking, the length of the

auxiliary spring 86 determines the torque peak point in relation to engine speed and the rating thereof determines the amount of torque.

The centrifugal mechanism 41 is arranged to limit the engine speed to a predetermined maximum. Thus, as illustrated in FIG. 12, it will be noted that, on increase in engine speed, the force exerted by the governor weights 81 becomes sufficient to shift the plunger 44 toward the right to move the shoulder 90 at the left end of the reduced diameter portion 63 across the passage 61 and to move the portion 63 completely out of registry with the passage 61. Thus, all fuel flow through the main path or branch is shut off, but the passage 59 is wider than the passage 61 and thus remains open so that the entire output of the pump 32 is by-passed back to its inlet. The centrifugal device 45 thus functions as a governor at maximum speed as the shoulder 90 becomes effective to vary the effective size of or close the passage 61.

If the engine is driven beyond its maximum governed speed, as in the case of a vehicle going down a steep hill, the auxiliary spring assembly 85 becomes effective to prevent damage to the mechanism 41 and the spring pack 46 in particular, by preventing further movement of the plunger 44 to the right. Such action occurs as a result of an abutting engagement between the flange 91 of the member 88 and the retainer 87. Such engagement occurs before the springs 78 and 86 become fully compressed.

The centrifugal mechanism 41 also controls the engine when operating at idle speed. Thus, during idling, the mechanism 41 is adapted to exert both a by-pass and governor control of the fuel flow to injectors 27 to maintain the engine at a substantially constant idle speed. The position of the parts of the mechanism 41 at idle speed is shown in FIG. 9. The mechanism 41 includes a separate idle fuel path or branch connected at its upstream end to the passages 37, and at its downstream end to a passage 93 for directing the major portion of the idle flow to an idle passage 94 in the throttle 49 and thence to the injectors 27. The idle fuel path through the mechanism 41 comprises the flattened portion 57 and a pair of passages 96 and 97 in the barrel 42 and sleeve 43, respectively, which extend inwardly from the flattened portion 57 at the left of the passages 58 and 59 as viewed in FIG. 1 and which open into the bore of the sleeve 43. A second pair of passages 98 and 99 in the sleeve 96 and barrel 97, respectively, extend from the bore in the sleeve 43 and communicate with the passage 93.

The plunger 44 includes an annular groove 101 adjacent and to the left of the reduced diameter portion 63. At idle speed, the centrifugal device 45 shifts the plunger 44 so that the groove 101 is in registry with the passages 97 and 98 to complete the idle flow path through the mechanism 41. At such position of the plunger 44, the right end of the reduced diameter portion 63 will have moved partially into registry with the passages 59 and 61. Thus, at idle speed, both the idle and main branches of the fuel paths through the barrel 42 and sleeve 43 and into the plunger 44 are open. The main flow path through the mechanism 41, however, is only effective to permit a by-pass flow through the duct 64 and thence back to the inlet side of the pump 32, since the passage 47 is substantially closed by the throttle 49 at idle speed. The by-pass flow thus controls the pressure of the fuel in the idle flow path and provides the primary control of the flow through the idle branch at idle speed.

If the engine speed should tend to exceed the idle speed, the mechanism 41 becomes effective to exert a governor control of the idle flow through the passage 98. Thus, the plunger 44 and groove 101 are shifted toward the right beyond their full registry position by the centrifugal device 45. The groove 101 will accordingly begin to close the passage 98 to provide a governor action. Such governor action restricts fuel flow to the injectors 27 and thereby reduces the engine speed to idle speed.

It should be noted that in FIG. 1 and FIGS. 8 to 12,

inclusive, all of the passages in the mechanism 41 have been shown in a vertical plane for purposes of clarity. Actually, the flattened portion 57, main inlet passages 58 and 59, main outlet passages 61 and 62, and idle inlet passages 96 and 97 lie in a horizontal plane. Only the idle outlet passages 98 and 99 lie in a vertical plane and extend upwardly toward the top of housing 106 as illustrated in FIGS. 4 and 6.

As previously mentioned, the closure 71 is urged toward the open end 66 of the plunger by the springs 73 and 74, the size and rating of the springs 73 and 74 being such as to permit the closure 71 to move away from the end face 66 to permit a by-pass flow of fuel through the main path or branch when the engine is operating at idle speed. An adjusting screw 102 is provided in the outer end of the guide member 77 for varying the force of the spring 74 to permit adjustment of the idle speed of the engine. The forces exerted on the spring pack 46 at idle speed are, of course, insufficient to cause the closure 71 to seat on the shoulder 76 in the guide member 77.

Thus, at idle speed, the pressure of the fuel supplied to the injectors 27 is controlled by a by-pass flow through the main branch or path, and the idle speed is maintained by a governor action of the centrifugal mechanism 41.

For starting and cranking, it is desirable to supply the entire output of the pump 32 to the injectors 27. Thus, as illustrated in FIG. 8, the engine speed at starting and cranking is such that the force of the weights 81 and the opposing force of the idle springs 73 and 74 result in movement of the plunger 44 to the right to bring the groove 101 into registry with the passages 97 and 98 but not so far as to bring the reduced diameter portion 63 into registry with the passages 59 and 61. Consequently, there is no by-pass flow, and full pump pressure is applied to the metering orifices of the injectors 27 to facilitate starting. Thus, at cranking and starting, fuel flows only through the idle path or branch of the mechanism 41 and thence to the passage 93 and idle passage 94 in the throttle 49. As soon as the engine starts, the centrifugal device 45 causes the plunger 44 and the other parts to assume their respective normal idle positions as illustrated in FIG. 9. If the throttle 49 is positioned at a speed setting above idle at starting, the engine, on starting, will continue to accelerate until it reaches the set speed.

From the foregoing description, the general layout of the present fuel supply apparatus and fuel supply unit 40 can be seen. The preferred embodiment of the invention is shown in FIGS. 2 to 7, and the fuel supply unit 40 is illustrated as including a housing, indicated generally at 106, comprising a main section 107 and cover section 108, in which the centrifugal mechanism 41 and the throttle 49 are incorporated. The pump 32 includes a pump housing 109 which is mounted on a flat mounting surface 110 on the main section 107, as shown in FIG. 4.

The pump 32 is of the positive displacement gear type having a drive gear 111 which meshes with a driven gear 112, the drive gear 111 being mounted on the shaft 83 which extends from the main section 107 into the pump housing 109. The inner or left end, indicated at 114, of the shaft 83 is splined for engagement with a coupling 116. The coupling 116 is adapted to be driven by a shaft 117 extending through the cover section 108, the outer or remote left end of the shaft 117 being provided with a fitting 118 connected to be driven from the crankshaft of the engine. The coupling 101 in this instance has an external gear 119 therearound which may be used as a drive for a tachometer.

Fuel is supplied to the intake side of the pump 32 by a fitting 121 (FIG. 3) which is connected to the line 21 and thus to the tank 20. Fuel under pressure from the discharge or outlet side of the pump 32 is directed through a short axial passage 122 (FIG. 3) in the housing 109 to a bore which extends diagonally upwardly and inwardly in the main section 107 to form the passage 34. The pulsation damper 33 is connected to the discharge side of

the pump by a fitting 123 threaded into the gear pump housing 109. The upper end of the passage 34 is connected to the lower end of a recess 124 at the top of the main section 107 in which the fuel filter 36 is mounted. Fuel from the passage 34 enters the filter 36 centrally thereof. A removable cap 126 retains the filter 36 in its recess 124 and facilitates removal and replacement of the filter 36.

Upon leaving the filter 36, fuel flows from the periphery thereof diagonally downwardly through a bore 127 (FIG. 3) in the main section 107, which intersects a vertical bore 128 (FIG. 3) also formed in the section 107 at the right or back side thereof as viewed in FIGS. 3 and 6. The vertical bore 128 extends from the top of the section 107 downwardly to a point 129 in general transverse alignment with the mechanism 41. A plug 131 is mounted in the vertical bore 128 at a point above the intersection of the bore 127 therewith to thus divide the vertical bore 128 into an upper section 132 and a lower section 133. Fuel from the bore 127 thus flows downwardly through the lower section 133 to the lower end of the bore 128 and thence transversely inwardly, or toward the left as viewed in FIGS. 3, 6 and 7, through a bore 134 toward an enlarged opening 136 in the main section 107 in which the barrel 42 of the mechanism 41 is mounted. The outer end of the transverse bore 134 is closed by a plug 137. Fuel in the transverse bore 134 flows into the passage 57 formed by the flattened portion of the barrel 43, at the rear or right side thereof, and then enters the mechanism 41 as heretofore described.

Axial movement of the plunger 44 is effected by the centrifugal device 45. The centrifugal device 45 includes the weights 81, in this instance two, which are pivotally mounted on a carrier 141. The carrier 141 includes a shaft portion 142 that is rotatably journaled in a flanged bearing 143 mounted in the cover section 108. A thrust washer 144 is interposed between the weight carrier 144 and a gear 146 mounted on the shaft 142 between the flange of the bearing 143 and weight carrier 141. The gear 146 meshes with another gear 147 carried by the shaft 117 for rotating the carrier 141, the gears 146 and 147 comprising the gearing indicated at 82 in FIG. 1.

The weights 81 include a pair of laterally offset arms 148 (FIG. 7) only one of which is shown in FIG. 4, the arms 148 being adapted to be disposed on either side of a flattened section 151 (FIGS. 4, 5 and 7) at the remote end of the plunger 44. Rotation of the weight carrier 141 thus causes rotation of the plunger 44 due to the position of the arms 148 on each side of the section 151. The end faces of the arms 148 engage a washer 152 mounted on the flattened section 151, the washer 152 being retained on the section 151 at its inner end so that pivotal movement of the arms 148 is transmitted to the plunger 44.

The auxiliary spring assembly 85 includes the washer 152 which is provided with a central rectangularly-shaped opening 153 (FIG. 5) therethrough, permitting assembly of the washer 152 on the section 151. In order to prevent the washer 152 from moving inwardly or toward the right past the rectangular section 151, the plunger 44 is provided with a reduced diameter cylindrical portion 154 defining flat radial shoulders 156 on the inner end face of the section 151, and segmental shoulders 157 formed by that portion of the reduced diameter portion 154, which projects radially outwardly of the side faces of the section 151.

The retainer 87 in this instance is in the form of a cup having an annular axially extending flange 161 and is mounted on the reduced portion 154 with the flange 161 extending inwardly toward the member 88. As shown in FIG. 5, the retainer 87 is provided with a central generally circular opening 162 therethrough, the opening 162 having a pair of diametrically spaced rectangular cutouts 163 extending therefrom and corresponding to the width and thickness of the section 151 to permit movement

of the retainer 87 over the section 151. When the retainer 87 is moved over the section 151 and onto the reduced portion 154, it is rotated through 90° to move the cutouts 163 out of alignment with the section 151. The retainer 87 thus abuts the shoulders 156 on the section 151. To maintain such relationship, the retainer 87 is provided with a pair of diametrically spaced axially extending tabs 166, the latter extending toward the washer 152 and being adapted to seat in a pair of diametrically spaced notches 167 in the outer periphery thereof (FIG. 5). The retainer 87 is thus held against rotation. The retainer 87 has its outer end face, indicated at 164, held against the shoulders 156 by the auxiliary spring 86, and the washer 152 is held against the retainer 87 and shoulders 157 by the action of the centrifugal weights 81.

The auxiliary spring 86 at one end is seated within the flange 161 of the retainer 87 and at its other end bears against the flange 89 at the right end of the member 88, as shown in FIG. 1. When the engine is operating at speeds below that at which the auxiliary spring assembly 85 starts to function, the flange 91 at the left end of the member 88 bears against the shoulder 92 on the plunger 44, the shoulder 92 being formed by the reduced portion 154 of the plunger. The dimensions of the parts are such that the spring 86 is preloaded when the engine is operating at speeds below that at which the assembly 85 starts to function.

As heretofore mentioned, the mechanism 41 is adapted to discharge or by-pass a portion of the fuel flow from the pump through the duct 64 in the plunger 44 to control the pressure of the fuel supplied to the injectors 27, the pressure of the fuel in the duct 64 acting against the closure 71 and tending to open it, while the spring pack 46 tends to move the closure 71 to its closed position. The spring pack 46 is mounted within the tubular member 79 which is mounted in a bore 168 (see FIG. 4) in the main section 107 of the housing 106, the bore 168 extending from the opening 136 in which the barrel 42 is mounted. The major portion of the tubular member 79 extends outwardly or toward the right of the surface 110 of the housing 106. To hold the tubular member 79 in place, it is provided with an annular radially outwardly extending flange 169 at its inner or left end, that is adapted to seat on a shoulder at the inner end of the opening 136. The projecting end of the tubular member 79 is enclosed by a housing 182 having a threaded plug 183 mounted in its outer end, providing access to the screw 102.

The guide member 77 is slidably mounted within the tubular member 79 and comprises an annular body portion 172 and a stepped-down portion 173. The body portion 172 is provided on its exterior with an annular groove 174 and a plurality of axially extending symmetrically arranged longitudinal grooves 176 (FIGS. 13 and 14), in this instance three, the grooves 176 extending for the full length of the body portion 172 and intersecting the annular groove 174. The spring 78 has its inner or left end seated on a shoulder 177 formed at the right end of the body portion 172 and its outer or right end seated on an annular dished retainer 178 mounted in the outer or right end of the tubular member 79. The retainer 178 is removably held in the end of the member 79 by a snap ring 179 seated in an internal groove 181 in the end of the member 79.

The cup-shaped closure 71 is slidably mounted in the body portion 172 of the guide member 77 and is provided with a plurality of axially extending symmetrically arranged grooves 185 (FIGS. 13 and 14), in this instance three, which serve to eliminate any piston effect during movement of the closure 71 in the body portion 172. The grooves 185 at their right end open inwardly to the interior of the body portion where the idle springs 73 and 74 are located. The end wall 72 of the closure 71 preferably is recessed as at 186 to provide a chamber for receiving fuel under pressure from the duct 64, so that the area against which the pressure of the fuel acts

is increased to increase the force tending to separate the closure 71 from the open end 66 of the plunger 44.

In order to provide for the flow of by-passed or discharged fuel from the duct 64, the right or inner end of the sleeve 43 is beveled as at 187 to define an annular passage therearound within the barrel 42. A radial groove or passage 188 is provided in the inner end of the barrel 42, extending from the annular passage 187. The groove 188 registers at its outer end with a diagonal bore 189 in the main section 107 of the housing, the bore 189 communicating with the inlet side of the pump 32. The passages 187, 188 and 189 thus comprise the flow path for the by-pass fuel flow from the duct 64. The passages 188 and 189 have been illustrated as extending downwardly in FIGS. 1 and 8 to 12, inclusive, but are actually disposed as shown in FIG. 4. By-passed fuel may also flow through the grooves 176 in the body portion 172 and then through the retainer 178 to the interior of the housing 182. Such fuel is returned to the intake side of the pump 32 by means of passage 184 (FIG. 4) which connects the interior of the housing 182 with the interior of the main housing 106. A second passage (not shown) connects the interior of the housing 106 with the intake side of the pump 32.

The screw 102 for adjusting the inner idle spring 74 is threaded in the stepped-down portion 173 of the guide member 77. The head of the screw 102 is accessible for adjustment when the plug 183 is removed. The end of the stepped-down portion 173 is provided with a spring clip 180 adapted to grip the head of the screw 102 to prevent the screw from turning.

Once the spring pack 46 has been adjusted for a particular engine and set of operating conditions, variations or reduction of the output of the pump 32 due to wear or other causes are automatically compensated for by variation in the quantity of fuel by-passed.

Fuel flowing from the control mechanism 41 through the main outlet passage 62 flows into the passage 47 which is a bore 191 (FIGS. 6 and 7) in the left side of the main section 107, as viewed in FIG. 6, the flow through the bore 191 being controlled by the throttle 49. The lower end of the bore 191 is closed by a plug 192. A transverse bore 193 intersects the upper end of the bore 191 beyond the throttle 49, the outer end of the bore 193 being closed by a plug 194. A short diagonal passage 196 in the main section 107 of the housing connects the end of the bore 193 with the upper section 132 of the vertical bore 128. The upper part of the bore 191, the bore 193, the passage 196, and upper section 132 of the vertical bore 128 thus comprise the passage indicated at 51 in FIG. 1. Fuel leaving the idle outlet passage 99 passes directly upwardly through the passage 93 in the main section 107 of the housing 106 to the throttle 49, and thence through the throttle idle passage 94. The main and idle passages 48 and 94 intersect within the throttle 49 so that idle fuel then flows through the upper end of the bore 191.

The throttle 49 comprises a generally cylindrical body 200 (see FIG. 6) in which the main passage 48 and the idle passage 94 are formed. A circumferential groove 201 is provided around the body 200, the groove 201 registering with the inlet end of the idle passage 94. The throttle body 200 is rotatably mounted in a sleeve 203 which is fitted into a transverse bore 204 in the main housing section 107, the bore 204 intersecting the vertical bore 191 as seen in FIGS. 4 and 6.

The sleeve 203 is provided with a pair of longitudinally spaced openings 206 and 207 in its lower side, the opening 206 registering with the circumferential groove 201 and the passage 93, and the opening 207 registering with the lower portion of the passage 191. A third opening 208 is provided in the upper side of the sleeve 203 diametrically opposite the opening 207 and registering with a recess 202 in the top of the throttle body 200 at the upper end of the passage 48. Rotation of the throttle

body 200 moves the passage 48 into and out of registry with the opening 207 in the sleeve 203. The openings 207 and 208 and passage 48 form a part of the main fuel path, and the opening 206, together with the passage 94, recess 202, and opening 208 form a part of the idle fuel path. The recess 202 is sufficiently wide so that registry with the opening 208 is maintained throughout the full range of rotative movement of body 200, including idle position where the lower end of the passage 48 is substantially closed by movement thereof out of registry with the opening 207. In order to effect rotation of the throttle body 200, an arm 209 is secured to its outer end.

If the throttle were fully closed when moved to idle position and the engine was operating at a speed above idle, no fuel would flow to the injectors. Under this condition, air or combustion gases would accumulate in the injector passages, resulting in improper fuel metering and more importantly, damage to the injector plungers might also occur due to the absence of an adequate supply of lubricating fuel. For this reason, a small leakage through the throttle when set at idle position is permitted by limiting the rotative movement of the throttle body 200 to a point where the passage 48 is open slightly to the opening 207 in the sleeve 203. The amount of leakage flow is determined by an idle screw 210 (see FIGS. 2 and 6) threaded in the housing 106 and adapted to engage an arm 211 on the throttle. Such leakage flow also serves to maintain a predetermined minimum fuel pressure at the metering orifices of the injectors to facilitate acceleration of the engine.

From the upper section 132 of the bore 128, fuel flows to the shutoff valve 22 and thence to the line 23 and injectors 27. The shutoff valve 22 is preferably of the type that is normally closed and requires energization from a suitable electric source, such as the battery of the vehicle, to effect opening thereof. Thus, current may be supplied to the valve 22 by a wire 212 (FIG. 1).

In FIG. 15, an alternate throttle construction is shown, such construction comprising a throttle body 220 differing from the throttle body 200 in that it includes means cooperable with the main fuel passage for varying the size of the main passage in the throttle body with changes in temperature. Thus, the body 220 includes a transverse bore forming a main fuel passage 221 therethrough and a diagonal bore intersecting the upper end of the passage 221 and forming an idle fuel passage 222. A circumferential groove 223 is provided around the body 220, the groove 223 registering with the inlet end of the passage 222 and the opening 206 in the sleeve 203. The upper end of the passage 221 is flattened or recessed as at 202 in the same manner as the throttle body 200 to assure registry with the opening 208 throughout the full range of rotational movement of the throttle body 220.

In order to provide for temperature compensation, the throttle body 220 includes a central axial bore 224 which intersects both the main and idle fuel passages 221 and 222. A plunger 226 is mounted in the bore 224, the latter being provided with a pair of spaced lands 227 and 228 defining a reduced diameter portion 229 therebetween. Another land 231 is provided at the inner end of the plunger 226 defining a second reduced diameter portion 232 between the lands 228 and 231. The reduced diameter portion 229 and the land 227 are dimensioned so that they restrict the flow through the passage 221. The plunger 226 affords no restriction to flow through the idle passage 222. The right hand end of the plunger 226, as shown in FIG. 15, is rigidly secured in the throttle body 220. Thus, the right end of the plunger 226 is formed with an enlarged head 233 mounted in a counterbore 234 at the end of the bore 224. The counterbore 234 is sufficiently deep to accommodate the insertion of one or more spacers or shims 236 between the head 234 and the bottom of the counterbore 234 for axially positioning the plunger 226 in the bore 224. The outer end of the counterbore 234 is enlarged and threaded as at 237 to receive a set screw 238 for holding the head 233 in position in its

bore 234. A lock washer 239 may be inserted between the head 223 and set screw 238 to hold the set screw against turning.

The plunger 226 is preferably made of nylon or a similar material having a coefficient of expansion greater than that of the material of the throttle body 220 which is usually steel. Thus, assuming the engine is cold, as the temperature of the fuel increases after the engine is started and continues running, the plunger 226 will expand at a greater rate than the throttle body 220, thereby causing the land 227 to move toward the left in the bore 224 as viewed in FIG. 15.

The main fuel passage 243 is thus restricted to a lesser extent and more fuel may pass through the throttle 220 to the injectors. Conversely, if the temperature of the fuel falls, the plunger will shorten relative to the throttle body 220 thereby causing the land 227 to move toward the right to further restrict the main fuel passage 221. The plunger 226 is, of course, initially adjusted by adding or removing shims 236 between the underside of the head 223 and the end of the counterbore 234.

When the fuel is cold, as on starting the engine, the viscosity of the fuel is greater. As the fuel heats up, the viscosity decreases and, for a given opening between the closure 71 and the end 66 of the plunger 44, more fuel would be by-passed and less would flow to the injectors. By decreasing the restriction at the throttle with a change in temperature of the fuel, compensation for the change in viscosity is provided.

From the foregoing description it will be apparent that I have provided a novel and improved fuel supply apparatus which is capable of effecting an accurate control of the quantity of fuel supplied to the cylinders of a diesel engine throughout the entire speed range thereof. The engine-driven centrifugal mechanism 41 functions to control by-passing of fuel throughout the operating speed range of the engine, including idle speed, and thus accurately controls the pressure of fuel supplied to the injectors. The mechanism 41 also functions as a governor at idle and maximum speeds. Moreover, the mechanism 41 automatically compensates for variations in the output of the pump without the necessity of manual readjustment of the unit. The provision of a pulsation damper to eliminate pressure peaks in the pump output further assures accuracy of control and operation of the mechanism. The mechanism 41 also incorporates a novel torque curve control means in the form of an auxiliary spring assembly 85.

I claim:

1. A fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a source of fuel under pressure, delivery means for supplying fuel to the respective cylinders of the engine, conduit means connecting said source and said delivery means for supplying fuel to the latter, means for discharging fuel from said conduit means upstream of said delivery means including a body and a plunger mounted therein and having an axial duct open at one end and communicating with said conduit means at its other end, and a device responsive to engine speed for controlling said fuel discharging means, said device including a movable closure coacting with the open end of said plunger to control the flow through said duct and the pressure of the fuel in said conduit at said delivery means throughout the operating range of the engine.

2. A fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a source of fuel under pressure, delivery means for supplying fuel to the respective cylinders of said engine, conduit means connecting said source and said delivery means for supplying fuel to the latter, means for discharging fuel from said conduit means upstream of said delivery means comprising a body and a movable member mounted therein and defining a duct, and a device responsive to engine speed for controlling said fuel discharging means comprising engine-driven centrifugal means acting on said member, a mov-

able closure for varying the flow through said duct, and spring means acting on said closure tending to urge said closure toward closing position to control the pressure of the fuel at said delivery means throughout the operating range of the engine.

3. A fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a source of fuel under pressure, delivery means for supplying fuel to the respective cylinders of said engine, conduit means connecting said source and said delivery means for supplying fuel to the latter, means for discharging fuel from said conduit means, a hand throttle mounted in said conduit means between said fuel discharging means and said delivery means, and a device responsive to engine speed for controlling said fuel discharging means to control the pressure of the fuel at said delivery means throughout the operating range of the engine.

4. A fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a source of fuel under pressure, a plurality of injectors, one for each cylinder, for supplying fuel to the respective cylinders of the engine, each injector having a metering orifice for metering fuel in accordance with the pressure applied to the orifice, conduit means connecting said source and said injectors for supplying fuel to the latter, means for discharging fuel from said conduit means upstream of said injector, and a device responsive to engine speed for controlling said fuel discharging means to control the pressure of the fuel at said metering orifices to determine the quantity of fuel supplied to each cylinder by said injectors throughout the operating range of the engine.

5. A fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a source of fuel under pressure, delivery means for supplying fuel to the respective cylinders of said engine, conduit means connecting said source and said delivery means for supplying fuel to the latter, means for discharging fuel from said conduit means upstream of said delivery means, and a device responsive to engine speed for controlling said fuel discharging means to control the pressure of the fuel at said delivery means throughout the operating range of the engine, said device including means rendered operable at a predetermined engine speed to modify the control of said fuel discharging means by said device to thereby modify the pressure of the fuel at said delivery means.

6. A fuel supply apparatus according to claim 2, in which said member comprises a plunger having an axial duct communicating with said conduit means and open at one end of said plunger, and said closure overlies said open end and is movable relative to said open end for varying the flow through said duct.

7. A fuel supply apparatus according to claim 6, in which said centrifugal means acts on said plunger in one direction, said spring means acts on said closure in the opposite direction, and the pressure of the fuel in said duct tends to separate said closure and said plunger.

8. A fuel supply apparatus according to claim 7, in which said spring means includes a pair of springs bearing against said closure for controlling the separation between said closure and said plunger when the engine is operating at idle speed, and means for adjusting the pressure exerted by one of said springs on said closure.

9. A fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a source of fuel under pressure, delivery means for supplying fuel to the respective cylinders of the engine, conduit means connecting said source and said delivery means for supplying fuel to the latter, and engine speed responsive mechanism communicating with said conduit means and having an opening for variably discharging fuel from said conduit means upstream of said delivery means to control the pressure of the fuel at said delivery means.

10. A fuel supply apparatus according to claim 9, in which said mechanism includes a body and a movable member mounted therein and having a duct providing said

opening, and a movable closure coacting with said opening to control the effective size thereof.

11. In a fuel supply apparatus for a multi-cylinder internal combustion engine comprising a source of fuel under pressure, delivery means for supplying fuel to the respective cylinders of the engine, and conduit means connecting said source and said delivery means for supplying fuel to the latter, and mechanism for controlling the pressure of the fuel at said delivery means, said mechanism comprising a housing having a passage forming part of said conduit means, a plunger slidably mounted in said housing and having a duct communicating at one end with said passage and open at its other end for discharging a portion of the fuel received from said source through said passage, the remainder of said fuel flowing to said delivery means, a closure for said open end, engine-driven centrifugal means for urging the plunger toward said closure, and spring means acting on said closure and tending to urge said closure toward said plunger.

12. A fuel supply apparatus according to claim 4, in which a hand throttle is mounted in said conduit means between said fuel discharging means and said delivery means, and in which a stop is provided to control the minimum open position of said hand throttle to provide a small flow of fuel to said injectors when the throttle is moved to said minimum open position, whereby flow of fuel is maintained through said injectors to purge air therefrom and to lubricate the injectors.

13. Mechanism according to claim 11, in which auxiliary spring means is mounted on said plunger and is adapted to engage said housing at a predetermined engine speed to oppose the action of said centrifugal means.

14. In a fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a source of fuel under pressure, delivery means for supplying fuel to the respective cylinders of the engine, and conduit means connecting said source and said delivery means for supplying fuel to the latter, engine speed responsive mechanism having an opening communicating with said conduit means for variably discharging a portion of the fuel received from said source through said conduit means to control the pressure of the fuel at said delivery means, said mechanism being operable to shut off the supply of fuel to said delivery means when the engine reaches a predetermined maximum speed.

15. Mechanism according to claim 14, said mechanism including a body and a movable member mounted therein and having a passage providing said opening, with a portion of said member operable to shut off the supply of fuel to said delivery means.

16. Mechanism according to claim 15, in which said member comprises a plunger having an axial duct with said opening being at one end of said duct, said plunger having a reduced portion defining an annular space communicating with said duct and defining a shoulder at one end of said annular space, said shoulder being adapted to shut off the supply of fuel to said delivery means when said engine reaches a predetermined maximum speed.

17. In a fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a source of fuel under pressure, and delivery means for supplying fuel to the respective cylinders of the engine, fuel control means comprising a housing having a first passage adapted to be connected with said source and a second passage adapted to be connected to said delivery means, said housing having a plunger-receiving bore connecting said passages, and mechanism for controlling the pressure of the fuel at said delivery means including a plunger slidably mounted in said plunger-receiving bore and having a duct open at one end for discharging fuel from said source to control the pressure of the fuel at said delivery means, said duct having its other end normally communicating with said first and second passages, means for controlling the discharge of fuel through said duct, and means responsive to the speed of said engine for moving said plunger in said

plunger-receiving bore to effect a closing of said second passage when said engine reaches a predetermined maximum speed.

18. Fuel control means according to claim 17, in which said plunger is provided with a first reduced portion defining a shoulder and an annular space normally communicating with both of said passages and said duct, said shoulder being operable to close said second passage upon a predetermined movement of said plunger, the openings of said first and second passages into said bore being offset so that a discharge flow of fuel is maintained through said duct when said second passage is closed by said shoulder.

19. Fuel control means according to claim 18, in which limiting means is provided for limiting movement of the plunger on closing of said second passage to prevent said shoulder from closing said first passage.

20. Fuel control means according to claim 19, in which said limiting means comprises a sleeve mounted on said plunger and adapted to abut said housing.

21. In a fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a source of fuel under pressure, delivery means for supplying fuel to the respective cylinders of the engine, and conduit means connecting said source and said delivery means for supplying fuel to the latter, speed responsive mechanism having an opening for variably discharging fuel from said conduit means to control the pressure of the fuel at said delivery means, said mechanism being operable to control the flow of fuel to said delivery means when the engine is operating at idle speed.

22. Mechanism according to claim 21, including a body and a movable member mounted therein and having one portion having a duct provided with said opening, said movable member having another portion for controlling the flow of fuel to said delivery means when the engine is operating at idle speed.

23. In a fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a source of fuel under pressure, and delivery means for supplying fuel to the respective cylinders of the engine, fuel control means comprising a housing having a pair of branch passages both adapted to be connected to said source and said delivery means, and speed responsive mechanism including a plunger having a first reduced portion defining a first annular space communicating with one of said branches, said plunger having a duct extending from said first annular space for variably discharging fuel from said one branch to control the pressure of the fuel at said delivery means, said plunger also having a second reduced portion defining a second annular space communicating with the other of said branches and defining a shoulder for controlling the flow of fuel through said other branch to said delivery means when the engine is operating at idle speed.

24. Speed responsive mechanism according to claim 21, operable to prevent discharging of fuel through said opening during cranking and starting of the engine.

25. In a fuel supply apparatus for a multi-cylinder internal combustion engine, comprising a source of fuel under pressure, and delivery means for supplying fuel to the respective cylinders of the engine, fuel control means comprising a housing having a pair of branch passages both adapted to be connected to said source and to said delivery means, and speed responsive mechanism including a movable member having a first portion provided with a duct for variably discharging fuel from one of said branches to control the pressure of the fuel at said delivery means, said movable member having a second portion for controlling the flow of fuel through the other branch to said delivery means when the engine is operating at idle speed, said movable member being operable to shut off the flow of fuel through said one branch during cranking and starting of the engine, whereby the fuel flowing from said source to said delivery means flows only through said other branch.

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26. A fuel supply apparatus according to claim 9, in which said source of fuel under pressure comprises a positive displacement pump, and means is provided for minimizing pulsations in the output of said pump to thereby stabilize the discharge of fuel by said mechanism and thereby the pressure of said fuel at said delivery means.

27. In a fuel supply apparatus according to claim 9, a manually operable throttle mounted in said conduit means between said speed responsive mechanism and said delivery means and having a passage therethrough forming part of said conduit means, said passage including means for varying the effective size thereof, said throttle having a bore intersecting said passage, and the means for varying the size of said passage comprising a plunger adjustably mounted in said bore and having a portion projecting into said throttle passage for varying the effective size thereof.

28. A throttle according to claim 27, in which said throttle plunger is of a material having a different coefficient of expansion from that of said throttle and said

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throttle plunger thereby varies the effective size of said throttle passage in a manner proportional to changes in temperature.

29. A fuel supply apparatus according to claim 9, in which said source of fuel under pressure comprises an engine-driven pump, and said speed responsive mechanism is effective to maintain said predetermined range of pressure at said delivery means regardless of decrease in the quantity of fuel supplied by said pump due to wear in the pump.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,159,152

December 1, 1964

Neville M. Reiners

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 14, line 56, before "operable" insert -- in which said speed responsive mechanism is --.

Signed and sealed this 4th day of May 1965.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents