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C. L. CUMMINS, JR.
FUEL SUPPLY SYSTEM FOR COMPRESSION IGNITION
INTERNAL COMBUSTION ENGINES

3,185,140

Filed July 2, 1963

4 Sheets-Sheet 1

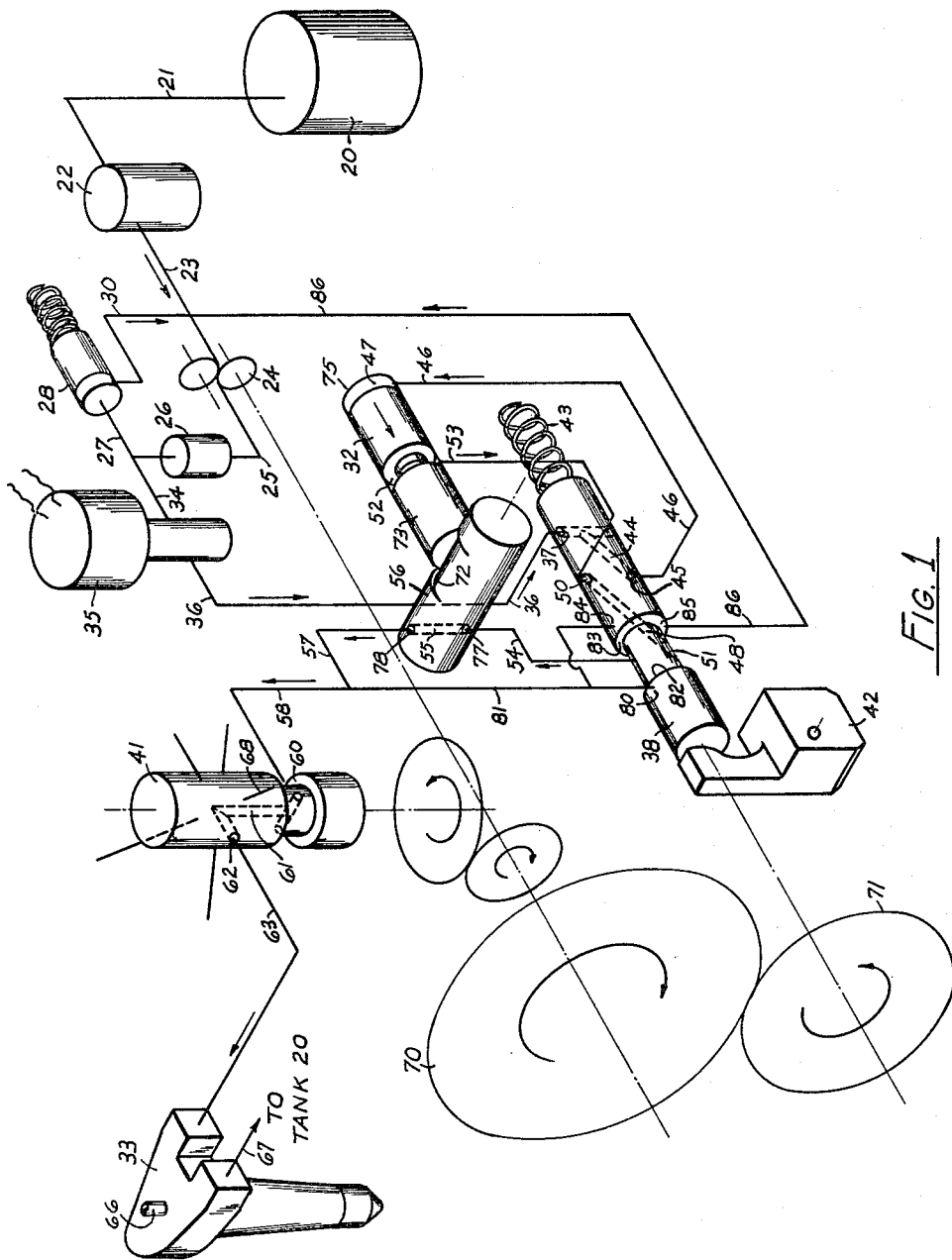


Fig. 1

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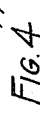
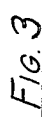
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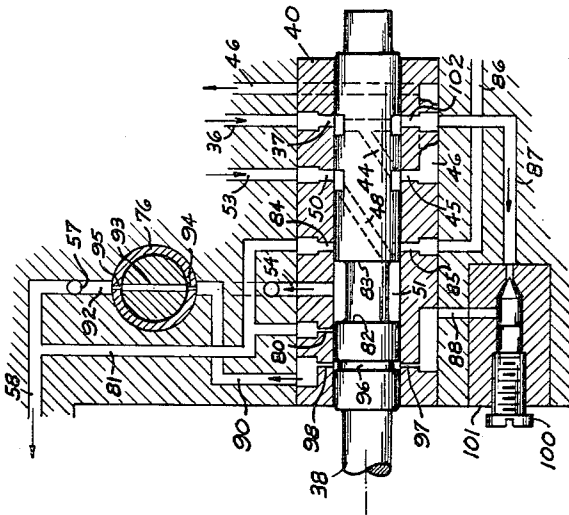


FIG. 6

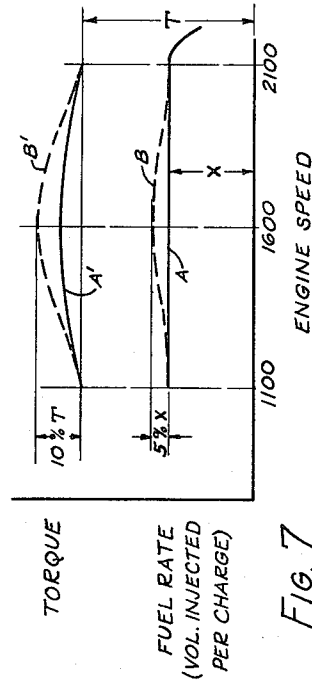


FIG. 7

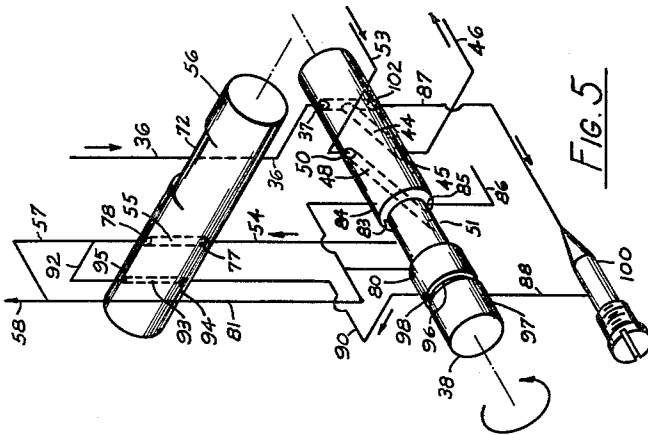


FIG. 5

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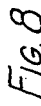


FIG. 10

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FUEL SUPPLY SYSTEM FOR COMPRESSION IGNITION INTERNAL COMBUSTION ENGINES
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 Clessie L. Cummins, Sausalito, Calif.
 Filed July 2, 1963, Ser. No. 292,326
 20 Claims. (Cl. 123-140)

This invention relates to improvements in a fuel supply system for compression ignition internal combustion engines. The invention also lends additional value and usefulness to the fuel supply system described in the co-pending application S.N. 166,730, filed December 14, 1961, now Patent No. 3,143,104.

Fuel cut-off problem

A problem met with in fuel-metering pumps for compression ignition or diesel type engines is how to substantially shut off the flow of fuel to the injectors when the throttle is closed and the engine speed is above idle. For example, when an engine is in a vehicle coasting down hill, excessive fuel leakage through the engine wastes fuel and prevents the engine from providing its maximum retarding effort. As another example, positive fuel shut-off is also very desirable when the driver of the vehicle is shifting to a higher gear and the engine must decelerate quickly while the clutch is disengaged between the gear changes. Excessive closed-throttle fuel leakage in most cases prevents the driver from shifting to a higher gear without placing undue strain on the clutch and other driveline components.

However, when the engine speed drops to the desired idling speed, with the throttle closed, fuel should again be delivered to the injectors so that the engine can continue to run at the predetermined idling speed.

It is, therefore, one object of this invention to provide, in a fuel supply and metering pump of the type described in the co-pending application S.N. 166,730, now Patent No. 3,143,104, positive and controllable means for shutting off the fuel flow to the injectors when the engine is rotating above the idle speed and the throttle is closed.

A further object of my invention is to provide means for controlling the idle speed of an engine so that, when idling, the engine runs at a constant predetermined minimum speed and so that the fuel system is instantly ready to deliver measured quantities of fuel to the injectors when the throttle is again opened.

Control of overspeed

The present invention also provides a control to prevent the engine from overspeeding beyond a desired maximum speed, due either to excessive fuel delivery for a given load or to entrapment of a large volume of air between the transfer pump and the injectors. Such entrapped air has heretofore acted as a pneumatic ram which for a short time greatly overfuels the engine by shoving into the injector plunger chambers the fuel that is in the supply lines ahead of the compressed air. If enough air has entered the lines, either from an emptying fuel tank or from a ruptured suction line, the throttle no longer has control over the situation.

Hence, another object of my invention is to provide control means for preventing the engine from exceeding a predetermined maximum speed even though factors are present which would ordinarily result in an over-delivery of fuel.

Barometric control of overfueling due to lag of turbocharger

When a fuel metering pump is used on engines equipped with a turbo-supercharger, some transient operating con-

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ditions tend to cause overfueling. For example, in accelerating a turbocharged engine from a low speed or under very light load conditions, the engine tends to be overfueled momentarily by an excessive opening of the throttle. At low engine speeds and light throttle, the turbocharger is almost "free-wheeling," and the engine is operating for all practical purposes as if it had no turbocharger. Hence the combustion chamber is then receiving only a naturally aspirated air charge. With a sudden opening to full throttle, the engine tries to burn a fuel charge intended for a cylinder with the air packed in by a turbocharger operating at full speed. Excessive exhaust smoke is the inevitable result.

Therefore, another object of the invention is to provide a barometric control means operated by the engine air intake manifold pressure for preventing a momentary overfueling of a turbocharged engine if the throttle is quickly opened from a "light" to a "full" position.

Control of torque rise

In certain engine applications, such as in many truck installations, it is desirable to provide a special increase in the fuel delivery to the injectors at maximum-throttle, so long as the truck is in the intermediate speed range. The fuel metering system described in the co-pending application S.N. 166,730 delivers the same volume of fuel for each injection at maximum throttle, no matter what the speed. The present invention helps the driver accelerate the vehicle speed more quickly by superimposing on the normal constant-volume-per-injection fuel delivery a small additional amount which is fed only at speeds well above idle and below the maximum vehicle speed. The addition in the middle speed range of a small quantity of fuel to the fuel normally pumped when the throttle is fully open causes the torque curve of the engine to rise more quickly upward to a higher peak, the increase in the maximum torque value over that produced by constant-volume fuel metering being known as the controlled "torque rise." A commonly desired torque rise is ten percent of the torque value attained at the engine's rated speed. It is important that both the amount of torque rise and the engine speed at which the torque curve peaks be accurately controlled; otherwise the engine may become overloaded and smoke excessively.

Consequently, another object of this invention is to provide means for superimposing onto the maximum-throttle fuel delivery of a hydraulically operated positive displacement fuel metering pump, an additional controlled volume of metered fuel, which causes the engine to operate, at full load, on a torque curve having the desired torque rise characteristics.

Other objects and advantages will appear from the following description and the attached drawings in which:

FIG. 1 is a schematic view in perspective of a fuel supply system incorporating with a hydraulically actuated metering piston a control means embodying the principles of this invention for positively shutting off the flow of fuel to the engine when the engine is above the idle speed and the throttle is closed;

FIG. 2 is a view, partly in cross section, of a portion of the system of FIG. 1 showing the position of the parts when the throttle is fully open and the fuel passages connect the metering chamber at one end of the metering piston to the plunger chamber in one of the injectors;

FIG. 3 is a similar view of a portion of FIG. 2 but with the throttle and the governor-controlled rotor in their idle-speed positions; the governor-controlled rotor being turned 180 degrees from the position shown in FIGS. 1 and 2;

FIG. 4 is a similar view of a portion of FIG. 3 showing the governor-controlled rotor of FIGS. 1-3 in the

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position where it is controlling the maximum speed of the engine;

FIG. 5 is a schematic view in perspective of part of the fuel supply system of FIG. 1, to which has been added a bypass circuit and valves according to the principles of the present invention, in order to control the "torque rise" of the engine;

FIG. 6 is a view, partly in cross section, of the fuel passages shown in FIG. 5 and with the governor-controlled rotor and throttle in position to bypass to the injectors a controlled volume of additional metered fuel when the engine is in its intermediate operating speed range;

FIG. 7 is a graph showing how engine speed affects the volume of fuel injected per charge at maximum throttle and the engine torque both with and without a torque-rise control of this invention incorporated in the fuel supply system;

FIG. 8 is a view partly in cross section of a similar system having a modified form of the invention for controlling the torque-rise of a diesel engine by means of a second metering piston;

FIG. 9 is a view partly in cross section of the governor rotor of FIGS. 1-4 showing another modified form of the invention for controlling engine torque-rise by the use of a spill-off shoulder on the governor rotor that diverts a small, controlled part of the metered fuel charge; and

FIG. 10 is a view partly in cross section of a part of the fuel supply system of FIG. 1 having incorporated a barometric control means embodying the principles of this invention, for use on turbocharged engines to prevent momentary overfueling under certain operating conditions.

Some characteristics of this invention

Before describing the details of the new controls which this invention adds to the basic fuel supply system described in the co-pending application S.N. 166,730, some of the outstanding characteristics of those controls may be summarized in general terms:

(1) A first valve, manually operated by the throttle shaft, shuts off the fuel fed into the engine whenever the throttle is "closed."

(2) A second governor-operated valve is closed when the engine speed is above idle, but is opened as the engine speed decreases to idle. This second valve is in a circuit which bypasses the above-mentioned first valve so that, with both the throttle and the first valve closed, the injectors receive enough fuel to operate the engine at the idle speed. Thus, the second, governor-controlled valve becomes the control for maintaining the idle speed of the engine.

(3) A third, governor-operated valve is closed whenever the engine is rotating at a speed below a predetermined maximum speed and is open to the suction side of the fuel supply pump above that speed. The flow circuit containing the third valve also bypasses the first valve, enabling the fuel conduits leading to the injectors to be opened to the pump suction regardless of the position of the first valve. This third valve controls the maximum speed of the engine by returning to the suction side of the supply pump all fuel which would otherwise be injected into the engine above the predetermined maximum speed.

(4) In a preferred form of the invention a fourth, governor operated valve is in series with a fifth valve, which is manually operated by the throttle shaft. Both the fourth and fifth valves are in a circuit bypassing the metering piston, and they open to allow fuel under pressure to flow to the injectors (a) when the engine is running in approximately the middle half of its normal operating speed range, and (b) when the throttle shaft is rotated to its fully open position. An adjustable bypass-flow-control orifice is additionally used in this circuit to meter the volume of fuel that passes through the above two series-connected valves. By superimposing a continuous measured flow of fuel through the bypass circuit onto the

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volume pumped by the metering piston, an engine torque curve of any desired shape can be generated. This torque control bypass circuit is closed off regardless of throttle opening when the engine is running either below the normal operating speed range or near the maximum governed speed. Thus the maximum-speed power output remains under the sole control of the depth of the metering piston stroke-determining-groove on the throttle shaft. Some other ways of providing this controlled torque rise are also shown herein.

(5) In a preferred form of the invention, a sixth valve, opened by fuel pressure, in series with a seventh valve, operated by air intake manifold pressure, prevents momentary overfueling in a turbocharged engine, where the throttle is quickly opened from a part to full position before the turbocharger has increased in speed to pump sufficient air into the combustion chamber to burn cleanly a full throttle charge of fuel. In one form of the invention, the sixth valve cannot open until the throttle is at least three-quarters open and the engine is above the idle speed. The seventh valve is closed whenever the air manifold pressure is high enough to enable the fuel charge to burn cleanly. If the sixth valve is open and air manifold pressure has not reached a predetermined value, a part of the metered fuel charge is spilled off to the suction side of the supply pump.

A fuel-supply and metering system with which the controls of this invention may be used

The fuel supply system shown diagrammatically in FIG. 1 is, except for the controls of this invention, basically that described and claimed in the co-pending application S.N. 166,730. The system may be mounted at any convenient location on the engine where a drive synchronized to the crankshaft is available. Fuel for the engine may be drawn from a tank 20 through a conduit 21, a filter 22 and a conduit 23 to an engine-driven pump 24, herein illustrated as a gear pump. Fuel under pressure from the pump 24 flows through a conduit 25, a filter 26 and a conduit 27 to a pressure regulator 28. Spill-off from the regulator 28 passes back through a line 30 to the suction side of the pump 24, the pressure regulator 28 maintaining sufficient pressure of fuel to operate a metering or shuttle piston 32 through its full stroke for all speeds from idle to full speed in order to deliver the entire fuel charge pumped to an injector 33. Close pressure control is not required from the regulator 28. This fuel that is not spilled off from the regulator 28 passes through a conduit 34, a shut-down valve 35 (which may be an electric solenoid valve), and a conduit 36 to a supply port 37 at a governor-controlled rotor 38.

The rotor 38, moving in a sleeve 40 (FIG. 2), admits fuel under pressure first to one end of the metering piston 32 and then alternately to the other end, while the opposite end of the piston 32 in each instance pushes fuel to the injectors 33. The rotor 38 thus fulfills the pressure distributing function, while the charge distributing function of dispatching the fuel charge pumped by the piston 32 to the injectors 33 in firing order sequence is accomplished by a distributor rotor 41 which turns at camshaft speed for a four-cycle engine. The governor-controlled rotor 38 rotates in timed relationship with the rotor 41 and with engine speed, the ratio of its speed of rotation to engine speed being dependent on the number of engine cylinders. For example, in a six cylinder, four-cycle engine the rotor 38 turns at one and a half times the engine speed. The rotor 38 is also speed-responsive, in that its axial position is determined by the balance of forces between centrifugal governor weights 42 acting on one end of the rotor 38 and a spring or springs 43 acting on the opposite end.

In FIGS. 1 and 2 a branching rotor conduit 44 is shown connecting the rotor sleeve port 37 with a sleeve port 45, so that fuel under pressure can pass from the conduit 36 through conduits 44 and 45 into a chamber 47 at

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one end of the piston 32. At the same time that the conduit 44 connects the ports 37 and 45, an angling conduit 48 connects another sleeve port 50 with a groove 51 on the rotor 38, so that a chamber 52 at the opposite end of the piston 32 is then connected to a fuel injector 33 through conduits 53 and 54, a passage 55 in a throttle shaft 56, conduits 57 and 58, a groove 60 on the rotor 41, a rotor passage 61, a distributor port 62 on the rotor, and a conduit 63 leading from a distributor housing 64 to a fuel receiving chamber 65 in the injector 33 (FIG. 2). The injectors 33, each with a mechanically operated injector plunger 66, can be of the type shown in the co-pending application S.N. 157,730, filed December 7, 1961, and when the plunger 66 is retracted, the delivery port 68 is uncovered. The injectors 33 all include fuel return lines 67 (FIG. 2) for carrying the minute quantity of fuel which has leaked up the clearance in the plunger bore back to the fuel source or tank 20.

When the governor-controlled rotor 38 has turned through 180 degrees, as shown in FIG. 3, the conduit 36 under pressure is connected with the conduit 53 leading to the chamber 52, since the ends of the branching rotor conduit 44 are aligned with both the port 50 and the port 37. Likewise, the rotor groove 51 is connected with the port 45 by the rotor conduit 48. Fuel under pressure in the chamber 52 acts against the piston 32 and pumps the fuel charge from the chamber 47 through the conduits 46, 48, 54, 55, 57 and 58 to the distributor rotor groove 60. The rotor 41 has also rotated, and the port 62 is now aligned with the next distributor outlet 68 (FIG. 1) leading to the next injector (not shown) in the engine firing order.

During each revolution of the rotor 38, two fuel charges are pumped into the conduits 54, 57, and 58 leading to the distributor rotor 41. Since a four-cycle six-cylinder engine requires six fuel charges every two revolutions of the crankshaft, it follows that for a six-cylinder engine the governor-controlled rotor 38 makes three revolutions for every two of the engine, turning at one and one-half times the engine speed. FIGS. 1 and 2 show a distributor for a six-cylinder engine, but the same governor-controlled rotor 38 with its adjacent ports can be used for a four, an eight, or twelve cylinder engine simply by changing the speed of the rotor 38. The construction of the distributor 64 may be altered to accommodate more fuel outlets, since this component is not incorporated in the basic pump casting. Thus, for an eight-cylinder four-cycle engine requiring four charges for each revolution of the crankshaft, the ratio of rotor speed to engine speed becomes four to two, the rotor turning at two times the engine speed. These ratios may be determined by the ratio of the gear 70 on the driving shaft to the gear 71 on the governor shaft, so that in changing from a six-cylinder to an eight-cylinder engine only the gears 70 and 71 need be changed. The speed of the distributor rotor 41 remains at one-half engine speed regardless of the number of engine cylinders for a four-cycle engine.

In order to control the volume of the fuel charge delivered to the injectors 33 by the shuttle piston 32, means are provided to vary the length of stroke of the piston 32, so that the volume of the metered charge changes from an approximate idle charge to that required for maximum power at the engine's rated speed. A cam-shaped groove 72 on the manually operated throttle shaft 56 controls the swept volume of the fuel metering chambers 47 and 52. The swept volume is defined as the area of the head of the metering piston 32 multiplied by its stroke. A slidable tappet 73 and the piston 32 are both contained in a sleeve 74 (FIG. 2). The tappet 73, inserted between the throttle shaft 56 and the piston 32 provides a fluid tight seal for the chamber 52, and a fixed stop 75 at the opposite end of the piston 32 provides a seal for the chamber 47.

In FIGS. 1 and 2 the shaft 56 is shown in the position

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enabling the shuttle piston 32 to move through its full stroke, representing the "wide-open" position. As the shaft 56 is rotated in a clockwise direction by the engine operator, the groove 72 decreases in depth, decreasing the stroke of the piston 32. The tappet 73 is held against the cam groove 72 by fuel pressure in the chambers 47 and 52. The maximum fuel requirements of the engine determine the stroke of the metering piston 32 and, in turn, the depth of the groove 72. The groove 72 is shaped to permit the maximum desired piston stroke, but no more, regardless of how much farther the throttle shaft 56 is rotated in a counterclockwise direction.

Control of idling and coasting

In addition to the functions of accurate fuel metering and distributing, which are further described and are claimed in application Serial No. 166,730, other controls are provided in the fuel supply system of this invention, in order to handle the variable operating conditions of a diesel engine installed in a vehicle. The first of these new controls to be explained are those for idle speed and coasting fuel shutoff.

In FIG. 3 the governor-controlled rotor 38 is located axially in its sleeve 40 in the position it takes when the engine is running at its predetermined idle speed. With the shaft 56 rotated in its sleeve 76 to its closed position, the passage 55 is out of index with the throttle sleeve ports 77 and 78, so that no fuel can pass from the conduit 54 to the conduit 57. With the throttle closed, the depth of the groove 72 is reduced to an amount sufficient for the piston 32 to pump slightly more fuel than that required to idle the engine. The small measured charges of fuel pumped alternately from the respective chambers 47 and 52 into the rotor groove 51 must now bypass the throttle passage 55 in order to reach the conduit 58.

When the engine is at rest, the governor-controlled rotor 38 is forced to the left, as seen in FIGS. 2-4, by the spring or springs 43, and an idle flow control port 80 is fully open to the rotor groove 51. The port 80 leads to a conduit 81 that bypasses the throttle valve 55 and connects with the passage 58 leading to the distributor rotor groove 60. As the engine is cranked over by its starter, the port 80 is still fully open and passes the entire charge of fuel pumped by the piston 32. When the engine begins to run and increase its speed toward the idle speed, the governor weights 42 begin also to increase their rightward force against the rotor 38 and to move it to the right, as seen in FIGS. 2-4, slightly compressing the spring 43. As the rotor 38 moves axially in this manner the port 80 is gradually shut off by a shoulder 82 on the rotor 38. If the port 80 remained open, the engine would run faster than the desired idle speed since the charges of fuel pumped by the piston 32 are greater than what is needed to maintain the engine just at the idle. However, as the engine speed exceeds the idle speed, the rotor 38 moves farther to the right, and the shoulder 82 completely cuts off the port 80, stopping the flow of fuel to the injectors. Hence, the engine speed drops again and the port 80 opens. The proper design and sizing of the port 80 and the shoulder 82 assure that the engine speed is quickly stabilized to an essentially constant idle speed. The idling speed may be adjusted by varying the initial compression of the springs 43.

Rotating the throttle shaft 56 from its closed position immediately opens the throttle passage 55 to the sleeve ports 77 and 78 and, with the increased depth of the groove 72 a greater volume of fuel is pumped by the piston 32. Engine speed increases, the rotor 38 moves still farther to the right, and the port 80 is fully cut off, remaining so until engine speed drops near the idle again.

This type of idle and throttle shutoff control provides an excellent means of stopping the flow of fuel to the injectors when the engine is in a coasting vehicle. With the engine above the idle speed and the throttle closed, the idle port 80 (as shown in FIG. 2) and the throttle

passage 55 (FIG. 3) are both closed off, so that, within the limits of hydraulic fits, the fuel pumped to the injectors is reduced to zero. Also, as fuel under pressure is always standing at the throttle port 77 when coasting, there is an immediate response by the engine when the throttle is next opened. A further advantage is that the piston 32 remains stationary in the coasting condition because it is hydrostatically locked when the throttle is closed. The life of the wearing surfaces on the piston 32 and the sleeve 74 is thereby extended.

Control of overspeed

FIG. 4 illustrates how overspeed of the engine is controlled by this invention. As the speed of the engine increases, the governor rotor 38 is forced to the right in FIG. 4, due to the centrifugal governor weights 42 compressing the spring 43. With the proper spring or spring pack design, the position of a shoulder 33 on the rotor 38 is just ready to uncover high-speed spill-off ports 84 and 85 when the engine reaches the predetermined maximum speed. The port 84 leads into the throttle bypass conduit 81, and the port 85 leads into a conduit 86 that (see FIG. 1) connects with the conduit 23 at the suction side of the gear pump 24. It is preferable but not essential that the fuel be returned to the pump suction. The diverted fuel could be returned directly to the tank 20, but this necessitates another external fuel line. As soon as the ports 84 and 85 are uncovered, part of the charge which would normally pass through the groove 51 and on to an injector is now spilled off and passes through the port 85 and into the conduits 86 and 23 to the suction side of the pump 24. If the engine should speed up still more, a greater percentage of the charge is spilled off, because more of the port 85 is uncovered.

At the same time that the port 85 is uncovered, the branching rotor conduit 44 begins to pass out of alignment with the port 37, so that the fuel to the metering chambers 47 and 52 is restricted, or if engine speed goes high enough, is completely shut off. Regardless of load or throttle opening, the equilibrium overspeed position is quickly reached and is held there within a very small range of r.p.m.

A very important advantage obtained by adopting this form of overspeed control is that the engine is prevented from "running away" if the suction line 21 between the tank 20 and the gear pump 24 should rupture or if the tank should become empty while the engine is running. Without some form of "runaway" control a diesel engine can destroy itself by overspeeding under these conditions. For all practical purposes fuel oil is incompressible, and under normal conditions the fuel in the supply passages is "batched" through by a new charge pumped from the metering chambers 47, 52 (FIG. 4). But air is highly compressible and can continue to force fuel to the injectors in a manner similar to a pneumatic ram as long as the delivery port 68 (FIG. 2) indexes with passages leading to the plunger chamber 65. Then, an excess of fuel over the required charge is injected into the engine, causing an extremely rapid acceleration of the engine to speeds which are destructive if there is no control, for the engine slows down again only after the expanding air behind the column of fuel in the lines to the injectors has shoved all of the fuel into the plunger chambers and injected it into the engine, or when the engine has destroyed itself. Even with the engine under heavy load there is a period of uncontrolled high speed, although not as dangerous as when under light load.

In this invention, by opening one end of the conduit between the governor rotor 38 and the injectors 33 to the suction side of the pump 24 through the conduit 86 and the port 85, any air which might pass into the conduit 53 is sucked out through the conduit 81 and the port 84 and carried on through the conduit 86 to the supply pump 24, thereby eliminating the possibility of the pneumatic ram effect. At the same time, the air can no longer be effec-

tively pumped by the shuttle piston 32 because the rotor conduit 44 has passed out of index with the port 37. The engine simply comes up to its governed speed and remains at that speed until all of the fuel in the lines has been burned, and this does no harm to the engine. Since the conduit 81 bypasses the throttle valve 55, the instinctive closing of the throttle by the operator when this situation commences can cause no harm. The lines to the injectors are always open to the pump suction in the overspeed position regardless of the throttle position.

Torque rise control by the device of FIGS. 5 and 6

By means of the additional hydraulic circuitry and controls shown in FIGS. 5 and 6, the torque curve of a diesel engine may be precisely tailored to suit the engine operating conditions. While engines in generator and marine service have no need of this additional feature, most vehicular applications can benefit by its use.

In FIG. 7 a graph illustrates the effect of the fuel delivery characteristics on the maximum torque curve of the engine. With the fuel metering system of FIGS. 1-4 the fuel delivery curve (volume of fuel per injection) at maximum throttle is a horizontal straight line over the engine operating speed (curve A). When the engine exceeds its maximum governed speed, the fuel flow is cut off so that curve A drops to zero at its upper end. In a naturally aspirated diesel engine the fuel delivery rate "X" is usually determined by how much exhaust smoke can be tolerated at the maximum rated speed. The torque curve A', generated by the flat fuel delivery curve A, is not flat, but has a slight rise, because the volumetric efficiency or air induction capabilities improve as the engine drops off in speed from say 2,100 r.p.m. to the 1,600 r.p.m. shown. Since there is more air in the cylinder at 1,600 r.p.m. than at 2,100 r.p.m. for the same amount of fuel injected (curve A) there is more complete burning (with less exhaust smoke) and thus more work cycle or torque produced by the engine.

However, the torque "rise" as speed falls off to its most efficient point is sometimes not enough in truck applications. In many truck transmissions, the ratio splits between different gears may cause the driver to have to drop his engine speed 500 to 600 r.p.m. when he begins to shift to the next higher gear. In order to accelerate the engine, and in turn the vehicle, from the new lower engine speed the available power (torque times speed) must be significantly greater than the power required to just maintain the vehicle's speed at the rate when the clutch is first engaged in the higher gear. If there is not an excess of power at the lower speed the engine (and vehicle) cannot accelerate to a higher speed. The driver must then content himself to run in the higher gear at a reduced speed and "lug" his engine or to drop back to a lower gear to bring up his engine speed. There are many times when ascending a grade the transmission could operate in "higher" gears at the more desirable higher engine speeds, but cannot because the engine does not have the power to accelerate to the higher speeds after making a gear change. (The needed complete shut-off of fuel when the throttle is closed when shifting so that the engine decelerates quickly and vehicle speed is not lost while waiting to make the shift, has already been provided by the structure shown in FIGS. 1 to 4.)

Increasing the fuel delivery per injection to approximate curve B in FIG. 7 produces a torque curve B' that humps to about 110 percent of the torque output at the engine's rated speed (2,100 r.p.m. in FIG. 7). This provides adequate vehicle acceleration characteristics for the average transmission-engine combination. The slight fuel increase with the resultant 10 percent torque rise is small enough for the exhaust smoke to remain within acceptable limits. In supercharged engines, where there is generally an excess of air for good combustion, the torque rise can be increased beyond the 10 percent required, but still only in the middle operating speed range.

Fuel delivery approximating curve B can be produced by the structure shown in FIGS. 5 and 6. A second bypass circuit, comprising conduits 87, 88, 90 and 92 connects the fuel under pressure standing at the port 36 to the conduit 58 when additional manually operated and governor-operated valves, in series, are opened. A small passage 93 through the throttle shaft 56 is of a diameter and location such that it begins to connect ports 94 and 95 in the sleeve 76 only when the shaft 56 is rotated to about 90 percent of its fully open position. At 100 percent shaft rotation the passage 93 is in full index with the ports 94 and 95.

When the engine speed is in the previously mentioned intermediate range and the governor weight-spring forces have axially positioned the rotor 38 as shown in FIGS. 5 and 6, a narrow groove 96 on the rotor 38 uncovers rotor ports 97 and 98 in the sleeve 40. A torque-rise flow adjusting valve 100, which is capable of accurately controlling the volume of fuel bypassed, is also placed in the bypass circuit, shown here in the conduits 87 and 88. The valve 100 can be calibrated in its own housing 101 during the pump assembly, locked at the desired setting, and then placed into the main pump housing as a complete unit. By its inaccessible location in the pump housing, and its precalibration, the essential tamperproof features of the pump are maintained. Another location for the valve 100, which would have manufacturing advantages, is in the passage 93 in the throttle shaft 56. In FIGS. 5 and 6 the conduit 87 is shown connected to the conduit 36 by the indexing of the rotor sleeve port 37 with another sleeve port 102 through the branching conduit 44. It is likewise feasible to permanently connect the conduit 87 with the conduit 36 and have fuel pressure standing against the adjusting valve 100 all the time.

Torque rise circuit—operation of the device of FIGS. 5 and 6

Since the valves 93 and 96 are in series the torque rise control circuit can only come into operation when: (a) the throttle is at least almost fully opened and (b) the engine is running below its maximum rated speed and in the range of its highest volumetric efficiency.

With the flow control valve 100 set to pass approximately five percent of the fuel volume pumped at the maximum metering piston stroke, and the throttle valve 93 fully open, the new fuel delivery curve B (shown dotted in FIG. 7) results. The gradual uncovering and covering of rotor ports 97 and 98 by the axial movement of the rotor groove 96 causes a gradual drop at each end of the fuel curve B. At the lower and higher speeds the engine operates only on the metering-piston-stroke-determined curve A. If the engine is operating under a part load condition, the axial position of the governor valve 96 has no effect on the fuel delivered to the injectors, since the throttle valve 93 is closed. Likewise, if the valve 93 is open but the engine is at its maximum rated speed, the valve 96 is closed, and the stroke of the piston 32 determines the fuel volume pumped.

Torque rise control by the device of FIG. 8

A modified form of this invention, which also superimposes an additional measured volume of fuel per charge onto that pumped by the piston 32 at full throttle is shown in FIG. 8. Here, there is a second metering piston 103, with its stroke set to pump five percent of the maximum fuel charge pumped by the piston 32. This piston 103 acts in conjunction with the throttle valve 93 and the governor rotor valve 96, to produce the fuel delivery curve B and torque curve B' of FIG. 7.

When the governor-controlled rotor 38 is in the position shown in FIG. 8, fuel under pressure from the conduit 36 enters the chamber 47 at one end of the piston 32 and also enters a chamber 104 at one end of the piston 103. The chamber 104 is connected to the rotor port 45 by conduits 46 and 105. A chamber 106 at

the opposite end of the piston 103 is connected to the rotor groove 51 at the same time as is the chamber 52; the connection is from the chamber 106 through a conduit 107, the valve 96 with its ports 97 and 98, a conduit 108, the valve 93 with its ports 94 and 95, and conduits 110, 53 and 43. Thus, if the valves 93 and 96 are both open, the metering piston 103 moves in synchronism with the piston 32 and the required additional fuel is delivered to the injectors.

As with the device of FIGS. 5 and 6, the valve 93 is only open when the throttle 56 is substantially fully open, and the valve 96 is open only when the engine is in the intermediate operating speed range, thereby reproducing the fuel curve B and torque curve B' of FIG. 7. When one or both of the valves 93 and 96 are closed, the piston 103 ceases to move even though the chamber 104 is open to the rotor port 45 at all times.

The stroke of the piston 103 is limited at one end by a stop 111 and at the other end by the lockable adjusting screw 112. The screw 112, piston 103 and stop 111 may be assembled in a sleeve 113, and the stroke of the piston 103 can be properly calibrated by inserting a gage through an inspection hole 114 in the stop 111 as the screw 112 is turned. The screw 112 is then locked, and the entire assembly in the sleeve 113 placed in the pump housing.

While two metering pistons are shown in FIG. 8, the one piston 32 may be used alone if it is provided with the shaped spool cam surface shown in FIGS. 1-6 of co-pending application S.N. 166,730, filed December 14, 1961.

Torque rise control by the device of FIG. 9

In FIG. 9 the 1600-2100 r.p.m. portion of the torque curve B' of FIG. 7 is generated by spilling off to the pump suction 23 a part of a larger fuel charge pumped by the piston 32 of FIGS. 1-4. The increase in fuel rate as the engine speed drops from 2100 r.p.m. to approximately 1600 r.p.m. is due to the amount of fuel spilled off decreasing, until at 1600 r.p.m. there is no fuel spilled off. The cam groove 72 on the throttle shaft 56 (not shown) is cut five percent deeper than is the groove 72 when used with the devices in FIGS. 5, 6 and 8. Thus, when the engine is operating at full throttle at 1600 r.p.m. and below, a metered fuel charge of $X + 5\%X$ (FIG. 7 is always delivered to the injectors from the chambers 47 and 52, and the torque curve generated does not drop back to the same point at 1100 r.p.m. as do the A' and B' torque curves. However, as engine speed increases beyond 1600-1700 r.p.m. and the governor-controlled rotor 38 is moved axially to the right, a slightly reduced diameter 115 adjacent the shoulder 83 on the rotor 38 spills off an increasing part of the fuel charge through the port 85 and returns it to the pump suction 23. The reduced diameter 115 creates a passage just sufficient to spill off a very small part of the charge so that at the engine's rated speed and at full throttle the fuel delivered to the injectors is still equal to that pumped by the metering piston 32 in FIGS. 5, 6 and 8 at full throttle. As the engine speed continues to increase beyond rated speed, the shoulder 83 uncovers the port 85 and the entire fuel charge is spilled off as shown in FIG. 4. Since a part of the fuel charge is spilled off at the higher engine operating speeds, regardless of throttle opening, the operator must compensate for this by opening the throttle slightly more than he would have to if no spill-off shoulder 115 was on the rotor 38.

Barometric control for turbocharged engines (FIG. 10)

The invention also contemplates the use of spill-off valve means controlled by air intake manifold pressure, to prevent overfueling of a turbocharged diesel engine under quick-acceleration conditions.

In FIG. 10 a bypass circuit provided by conduits 116, 117 and 118 connects the conduit 58, leading to the injectors, with the conduit 39 and thence the conduit 23

and the suction side of the gear pump 24. Inserted in the conduits 116, 117 and 118 are two valves 120 and 130 in series. A first valve 120 is opened only when the throttle 56 is opened a predetermined amount, preferably at least three-quarters open, and when the fuel pressure, as regulated by the pressure regulator 28, is higher than that normally required for operating the piston 32 during the starting and idling conditions. When the throttle 56 is open more than the approximate three-quarter position, a passage 121 in the shaft 56 connects ports 122 and 123 in the sleeve 76. The pressurized fuel in the conduit 27 can then pass through the throttle passage 121 and a conduit 124 leading into a chamber 125 at one end of the valve plunger 120. If the engine is above the idle speed, the fuel pressure in the chamber 125 is then high enough to move the valve plunger 120 against a stop 126 while compressing a spring 127. When the plunger 120 is against the stop 126, a groove 128 on the plunger 120 indexes with the conduit 116 and the conduit 117, so that some of the metered fuel in the conduit 58 enters the conduit 117.

A second valve 130 is axially positioned by the discharge air pressure of a turbocharger 131. The outlet from the turbocharger 131 pumps air into an air intake manifold 132. Leading off the manifold 132 is a passage 133 by which air at substantially manifold pressure enters a chamber 134 and acts against a diaphragm 135 forming one wall of the chamber 134. A spring 136 acting against a collar 137 on the end of the valve plunger 130 keeps the plunger 130 against the diaphragm 135 and counterbalances the air-pressure-created force of the diaphragm 135. An adjusting screw 138 limits the travel of the valve plunger 130 on the diaphragm end, so that, when the engine is at rest or the turbocharger 131 is not rotating at a high enough speed to raise the manifold pressure sufficiently above atmospheric pressure, the spring 136 keeps the plunger 130 against the adjusting screw 138. When the force of the spring 136 becomes larger than the air-pressure-created force acting on the collar 137, the plunger 130 moves toward the screw 138, and a shallow groove 140 with its shoulder 141 on the plunger 130 uncovers a port 142 at one end of the conduit 117 and a port 143 leading into the conduit 118.

When the valve 120 is open and while manifold pressure is low enough so that the shoulder 141 at the groove 140 has uncovered the ports 142 and 143, a controlled part of the metered fuel charge pumped by the piston 32 is spilled off to the suction side of the pump 24. Thus, the lower the air pressure in the intake manifold 132, the greater the area of the ports 142 and 143 that is uncovered and the larger the volume of fuel that is diverted from the injectors.

An equalizing circuit 144, connecting the chamber 145 at one end of the valve plunger 130 and the spring housing 146 at the opposite end, is open to the atmosphere through the passage 147. The passage 148 opens to the atmosphere from the spring chamber 150 at one end of the valve plunger 120.

As mentioned previously, there is, in a turbocharged engine, a time lag between the instant the throttle is abruptly opened to a full position and the time the turbocharger has speeded up to pump the air required to cleanly burn the air-fuel charge in the combustion chamber. In engines having no air pressure control as shown in FIG. 10, the engine is then overfuel. But, by the addition of the control of this invention, the full charge of fuel pumped by the metering piston 32 cannot reach the injectors until the air pressure in the intake manifold 132 and chamber 134 has increased sufficiently for the air pressure acting on the diaphragm 135 to overcome the force of the spring 136 and move the plunger 130 to shut off the ports 142 and 143.

By the use of the adjusting screw 138, the maximum uncovered area of the ports 142 and 143 is set, and, in turn, the volume of fuel spilled off at low manifold pressures is controlled.

Under many conditions, it is unnecessary to add the throttle valve 120 and the ports and passages 122, 123, and 124. The conduit 27 may be connected directly to the chamber 125 at one end of the valve 120. Without the valve 121, the operator will compensate for the fuel spilled off at part throttle by simply opening up his throttle a little more until the turbocharger 131 has speeded up to pump air at a high enough pressure to cause the valve 140 to be shut off.

To those skilled in the art to which this invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the spirit and scope of the invention. The disclosures and the description herein are purely illustrative and are not intended to be in any sense limiting.

I claim:

1. In a fuel system for use with a compression ignition engine having fuel injectors and engine-speed responsive means, said system having a housing with a bore in which a shuttle piston moves with its ends defining first and second ported chambers, one in each end of said bore, a fuel source, a fuel pump connected to said fuel source, conduit means for charging fuel under pump pressure to each said chamber alternately, thereby to move said shuttle piston and discharge fuel from the opposite chamber, and conduit means for connecting each said chamber at discharge to a said fuel injector, a manually controlled throttle having a cam face operatively engageable with one end of said shuttle piston to determine the extent of movement of the shuttle piston in one direction, and movement-limiting means engageable by the other end of said shuttle piston to determine its extent of movement in the other direction, the combination therewith of:

a normally-closed throttle-controlled first valve means in said housing, said throttle opening said first valve means when said throttle is opened,

a passage in said housing bypassing said first valve means, and

a normally open second valve means in said passage, said speed responsive means closing said second valve means at all speeds above idle speed,

whereby when said engine is operating at a speed above idle and said throttle is open, said second valve means is closed and all of the fuel pumped from said first and second ported chambers passes through said first valve means, and

when said engine is operating at or below the idle speed with said throttle closed, said second valve means is open to provide a flow of fuel to said injectors even though said first valve means is closed, and

when said engine is operating above idle speed and said throttle is closed, both said first and second valve means are closed, thereby shutting off all fuel to the injectors so that the engine decelerates at a maximum rate to facilitate gear shifting and to prevent fuel wastage during coasting.

2. The system of claim 1 having first control means opened by said engine-speed responsive means only during predetermined engine speeds, intermediate between idle speed and maximum speed, and

second control means actuated by said throttle to operate only when the throttle is in a substantially fully-open position,

said first and second control means, when said engine is running in said predetermined intermediate speeds and said throttle is fully open, sending a predetermined volume of metered fuel to said injectors in addition to the fuel charge normally delivered by said shuttle piston when said piston is moving through its maximum throttle-cam-determined stroke,

whereby in said intermediate engine speeds said increase in the fuel delivery rate causes the torque curve of said engine to rise to a higher value than it would

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with only the constant fuel delivery rate due to the action of said shuttle piston moving through its maximum throttle-cam-determined stroke.

3. The system of claim 1 having

a second passage bypassing said first valve means and connecting the conduit means connecting said chambers to said fuel injector to the suction side of said fuel pump, and

third valve means in said second passage controlled by said engine speed responsive means so as to be closed whenever the engine is below a predetermined maximum speed and to be opened when the engine reaches that maximum speed,

whereby said third valve means spills back to the suction side of said pump fuel that would otherwise pass to said injector, thereby helping to control the maximum speed of said engine.

4. The system of claim 1 having

a turbocharger for supplying air under pressure to said engine,

a second passage connecting the conduit means that connects said chambers to said fuel injector to the suction side of said fuel pump,

third valve means in said second passage opened by said throttle and by the fuel pressure only when said throttle is opened to a predetermined minimum fuel delivery and when the pressure of the fuel from said fuel pump is also greater than the amount required for operating said shuttle piston, and

fourth valve means in said second passage in series with said third valve means, controlled by the pressure of the air fed by said turbocharger to said engine, to open said fourth valve means only when said air pressure is below a predetermined value, pumping insufficient air to burn efficiently the fuel that would be fed to said injector if said fourth valve means were closed.

5. In a fuel system for use with a compression ignition engine having fuel injectors and a governor, said system having a housing with a bore in which a shuttle piston moves with its ends defining first and second ported chambers, one in each end of said bore, a fuel source, a fuel pump connected to said fuel source, conduit means including a plunger-rotor rotated at a speed synchronized with the speed of the engine and first passage means for charging fuel under pump pressure to each said chamber alternately, thereby to move said shuttle piston and discharge fuel from the opposite chamber, and second passage means for connecting each said chamber at discharge to a said fuel injector, a manually controlled throttle having a cam face operatively engageable with one end of said shuttle piston to determine the extent of movement of the shuttle piston in one direction, and movement-limiting means engageable by the other end of said shuttle piston to determine its extent of movement in the other direction, said plunger-rotor being moved axially by said governor to reduce the amount of fuel delivered to said fuel injector at predetermined engine speeds regardless of the position of said throttle, the combination therewith of:

a normally-closed throttle-controlled first valve means in said housing, said throttle opening said first valve means when said throttle is opened,

third passage means in said housing bypassing said first valve means, and

a normally open second valve means on said plunger-rotor and in said passage, said governor moving said plunger-rotor axially to close said second valve means at all speeds above idle speed.

6. The system of claim 5 having

fourth passage means connecting said fuel pump to said second passage means,

third valve means on said plunger-rotor and in said fourth passage means opened by said governor moving said plunger-rotor axially only during predeter-

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mined engine speeds that lie in between idle speed and maximum speed, and

fourth valve means also in said fourth passage means and in series with said third valve means and actuated by said throttle to open only when the throttle is in a substantially fully-open position,

said third and fourth valve means, when said engine is running in said predetermined speeds and said throttle is fully open sending a predetermined supplemental volume of metered fuel pumped to said injectors in addition to the fuel charge normally delivered by said shuttle piston when said piston is moving through its said fully-open-throttle cam-determined stroke,

whereby in said predetermined engine speeds said increase in the fuel delivery rate causes the torque curve of said engine to rise to a higher value than it would with only the constant fuel delivery rate due to the action of said shuttle piston moving through its maximum-throttle cam-determined stroke.

7. The system of claim 6 having a second shuttle piston in said fourth passage means for measuring said supplemental volume.

8. The system of claim 6 having a needle valve in said fourth passage means for measuring said supplemental volume.

9. The system of claim 6 having

fifth passage means bypassing said first valve means and connecting said second passage means to the suction side of said fuel pump, and

fifth valve means on said plunger-rotor, actuated by said governor moving said plunger-rotor axially so as to be opened only when the engine reaches a predetermined maximum speed.

10. In a fuel system for use with a compression ignition engine having fuel injectors and engine-speed responsive means, said system having a housing with a bore in which a shuttle piston moves with its ends defining first and second ported chambers, one in each end of said bore, a fuel source, a fuel pump connected to said fuel source, conduit means for charging fuel under pump pressure to each said chamber alternately, thereby to move said shuttle piston and discharge fuel from the opposite chamber, and conduit means for connecting each said chamber at discharge to a said fuel injector, a manually controlled throttle having a cam face operatively engageable with one end of said shuttle piston to determine the extent of movement of the shuttle piston in one direction, and movement-limiting means engageable by the other end of said shuttle piston to determine its extent of movement in the other direction, the combination therewith of:

first control means opened by said engine-speed responsive means only during predetermined engine speeds, intermediate between idle speed and maximum speed, and

second control means actuated by said throttle to operate only when the throttle is in a substantially fully-open position,

said first and second control means, when said engine is running in said predetermined intermediate speeds and said throttle is fully open, sending a predetermined volume of metered fuel to said injectors in addition to the fuel charge normally delivered by said shuttle piston when said piston is moving through its maximum throttle-cam-determined stroke, whereby in said intermediate engine speeds said increase in the fuel delivery rate causes the torque curve of said engine to rise to a higher value than it would with only the constant fuel delivery rate due to the action of said shuttle piston moving through its maximum throttle-cam-determined stroke.

11. In a fuel system for use with a compression ignition engine having fuel injectors and a governor, said system having a housing with a bore in which a shuttle

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piston moves with its ends defining first and second ported chambers, one in each end of said bore, a fuel source, a fuel pump connected to said fuel source, conduit means including a plunger-rotor rotated at a speed synchronized with the speed of the engine and first passage means for charging fuel under pump pressure to each said chamber alternately, thereby to move said shuttle piston and discharge fuel from the opposite chamber, and second passage means for connecting each said chamber at discharge to a said fuel injector, a manually controlled throttle having a cam face operatively engageable with one end of said shuttle piston to determine the extent of movement of the shuttle piston in one direction, and movement-limiting means engageable by the other end of said shuttle piston to determine its extent of movement in the other direction, said plunger-rotor being moved axially by said governor to reduce the amount of fuel delivered to said fuel injector at predetermined engine speeds regardless of the position of said throttle, the combination therewith of:

third passage means connecting said fuel pump to said second passage means,

first valve means on said plunger-rotor and in said third passage means opened by said governor moving said plunger-rotor axially only during predetermined engine speeds that lie in between idle speed and maximum speed, and

second valve means also in said third passage means and in series with said first valve means and actuated by said throttle to open only when the throttle is in a substantially fully-open position,

said first and second valve means, when said engine is running in said predetermined speeds and said throttle is fully open sending a predetermined supplemental volume of metered fuel pumped to said injectors in addition to the fuel charge normally delivered by said shuttle piston when said piston is moving through its said maximum-throttle cam-determined stroke, whereby in said predetermined engine speeds said increase in the fuel delivery rate causes the torque curve of said engine to rise to a higher value than it would with only the constant fuel delivery rate due to the action of said shuttle piston moving through its maximum-throttle cam-determined stroke.

12. The system of claim 11 having a second shuttle piston in said fourth passage means for measuring said supplemental volume.

13. The system of claim 11 having a needle valve in said fourth passage means for measuring said supplemental volume.

14. In a fuel system for use with a compression ignition engine having fuel injectors and engine-speed responsive means, said system having a housing with a bore in which a shuttle piston moves with its ends defining first and second ported chambers, one in each end of said bore, a fuel source, a fuel pump connected to said fuel source, first conduit means for charging fuel under pump pressure to each said chamber alternately, thereby to move said shuttle piston and discharge fuel from the opposite chamber, and second conduit means for connecting each said chamber at discharge to a said fuel injector, a manually controlled throttle having a cam face operatively engageable with one end of said shuttle piston to determine the extent of movement of the shuttle piston in one direction, and movement-limiting means engageable by the other end of said shuttle piston to determine its extent of movement in the other direction, the combination therewith of:

a passage connecting said second conduit means to the suction side of said fuel pump, and

valve means in said passage controlled by said engine speed responsive means so as to be closed whenever the engine is below a predetermined maximum speed and to be opened when the engines reaches that maximum speed,

whereby said valve means spills back to the suction side

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of said pump fuel that would otherwise pass to said injector, thereby controlling the maximum speed of said engine.

15. In a fuel system for use with a compression ignition engine having fuel injectors and a governor, said system having a housing with a bore in which a shuttle piston moves with its ends defining first and second ported chambers, one in each end of said bore, a fuel source, a fuel pump connected to said fuel source, conduit means including a plunger-rotor rotated at a speed synchronized with the speed of the engine and first passage means for charging fuel under pump pressure to each said chamber alternately, thereby to move said shuttle piston and discharge fuel from the opposite chamber, and second passage means for connecting each said chamber at discharge to a said fuel injector, a manually controlled throttle having a cam face operatively engageable with one end of said shuttle piston to determine the extent of movement of the shuttle piston in one direction, and movement-limiting means engageable by the other end of said shuttle piston to determine its extent of movement in the other direction, said plunger-rotor being moved axially by said governor to reduce the amount of fuel delivered to said fuel injector at predetermined engine speeds regardless of the position of said throttle, the combination therewith of:

third passage means connecting said second passage means to the suction side of said fuel pump, and valve means on said plunger-rotor, actuated by said governor moving said plunger-rotor axially so as to be opened only when the engine reaches a predetermined maximum speed.

16. In a fuel system for use with a compression ignition engine having fuel injectors, a turbocharger for supplying air under pressure to said engine, and engine-speed responsive means, said system having a housing with a bore in which a shuttle piston moves with its ends defining first and second ported chambers, one in each end of said bore, a fuel source, a fuel pump connected to said fuel source, first conduit means for charging fuel under pump pressure to each said chamber alternately, thereby to move said shuttle piston and discharge fuel from the opposite chamber, and second conduit means for connecting each said chamber at discharge to a said fuel injector, a manually controlled throttle having a cam face operatively engageable with one end of said shuttle piston to determine the extent of movement of the shuttle piston in one direction, and movement-limiting means engageable by the other end of said shuttle piston to determine its extent of movement in the other direction, the combination therewith of:

a passage connecting said second conduit means to the suction side of said fuel pump,

first valve means in said passage opened by said throttle and by the fuel pressure only when said throttle is opened to a predetermined minimum fuel delivery and when the pressure of the fuel from said fuel pump is also greater than the amount required for operating said shuttle piston, and

second valve means in said passage in series with said first valve means, controlled by the pressure of the air fed by said turbocharger to said engine, to open said second valve means only when said air pressure is below a predetermined value, pumping insufficient air to burn efficiently the fuel that would be fed to said injector if said second valve means were closed.

17. In a fuel system for use with a compression ignition engine having fuel injectors and an engine-speed governor, said system having a housing with a bore in which a shuttle piston moves with its ends defining first and second ported chambers, one in each end of said bore, a fuel source, a fuel pump connected to said fuel source, first conduit means for charging fuel under pump pressure to each said chamber alternately, thereby to move said shuttle piston and discharge fuel from the opposite cham-

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ber, and second conduit means for connecting each said chamber at discharge to a said fuel injector, a manually controlled throttle having a cam face operatively engageable with one end of said shuttle piston to determine the extent of movement of the shuttle piston in one direction, and movement-limiting means engageable by the other end of said shuttle piston to determine its extent of movement in the other direction, the combination thereof with of:

a normally-closed throttle-controlled first valve means in said housing, said throttle opening said first valve means when said throttle is opened, 10
a passage in said housing bypassing said first valve means, and

a normally open governor-controlled second valve means in said passage, said governor closing said second valve means at all speeds above idle speed, whereby when said engine is operating at a speed above idle and said throttle is open, said second valve means is closed by said governor and all of the fuel pumped from said first and second ported chambers passes through said first valve means, and 15 20

when said engine is operating at or below the idle speed with said throttle closed, said second valve means is opened by said governor to provide a flow of fuel to said injectors even though said first valve means is closed, and 25

when said engine is operating above idle speed and said throttle is closed, both said first and second valve means are closed, thereby shutting off all fuel to the injectors, so that the engine decelerates at a maximum rate to facilitate gear shifting, to prevent fuel wastage during coasting, and to maximize engine retardation during coasting. 30

18. The system of claim 17 having 35
first control means opened by said governor only during predetermined engine speeds, intermediate between idle speed and maximum speed, and
second control means actuated by said throttle to operate only when the throttle is in a substantially fully-open position, 40

said first and second control means, when said engine is running in said predetermined intermediate speeds and said throttle is fully open, sending a predetermined volume of metered fuel to said injectors in 45

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addition to the fuel charge normally delivered by said shuttle piston when said piston is moving through its maximum throttle-cam-determined stroke, whereby in said intermediate engine speeds said increase in the fuel delivery rate causes the torque curve of said engine to rise to a higher value than it would with only the constant fuel delivery rate due to the action of said shuttle piston moving through its maximum throttle-cam-determined stroke.

19. The system of claim 18 having
a second passage bypassing said first valve means and connecting said second conduit means to the suction side of said fuel pump, and

third valve means in said second passage controlled by said governor so as to be closed whenever the engine is below a predetermined maximum speed and to be opened when the engine reaches that maximum speed,

whereby said third valve means spills back to the suction side of said pump fuel that would otherwise pass to said injector, thereby controlling the maximum speed of said engine.

20. The system of claim 19 having
a turbocharger for supplying air under pressure to said engine,

a third passage also connecting said second conduit means to the suction side of said fuel pump,

fourth valve means in said third passage opened by said throttle and by the fuel pressure only when said throttle is opened to a predetermined minimum fuel delivery and when the pressure of the fuel from said fuel pump is also greater than the amount required for operating said shuttle piston,

fifth valve means in said third passage in series with said fourth valve means, controlled by the pressure of the air fed by said turbocharger to said engine, to open said fifth valve means only when said air pressure is below a predetermined value, pumping insufficient air to burn efficiently the fuel that would be fed to said injector if said fifth valve means were closed.

No references cited.

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