

[54] **FUEL SYSTEM OF INTERNAL COMBUSTION ENGINE**

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[56]

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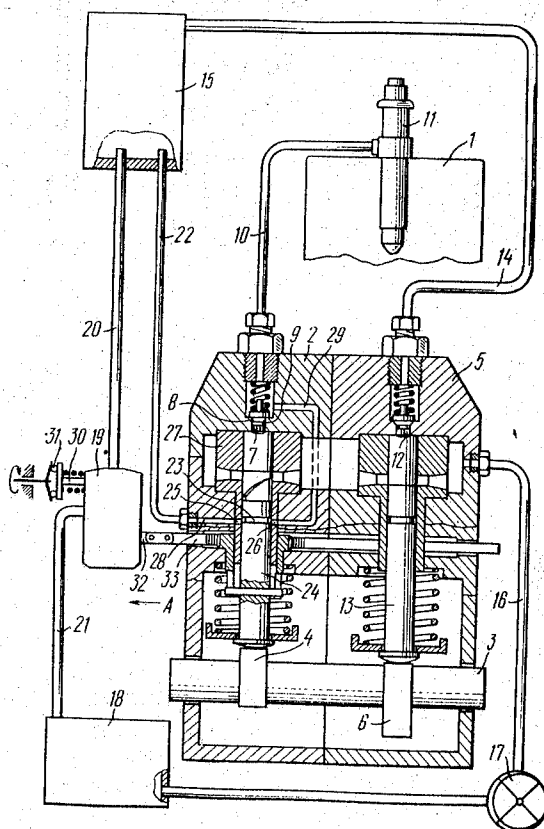
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ABSTRACT

A fuel system of an internal combustion engine comprising a high-pressure pump with a governing element in the form of a rack, and a discharge valve. Said high-pressure pump is connected with a closed-type fuel injector by a high-pressure pipe. For maintaining a high initial pressure in said pipe, it communicates with an accumulator by a pipe via a fuel distributor in the form of a groove and inlet and outlet holes. Pressure in the accumulator is built up by an auxiliary pump. The required high pressure in the accumulator is maintained by a controllable reducing valve communicating with said accumulator.

4 Claims, 2 Drawing Figures



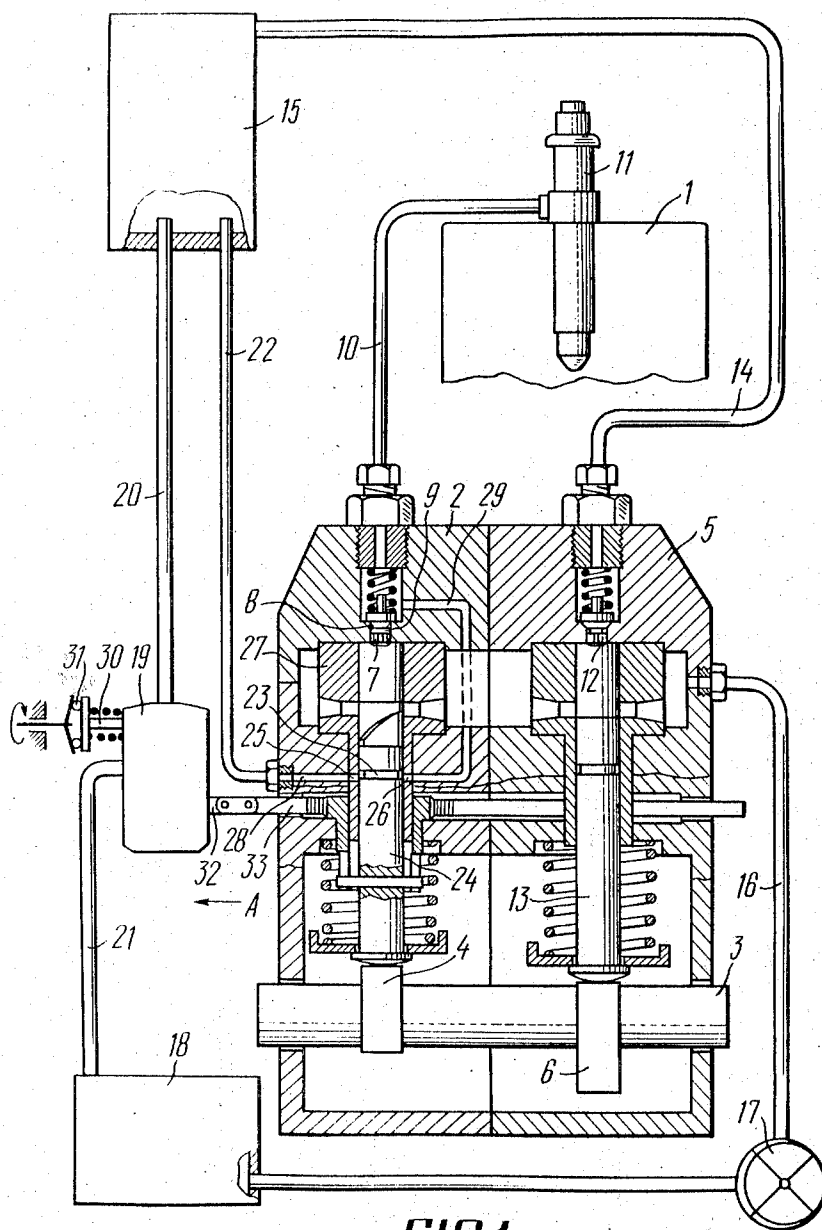
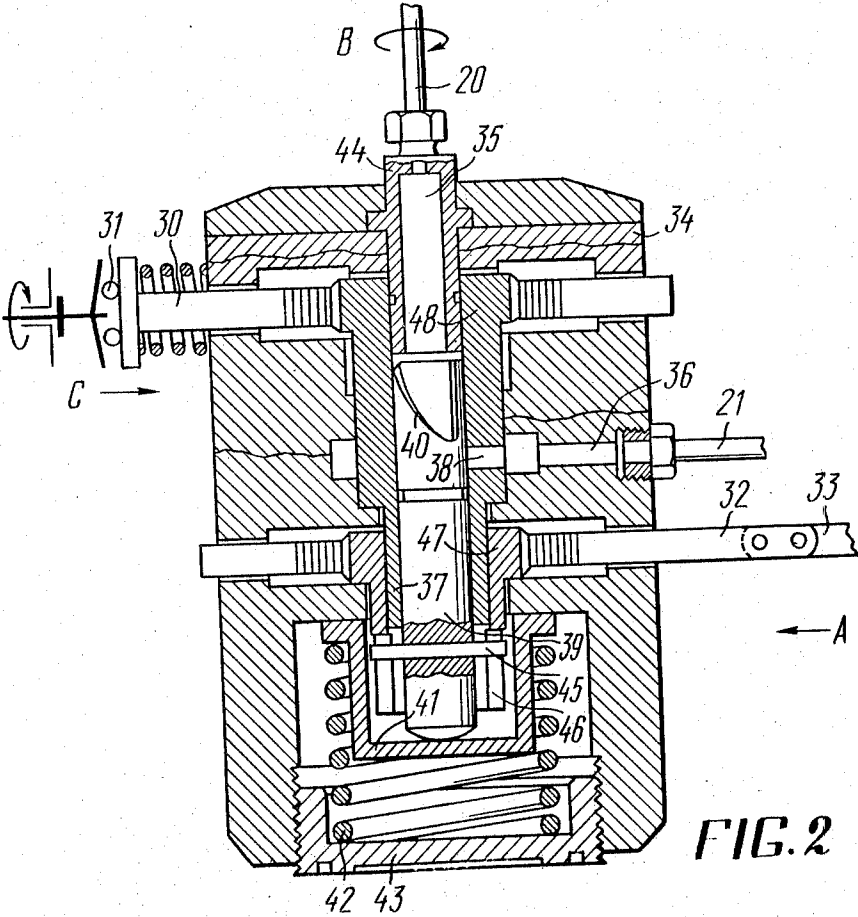


FIG. 1



FUEL SYSTEM OF INTERNAL COMBUSTION ENGINE

The present invention relates to internal combustion engines and more specifically it relates to the fuel systems of internal combustion engines.

The present invention can be utilized most successfully in Diesel engines with open combustion chambers, particularly in the Diesel engines running continuously under partial loads and unsteady-state conditions, i.e., mainly in the transport engines.

The overwhelming majority of the existing fuel systems of internal combustion engines consists of a high-pressure fuel pump, for example of a plunger type, driven by a cam and provided with a discharge valve with a suction collar. Besides, this system comprises a closed-type fuel injector connected to the high-pressure fuel pump by a high-pressure pipe.

The suction collar of the discharge valve relieves pressure in the high-pressure pipe after injection. A certain residual pressure in the high-pressure pipe serves at the same time as initial pressure for the subsequent cycle of fuel injection. This initial pressure determines to a considerable extent the fuel supply characteristic and the performance of the engine proper.

However, such a fuel system fails to ensure sufficient stability of the residual pressure in the high-pressure pipe from one cycle to another as well as in the high-pressure pipes of a multiple-cylinder engine; as a consequence, the fuel supply is unstable which reduces considerably the engine economy, particularly at duties other than nominal.

The instability of residual pressure in the high-pressure pipe exerts a particularly conspicuous influence on the functioning of the fuel system at low engine loads and speeds. This denies the possibility of reducing the minimum stable engine speed and increases the irregularity of crankshaft rotation which is most objectionable in Diesel-generator sets.

The residual pressure in the high-pressure pipe of this fuel system is set only for one engine duty, usually the nominal one. While the engine is running at various duties, the residual pressure in the high-pressure pipe varies within wide limits even to a residual vacuum which cuts down the engine efficiency and power.

During unsteady-state operation of the engine such a fuel system is characterized by high residual pressures accompanied by additional fuel injection into the engine cylinders, which increases the temperature of exhaust gases, causes smoking at the exhaust and reduces the reliability and durability of the fuel injectors and the engine as a whole.

The starting of the engine with such a fuel system is characterized by inefficient injection and distribution of fuel throughout the combustion chamber which impairs starting and causes a low crankshaft speed and a low residual pressure of fuel in the high-pressure pipe at the initial stage of starting.

Changing the residual pressure in the high-pressure pipe is one of the ways towards stepping up the economy, efficiency, reliability and durability of the engine.

Known in the art is a fuel system of an internal combustion engine which stabilizes the initial pressure in the high-pressure pipe within the entire range of engine speeds and loads. Such a fuel system comprises a high-pressure fuel pump with a governing element and a dis-

charge valve. The high-pressure pump is communicated by a high-pressure pipe with a closed-type fuel injector. In order to maintain a high initial pressure in the high-pressure pipe, the latter is connected with an accumulator via a fuel distributor and a pipe. Pressure in the accumulator is built up by an auxiliary pump and is maintained constant by a reducing valve at all engine duties. The fuel distributor controls the filling of the high-pressure pipe at predetermined moments of time before the beginning of each cycle of injection.

A disadvantage of such a fuel system lies in the impossibility of controlling the initial pressure in the high-pressure pipe on changes in the engine duty.

As has been shown by experiments, maximum economy of the engine at various speeds and loads will be reached if the above-mentioned initial pressure changes simultaneously with the changes in the speed of the engine crankshaft and in the position of the governing element of the high-pressure pump. To achieve a higher engine power both under steady- and unsteady-state conditions, it is practicable that the initial pressure in the high-pressure pipe should be increased above the limit which ensures a high engine economy.

During engine starting such a fuel system fails to create an initial pressure in the high-pressure pipe which would be higher than that ensured for all the engine duties; it means that this fuel system is not suitable for increasing greatly the reliability of engine starting.

An object of the present invention is to raise the engine economy.

Another object of the invention is to increase engine power.

Still another object of the invention is to increase the reliability and extend the service life of the fuel system and the engine as a whole under the conditions of maximum economy.

One more object of the invention is to improve engine economy and power under unsteady-state operating conditions.

And still another object of the invention is to increase the reliability of engine starting. The last object of the invention is to reduce the minimum stable speed of the engine crankshaft.

In accordance with these and other objects we hereby provide a fuel system of internal combustion engine comprising a high-pressure pump with a governing element and a discharge valve, connected with a closed-pipe fuel injectors by a high-pressure pipe in which a high initial pressure is maintained by connecting it via a fuel distributor and a pipe with an accumulator where a high pressure is built up by an auxiliary pump wherein, according to the invention, there is a controllable reducing valve connected with the accumulator for maintaining in it a required high pressure.

This fuel system builds up and maintains automatically a high initial pressure in the high-pressure pipe located between the discharge valve and the fuel injector. This raises the economy, reliability and durability of the engine by increasing the operational stability of the fuel system, improving the automatization of fuel and its distribution over the combustion chamber of the engine.

It is practicable that the controllable reducing valve should consist of a body with fuel inlet and outlet channels, said body accommodating a rotatable bushing

whose outlet hole is aligned with a fuel outlet channel in the body, said bushing being provided with a turning valve element loaded by a fuel pressure at one end and by a spring at the opposite end and connected by a gear rim with the rack of the high-pressure fuel pump, said bushing meshing by means of a gear rim with the rack of a governor which reacts to the changes in the rotation speed of the engine crankshaft.

The controllable reducing valve of this design controls automatically the initial pressure in the high-pressure pipe and maintains it either at a level ensuring a high engine power or at a level providing for a high engine economy; the initial pressure is controlled in accordance with two parameters, i.e., engine load and speed.

At the minimum engine speed this valve builds up and maintains automatically such an initial pressure which increases the stability of fuel supply at this speed, thus ensuring a reduction in the minimum steady engine speed.

Besides, it changes the initial pressure during unstable operation thereby improving the economy and power of the engine at this duty.

During engine starting this valve creates an initial pressure ensuring maximum reliability of starting.

In addition, such a design of the controllable reducing valve diminishes the pressure control force in the accumulator and, consequently, the force required for controlling the initial pressure in the high-pressure pipe.

It is recommended that the valve element should be made in the form of a cylindrical slide valve with a shaped edge facing the fuel inlet channel in the body.

Such a construction of the cylindrical slide valve increases the accuracy of adjusting pressure in the accumulator and, consequently, the initial pressure in the high-pressure pipe, and widens the field of application of the controllable reducing valve in the engines designed for various purposes because changes in the outline of the shaped edge of the slide valve bring about corresponding changes in the control of the initial pressure.

It is preferable that the fuel inlet channel in the body of the controllable reducing valve should accommodate an immovable bushing entering the rotatable bushing and forming, together with the latter, a precision pair.

Owing to this method of sealing the rotatable bushing is relieved of the axial component of the fuel pressure. This improves the accuracy of controlling the initial pressure in the high-pressure pipe and reduces the irregularity of governing the crankshaft speed.

The fuel system according to the invention, employed in a four-stroke six-cylinder supercharged Diesel with an open combustion chamber, a nominal speed of 1,500 rpm, a minimum steady speed of 500 rpm, a nominal power of 250 hp, a maximum torque of 130 kgm at 1,200 rpm, a specific fuel consumption of 168 g/BHP-hr at a nominal speed and 220 g/BHP-hr at a minimum speed reduces the minimum steady speed of the engine to 250 rpm, the specific fuel consumption at the nominal speed to 162 g/BHP-hr and at the minimum speed to 207 g/BHP-hr, increases the maximum torque to 144 kgm at 1,100 rpm, ensures a constant power within the engine speed range from 1100 to 1500 rpm and reduces the acceleration time of the Die-

sel with electric generator 1.6 – 1.8 times depending on the load.

Other objects and advantages of the invention will become apparent from the detailed description that follows and from the accompanying drawings, in which:

FIG. 1 is a diagrammatic view of a fuel system of an internal combustion engine, according to the invention;

FIG. 2 is a longitudinal section of the controllable reducing valve in the closed position.

The fuel system of a Diesel engine 1 (FIG. 1) comprises a high-pressure fuel pump 2 driven by a cam 4 of a camshaft 3 and an auxiliary pump 5 driven by a cam 6 of the camshaft 3. The high-pressure fuel pump 2 has a discharge valve 7 with a sealing seat 8 and a suction collar 9. The pump 2 is connected by a high-pressure pipe 10 with a closed-type fuel injector 11 installed on the Diesel 1. The auxiliary pump 5 has a discharge valve 12 and a plunger 13 and is connected by a pipe 14 with an accumulator 15. The pumps 2 and 5 are connected by a pipe 16 with a pump 17 which tops up a tank 18 to compensate for the fuel used up by the pumps 2 and 5. The fuel pressure in the accumulator 15 is controlled by a reducing valve 19 (FIG. 2) which receives fuel from the accumulator 15 through a pipe 20 and from which the fuel is discharged through a pipe 21 into the tank 18. The accumulator 15 is connected by a pipe 22 with a fuel distributor which is made in the form of a groove 23 on a plunger 24 of the pump 2, and of inlet 25 and outlet 26 holes in a bushing 27. A channel 28 communicates the pipe 22 with the inlet hole 25. The outlet hole 26 is connected with the high-pressure pipe 10 through the channel 29.

The controllable reducing valve 19 is connected by a rack 30 with a governor 31 while a rack 32 connects it with the rack 33 of the high-pressure fuel pump 2.

The controllable reducing valve 19 (FIG. 2) comprises a body 34 with fuel inlet and outlet channels 35 and 36. Inside the body 34 there is a rotatable bushing 37 with an outlet hole 38. The hole 38 is in communication with the channel 36. The rotatable bushing 37 accommodates a valve element in the form of a cylindrical slide valve 39 which forms a precision pair with said bushing. The slide valve 39 has a shaped edge 40 facing the fuel inlet channel 35 and is subjected to fuel pressure at one end while at the other end it is loaded, via a sleeve 41, by a spring 42 resting on an adjustable nut 43, the latter being used for pretensioning the spring 42. The fuel inlet channel 35 accommodates an immovable bushing 44 which enters the rotatable bushing 37, forming a precision pair with the latter.

A pin 45 of the slide valve 39 enters the axial slots 46 of a rotatable gear 47 whose teeth are in mesh with the teeth of the rack 32 (FIG. 1) which, in turn, meshes with the rack 33 of the high-pressure fuel pump 2. The upper part of the rotatable bushing 37 (FIG. 2) is provided with a gear rim 48 whose teeth mesh with the teeth of the rack 30 (FIG. 1) of the governor 31 which reacts to the changes in the rotation speed of the Diesel engine 1.

The fuel system of the Diesel engine functions as follows.

Engine starting.

When the crankshaft of the Diesel 1 (FIG. 1) is rotated at starting, the rack 33 of the high-pressure fuel pump 2 occupies the extreme right position which corresponds to zero fuel delivery to the combustion cham-

ber (not shown in the drawing) of the Diesel 1. During this period the fuel is delivered from the tank 18 by the pump 17 through the pipe 16 into the spaces above the plungers of the high-pressure pump 2 and auxiliary pump 5.

The camshaft 3 driven by the crankshaft (not shown in the drawing) of the Diesel 1 operates the plunger 13 of the pump 5 by its cam 6 while its cam 4 actuates the plunger 24 of the pump 2. The plunger 13 goes up, delivering fuel through the valve 12 and pipe 14 into the accumulator 15. From the accumulator 15 the fuel flows through the pipe 22 into the channel 28 of the high-pressure pump 2 and enters the controllable reducing valve 19 through the pipe 20.

In the valve 19 the fuel enters the channel 35 (FIG. 2) of the immovable bushing 44 and the space of the rotatable bushing 37 above the end of the slide valve 39 and its shaped edge 40. When the axial force of the fuel pressure applied to the end of the slide valve 39 exceeds the force applied by the spring 42 to the slide valve 39 via the sleeve 41, the slide valve 39 starts moving down. The beginning of the downward movement of the slide valve 39 under the effect of the fuel pressure applied to its end depends on the degree of pretensioning of the spring 42. The shaped edge 40 of the slide valve opens the hole 38 in the rotatable bushing 37 through which the fuel is returned into the tank 18 (FIG. 1) through the channel 36 (FIG. 2) and pipe 21 (FIG. 1). The pressure at which the shaped edge 40 of the slide valve 39 starts opening the hole 38 (FIG. 2) depends on the length of the generatrix between the shaped edge 40 of the slide valve 39 and the hole 38 and on the characteristic of the spring 42. It means that the stiffer the spring and the longer the generatrix between the shaped edge 40 and the hole 38, the higher pressure will have to be applied to the end of the slide valve to start the discharge of fuel from the accumulator 15 (FIG. 1).

As a result of the fuel discharge, pressure in the accumulator 15 drops, the axial force of the pressure on the end of the slide valve 39 (FIG. 2) is reduced too. Then the force of the spring 42 will exceed the force of the fuel pressure applied to the end of the slide valve 39, the latter will go upward and close the hole 38 in the rotatable bushing 37.

Thus, a required fuel pressure will be reached in the accumulator 15 (FIG. 1).

After the plunger 24 has come to the downmost position, the fuel at the predetermined pressure will flow from the accumulator 15 through the pipe 22 and channels 28 and 29 into the high-pressure pipe 10 via the holes 25 and 26 in the bushing 27 and via the groove 23 on the plunger 24.

Hence, the predetermined initial pressure will be ensured in the high-pressure pipe 10. The system is prepared for engine starting.

The rack 33 of the high-pressure pump 2 moves along arrow A (FIGS. 1, 2) to a position corresponding to the starting supply of fuel to the combustion chamber of the Diesel 1. The cam 4 of the rotating camshaft 3 raises the plunger 24. The fuel flows under pressure from the space above the plunger through the discharge valve 7 and the high-pressure pipe 10 into the fuel injector 11 which injects fuel into the combustion chamber of the Diesel 1. At the end of injection the discharge valve 7 closes and its suction collar 9 relieves pressure in the pipe 10.

Thus, the residual pressure in the pipe 10 either becomes lower than in the known systems or even drops to a vacuum.

The plunger 24 moves down. As soon as it comes to the downmost position, a new cycle of preparing the fuel system for injection is started by building up a high initial pressure in the high-pressure pipe 10.

Changes in engine operating duty.

If the engine load increases, the rack 33 of the high-pressure fuel pump 2 moves along arrow A thus increasing the amount of fuel supplied into the Diesel 1 while the rack 32 of the controllable reducing valve 19 (connected with the rack 33) turns the gear 47 (FIG. 2). The gear 47 turns the slide valve 39 along arrow B with the aid of the slots 46 and the pin 45.

The length of the generatrix of the cylindrical slide valve from the edge 40 to the hole 38 changes in accordance with the outline of the shaped edge 40 of the slide valve 39. Hence, the travel of the slide valve 39 to the moment of opening of the hole 38 by the shaped edge 40 is increased in accordance with the outline of said shaped edge 40.

In accordance with the characteristic of the spring 42 there will be an increase in the fuel pressure applied to the end of the slide valve 39 at which the hole 38 in the rotatable bushing 37 will open and discharge the fuel from the accumulator 15 (connected by the pipe 20 with the valve 19) into the tank 18 (FIG. 1) through the channel 36 (FIG. 2) and the pipe 21 (FIG. 1).

Thus, the fuel pressure in the accumulator 15 will become higher than it was before the change in the engine load while the pressure in the high-pressure pipe 10 will settle at a new normal level.

If, for example, the speed of the Diesel 1 is increased, the governor 31 will move the rack 30 along arrow C (FIG. 2). The rack 30 (FIG. 1) will turn the bushing 37 via the gear rim 48 (FIG. 2) of the rotatable bushing 37 against the direction of arrow B. The hole 38 in the rotatable bushing 37 will be displaced relative to the slide valve 39 so that the length of the generatrix of the cylindrical slide valve 39 from the shaped edge 40 to the hole 38 will be increased and so will be the length of travel of the slide valve 39 to the moment when the shaped edge 40 opens the hole 38. In accordance with the characteristic of the spring 42 there will be an increase in the fuel pressure applied to the end of the slide valve 39 at which the hole 38 in the rotatable bushing 37 will open and discharge the fuel from the accumulator 15 (FIG. 1) connected by the pipe 20 with the valve 19 into the tank 18 through the channel 36 (FIG. 2) and the pipe 21 (FIG. 1).

Thus, the pressure in the accumulator 15 will settle at a higher level than it was before the increase in the engine speed while the pressure in the high-pressure pipe 10 will come to a new predetermined initial value.

The fuel system of the Diesel engine according to the invention employs a manual drive connected to the rack 30 (FIG. 1) by any commonly known method.

In this version of the system the governor 31 is omitted. This design of the system provides for a higher engine power at various steady and unsteady operational duties, at the same time retaining the setting of the controllable reducing valve for obtaining maximum engine economy under various loads.

In this case the functioning of the fuel system is similar to that described above at changes in the engine crankshaft speed.

Another version of the fuel system with a manual drive incorporates its connection by any known method to the rack 32 (FIG. 1) of the controllable reducing valve 19.

In this case the rack 33 of the high-pressure fuel pump 2 is disconnected from the rack 32. This version of the fuel system retains the economy of the engine at changes in its speed while higher power of the engine at changes in its load is obtained by a manual control lever actuating the controllable reducing valve 19.

The functioning of the fuel system in this case is similar to that described above at changes in the engine load.

The fuel system of an internal combustion engine according to the invention increases the economy and power of the engine under various steady and unsteady operating conditions, reduces the minimum stable crankshaft speed, improves the reliability and promptness of starting and ensures a constant power characteristic within the speed range from the rated to two-thirds rated value.

What is claimed is:

1. A fuel system of an internal combustion engine comprising, in combination, a high-pressure fuel pump; an accumulator; an auxiliary pump communicating with said accumulator for building up pressure within said accumulator; a controllable reducing valve communicating with said accumulator and maintaining a pre-determined high pressure in said accumulator; a closed-type fuel injector; a high-pressure pipe connecting said closed-type fuel injector with said high-pressure fuel pump; a fuel distributor; a fuel pipe connecting said accumulator with said high-pressure pipe

through said fuel distributor for maintaining a substantially high initial pressure in said high-pressure pipe.

2. A fuel system of an internal combustion engine comprising, in combination, a high-pressure fuel pump with governor; an accumulator; an auxiliary pump communicating with said accumulator for building up pressure within said accumulator; a controllable reducing valve communicating with said accumulator and maintaining a pre-determined high pressure in said accumulator; a closed-type fuel injector; a high-pressure pipe connecting said closed-type fuel injector with said high-pressure fuel pump; a fuel distributor; a fuel pipe connecting said accumulator with said high-pressure pipe through said fuel distributor for maintaining a substantially high initial pressure in said high-pressure pipe, said controllable reducing valve comprising a body with fuel inlet and outlet channels, said body having a rotatable bushing with outlet hole aligned with the fuel outlet channel of said body, said bushing having a rotating valve element loaded by fuel pressure at one end, a spring for loading the other end of said valve element, a gear rack on said fuel pump, a first rim gear connecting said valve element with said gear rack, a gear rack on said governor, and a second rim gear connecting said bushing to said rack on said governor, said governor reacting to changes in the engine speed.

3. A fuel system of an internal combustion engine according to claim 2, wherein said rotating valve element comprises a cylindrical slide valve with a shaped edge facing said fuel inlet channel in said body.

4. A fuel system of an internal combustion engine according to claim 2, wherein said fuel inlet channel of said body has an immovable bushing entering said rotatable bushing.

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