

July 16, 1968

T. C. SCHULTZ  
FUEL REGULATING DEVICE

3,392,630

Filed Sept. 22, 1966

2 Sheets-Sheet 1

FIG. 2

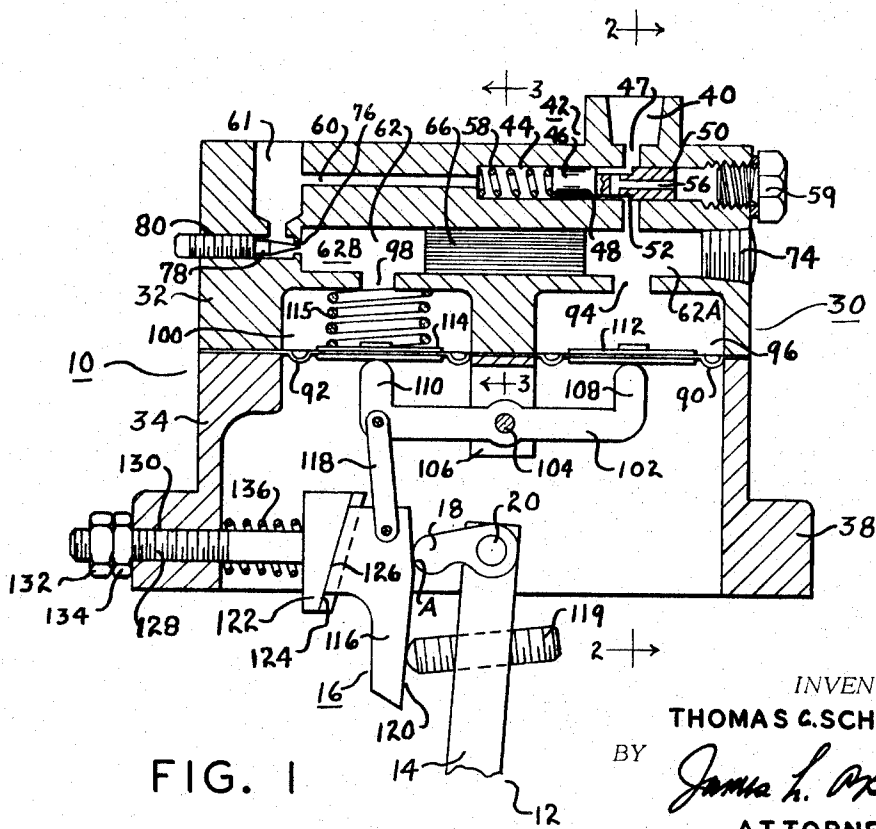
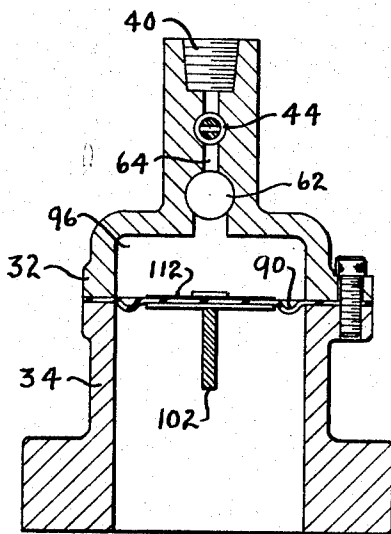


FIG. 1

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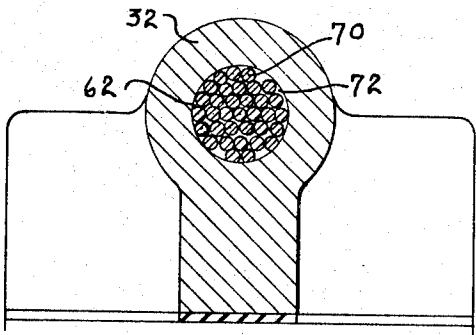


FIG. 3

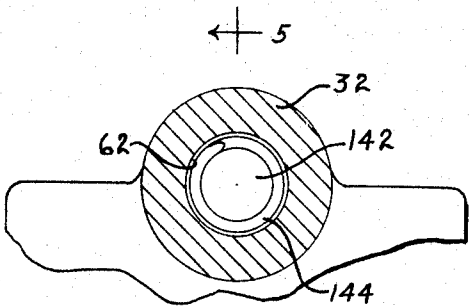


FIG. 4

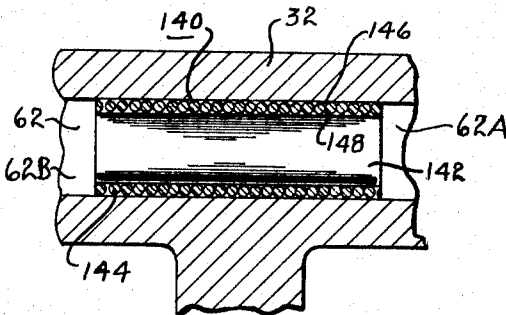


FIG. 5

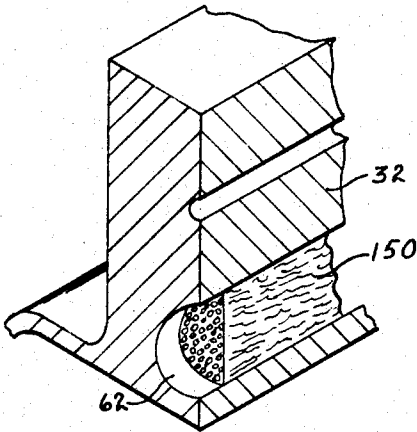


FIG. 6

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3,392,630

## FUEL REGULATING DEVICE

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9 Claims. (Cl. 91-52)

### ABSTRACT OF THE DISCLOSURE

A density and viscosity compensating device for multi-fuel internal combustion engines having a laminar flow restriction in series with a turbulent flow restriction in combination with a first diaphragm responsive to the pressure between the restrictions and a second diaphragm responsive to a substantially constant inlet pressure. The device is constructed such that one side of each diaphragm is isolated from the fuel in the device so that a linkage may be connected to the diaphragms without the use of sliding seals.

The present invention relates to a fuel regulating device and more particularly to a fuel compensating device for use with internal combustion engines, and particularly with multi-fuel compression ignition engines.

The density and viscosity of fuels used in the operation of internal combustion engines vary over a relatively wide range from one fuel to another, and with some fuels, the density and viscosity vary appreciably with variations in temperature. Optimum performance of the engine cannot be maintained from one fuel to another having a different density and viscosity and under various temperature conditions, without adjusting the fuel flow in the metering device to compensate for the differences in density and viscosity. Units have, in the past, been incorporated in engine fuel systems for varying the stroke or limiting the delivery of fuel metering pumps, but these prior units have generally been unsatisfactory in that they were difficult to adjust to obtain the required compensation from one fuel to another, and would not maintain their setting, or were otherwise unreliable. Further, the prior units have been complicated and/or difficult to manufacture, often involving close tolerances and expensive machining operations, and have been difficult to service and maintain in proper operating condition. Since the density and viscosity properties of the fuels vary with temperature variations and these properties have a definite relationship to the heat value of each specific fuel, a control mechanism which senses density and viscosity can be used successfully to provide the proper amount of each specific fuel over a wide range of fuels and over a wide temperature range, provided the mechanism can be properly adjusted with sufficient ease and can be made to maintain the required settings in the field for extended periods of time. It is therefore one of the principal objects of the present invention to provide a mechanism for sensing the density and viscosity of a number of different fuels at any operating temperature, which can be easily adjusted and maintained to control a fuel metering system of an engine to give optimum performance, and which is relatively simple in construction and inexpensive to manufacture.

Another object of the invention is to provide a density and viscosity fuel compensator having relatively simple but accurately formed flow passages capable of producing a different pressure differential for fuels having different density and/or viscosity, and including a means for sensing the differential and responding to the differential to regulate a fuel metering system in accordance with, in effect, the heat value per unit volume of each respective fuel.

Still another object of the invention is to provide a

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fuel density compensator which can be easily fabricated with little difficulty in maintaining the required tolerances, and which can be incorporated into a number of different types of engine fuel systems without any substantial changes, and used for extended periods of time with different fuels, without servicing or adjusting.

Further objects and advantages of the invention will become apparent from the following description and accompanying drawings, wherein:

FIGURE 1 is a vertical cross sectional view of the fuel density compensating device, embodying the invention and showing the relationship of the various operating parts;

FIGURE 2 is a vertical cross sectional view of the device, the section being taken on line 2-2 of FIGURE 1; FIGURE 3 is an enlarged fragmentary cross sectional view of a portion of the device, the section being taken on line 3-3 of FIGURE 1;

FIGURE 4 is an enlarged fragmentary cross sectional view of a modified form of the invention, the section represented in FIGURE 4 being similar to that shown in FIGURE 3;

FIGURE 5 is a vertical cross sectional view of the modified form of the invention illustrated in FIGURE 4, the section being taken on line 5-5 of the latter figure; and

FIGURE 6 is an enlarged fragmentary perspective view of a further modified form of the invention.

The present invention is embodied in one form in the device illustrated in FIGURES 1 and 2, wherein numeral 10 designates the present fuel density compensating device connected to a fuel metering pump (not shown) having a linkage 12, including lever 14 connected to a speed sensitive control system. The lever is connected to the control element 16 by a cam 18 on lever 14 pivotally mounted thereon by a pin 20 at the upper end of lever 14. In this particular installation, element 16 functions as a stop to limit the maximum output of the fuel metering pump. The type of pump with which the device is frequently used is of well known construction, in which the fuel metered in the plurality of cylinders under high pressure and is discharged directly into the combustion chambers of the engine. Since the construction and operation of this type of pump are well known, and since the details thereof are not important with respect to the present invention, they will not be described in detail herein.

The fuel density compensating device illustrated in the drawings consists of a housing 30 having an upper section 32 and a lower section 34, the lower section being secured to the fuel metering pump by a plurality of bolts or studs extending through flange 38 of the device into the pump housing. The upper section 32 of the device contains a fuel inlet passage 40 connected to a fuel pressure regulator 42 having a chamber 44 in which a fuel pressure responsive piston 46 reciprocates, the chamber being connected to inlet passage 40 by passage 47. The piston 46, which functions as a regulator valve, consists of two cylindrical portions 48 and 50 connected by a reduced diameter portion 52 and at the other end to the right-hand end of chamber 44, thus communicating the fuel pressure around the reduced diameter portion 52 on one side of portion 50 to the end of chamber 44 on the opposite side of portion 50. The piston is urged to the right-hand end of chamber 44 by a coil spring 58 reacting between the end of portion 48 of the piston and the adjacent end of the chamber, the chamber being closed by a plug 59 threaded into the end of the regulator for sealing the chamber. The left-hand end of chamber 44 is connected by a passage 60 to the outlet passage 61 of the device and hence balances the system by rendering the control valve

responsive to the outlet pressure and maintaining a predetermined drop in pressure across the device. Chamber 44 and reduced diameter section 52 of the regulator valve are connected by a passage 64 to an elongated chamber 62, which contains a laminar flow element 66 dividing the chamber into inlet and outlet portions 62A and 62B, creating an appreciable pressure drop from one end of the chamber to the other.

In the embodiment of the invention illustrated in FIGURE 1, the laminar element 66 consists of a plurality of straight, wire-like members 70 pressed together in firm contact with one another to form a series of parallel passages 72, these passages forming a plurality of elongated flow restrictions, best seen in FIGURE 3. The passages are preferably substantially uniform in size throughout and are substantially the same from one passage to another. The wires forming the laminar element are held in place by a snug fit in cylindrical chamber 62; however, if preferred, they may be lightly brazed, or sintered together so that they form a unitary structure which can be inserted and removed from chamber 62 as a body. While wires would normally be used in constructing this embodiment of element 66, in place of the wires, small tubes assembled in the same manner as the wires may be used. After the element has been inserted in position in chamber 62, the open end of the chamber is closed by a threaded plug 74.

Chamber 62 is connected to the fuel metering system by a conduit connected to section 32 at outlet 61. In order to maintain an elevated pressure in section 62B of chamber 62, and regulate flow rate, a restriction or orifice 76 is placed in the outlet passage of the chamber. The effective size of this orifice is adjusted by a valve 78 threadedly received in a threaded hole 80 in the housing. While orifice 76 is shown as a variable orifice, regulated by valve 78, it may be made a predetermined fixed size if the effective capacity of the laminar structure of element 66 is properly controlled.

The drop in pressure across element 66 is sensed by a pair of diaphragms 90 and 92, the pressure on the upstream side of the element being sensed by diaphragm 90 as transmitted through opening 94 and to chamber 96, and the pressure on the downstream side of element 66 being sensed by diaphragm 92 as transmitted through opening 98 and to chamber 100. The two diaphragms form movable walls for their respective chambers and are held in a fluid-tight relationship with the housing sections 32 and 34 by having their marginal edges clamped between the two sections thereby isolating one side of the moveable walls from the fuel passing through the device 10. A lever 102 is pivoted on pin 104 in boss 106 between the two diaphragms. The opposite ends of lever 102 contact the two diaphragms by upwardly projecting extensions 108 and 110 contacting metal reinforcing plate assemblies 112 and 114 of diaphragms 90 and 92. A coil spring 115 in chamber 100 permits presetting and regulation of the diaphragms. Lever 102 is connected to an operating control element or stop plate 116 by a lever 118 pivoted at its upper end to lever 102 and at its lower end to the stop plate. The stop plate surface 120 contacts cam nose "A" or pin 119, and through lever 14, controls the operation of the fuel metering pump. The stop plate 116 is adjustable to select predetermined pump output by a member 122 having a cam surface 124 for engaging the cam surface 126 of plate 116, member 122 being adjustable forward and away from the control element by a shaft 128 extending through a bore 130 in housing section 34. Two nuts 132 and 134 are threaded onto the outer end of the shaft and a spring 136 reacting between the internal wall of housing section 34 and one side of member 122 urges shaft 128 and member 122 to the right and, together with the nuts, holds member 122 in its adjusted position.

In the operation of the present fuel density compensating devices, fuel enters through inlet passage 40 and passes through regulator 42 into chamber 62, and thence through

laminar element 66, and out through passage orifice 76 and outlet conduit 61 to the fuel metering device. The pressure on the interior side of element 66 is maintained at a constant value by the operation of piston valve 46 in regulator 42, and the pressure on the posterior side of the element in chamber 62 is maintained at a controlled elevated pressure by orifice 76 for a given fluid. The differential between the pressures on opposite sides of element 66 in sections 62A and 62B of chamber 62 is sensed by the two diaphragms 90 and 92 which move upwardly and downwardly relative to one another in response to variations in density and/or viscosity of the fuel, causing lever 102 to rock or rotate one way or the other to adjust stop plate 116 to the proper position for obtaining optimum operation of the engine, as previously explained herein.

The flow of fluid through element 66 is laminar by nature of the narrow and relatively long passages, and by controlling the rate of flow to maintain an appropriate Reynolds Number. The flow rate is controlled by the size of orifice 76, and the flow through orifice 76 is turbulent. The pressure in chambers 62B and 100 is determined in part by the restriction in element 66, and particularly passages 72, and in part by the size of the opening in orifice 76 for any given regulated pressure in chamber 62A and passage 64. To eliminate any effect from changes in back pressure in passage 61, a passage 60 communicates the pressure in outlet passage 61 with the spring side of piston 46 in chamber 44. The net result of any change in the back pressure will result in no change in the pressure drop across the entire system and therefore the operative forces will not be effected. Once the device has been calibrated and placed in operation, further adjustment of valve 78 in orifice 76 is normally not necessary. The equations which depict the flow under the foregoing conditions, are as follows:

$$Q_L = K_1 \frac{\Delta P_L}{\text{Viscosity}} \quad \text{for laminar flow}$$

$$Q_T = K_2 \sqrt{\frac{\Delta P_T}{\text{Density}}} \quad \text{for turbulent flow}$$

where  $\Delta P_L$  is the pressure drop across the laminar flow element 66 and  $\Delta P_T$  is the pressure drop across the outlet orifice 76. Both  $Q_L$  and  $Q_T$  are volumetric flow rate. The constants  $K_1$  and  $K_2$  represent such things as physical dimensions and flow coefficients which normally do not change in any one unit.

Since this device involves steady state flow conditions where  $Q_L = Q_T$ , and  $\Delta P_L + \Delta P_T = \Delta P$ , where  $\Delta P$  is the total pressure drop across the unit, a relationship can be shown where  $\Delta P_L$  is proportional to the viscosity and the density of the fluid flowing through the device. The relationship is as follows:

$$\Delta P_L = \frac{-1 + \sqrt{1 + \Delta P G \gamma}}{2 G \gamma / V^2}$$

where, as discussed above,  $G$  is the lumped product of all constants,  $\gamma$  is the specific gravity of the fluid and  $V$  is the kinematic viscosity of the fluid.

Further, since the pressure in chamber 62A is held constant by regulator 42, the pressure sensed by diaphragm 92 is proportional to  $P$  and hence the device responds to the viscosity and density of the particular fluid passing through the device at any given moment.

FIGURES 4 and 5 illustrate a modified form of the present laminar flow element, like parts being given like numerals for the same parts shown in the previously described embodiment. Numeral 140 designates the laminar flow element consisting of a cylindrical core 142, preferably of metal, and a wire 144 helically wound on cylindrical core 142. The wire is tightly wound on the core and the total diameter of element 140 is substantially the same as the diameter of cylindrical chamber 62, the

element 140 providing two laminar flow passages indicated by numerals 146 and 148 on the external and internal sides of the helically wound wire, respectively. The two passages are closed by the wall of chamber 62 and by the external surface of core 142 to form well defined, constant size, helical passages extending the full length of the core. The present compensating device otherwise functions the same as that described in FIGURES 1, 2 and 3.

A further modified form of the invention is illustrated in FIGURE 6 in which only the laminar element has been changed from the structure of the previously described embodiments. The laminar element 150 consists of sintered metal in which there are numerous interconnecting small pores forming laminar passages extending from one end of the element to the other. The function of the element of FIGURE 6 and the operation of the device used in conjunction with it are the same as those corresponding parts in the embodiment of FIGURES 1, 2 and 3.

While three embodiments of the present invention have been described herein, further changes and modifications may be made without departing from the scope of the invention.

I claim:

1. A device responsive to density and viscosity of fuels for regulating a fuel metering means of an internal combustion engine, comprising a body with an inlet passage and an outlet passage, a pressure regulating means connected to said inlet passage for maintaining a predetermined fuel pressure in said inlet passage, a fluid flow restriction element for laminar flow therethrough and a restriction for turbulent flow therethrough connected in series between said inlet passage and said outlet passages, means responsive to the pressure between said restrictions including a first movable wall having one side isolated from said fuel, means responsive to a pressure proportional to said predetermined fuel pressure including a second moveable wall having one side isolated from said fuel, lever means operately interconnecting said one side of said moveable walls for responding to differential pressure across said moveable walls, and means connected to said lever means for regulating the fuel delivered to an engine.

2. A fuel regulating device as defined in claim 1, in

which said fluid flow element consists of numerous relatively small passages forming a laminar structure.

3. A fuel regulating device as defined in claim 1, in which said fluid flow element consists of a bundle of straight, round, wire-like members in contact with one another.

4. A fuel regulating device as defined in claim 1, in which the means connected to said lever means for regulating the fuel delivery to the engine consists of a number having a cam surface and a lever connecting said cam to the lever means interconnecting the two movable walls.

5. A fuel regulating device as defined in claim 1, in which the restriction includes a valve for varying the effective area thereof.

6. A fuel regulating device as defined in claim 1, in which the flow element consists of a cylindrical core and a wire helically wound on the surface thereof.

7. A fuel regulating device as defined in claim 1, in which said pressure regulating means senses the pressure in said outlet passage for maintaining a predetermined pressure drop across the fluid system embodied in the device.

8. A fuel regulating device as defined in claim 1, in which said fluid flow element consists of a bundle of small tubes defining passages through said element.

9. A fuel regulating device as defined in claim 1, in which said fluid flow element consists of sintered metal having numerous interconnecting pores forming laminar flow passages.

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