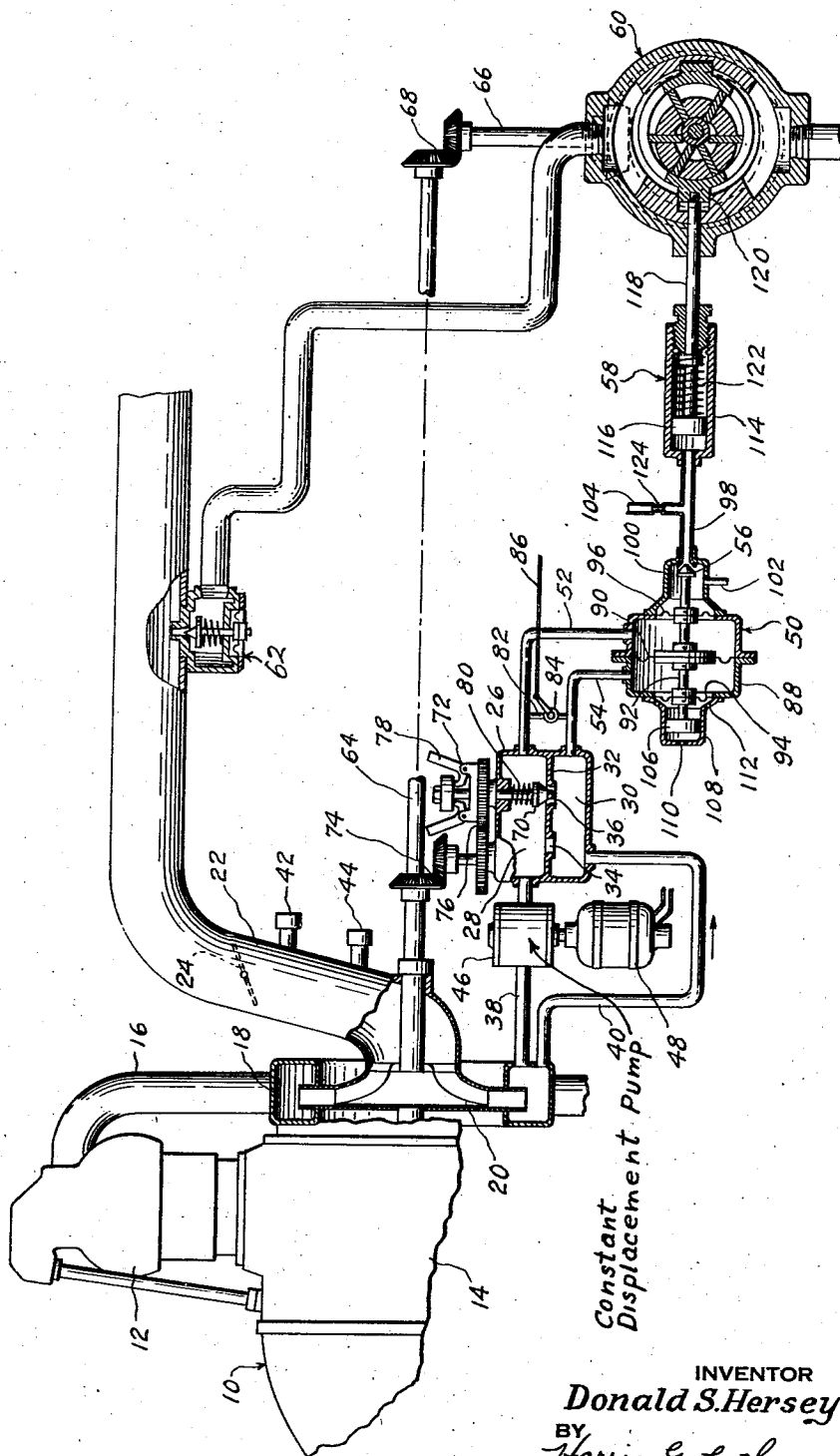


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AUTOMATIC FUEL CONTROL

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Constant Displacement Pump

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AUTOMATIC FUEL CONTROL

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This invention relates to improvements in fuel supplying and fuel regulating apparatus for an internal-combustion engine and has particular reference to such an apparatus for supplying to such an engine a quantity of fuel metered in proportion to the mass quantity of air flowing through the engine air intake per unit of time.

An object of the invention resides in the provision of improved and simplified mechanism for determining the mass rate flow of engine intake air and adjusting the engine fuel supply means in accordance with variations in the mass rate flow of intake air as determined.

A still further object resides in the provision of an improved apparatus for continuously sampling the air in the engine intake system between the engine throttle and the engine cylinders and determining the density of such intake air and applying to such density determination a correction factor to compensate for variation in the volumetric efficiency of the engine at different engine speeds, and in the provision of engine fuel supply means responsive to the speed of the engine and the compensated density determinations of said density determining device for supplying to said engine a quantity of fuel metered in proportion to the mass rate flow of engine intake air.

Other objects and advantages will be more particularly pointed out hereinafter or will become apparent as the description proceeds.

In the accompanying drawing, in which like reference numerals are used to designate similar parts throughout, there is illustrated a suitable mechanical embodiment for the purpose of disclosing the invention. The drawing, however, is for the purpose of illustration only and is not to be taken as limiting or restricting the invention, since it will be apparent to those skilled in the art that various changes in the illustrated embodiment may be resorted to without in any way exceeding the scope of the invention.

In the drawing, the single figure is a diagrammatic illustration of an engine fuel supplying and metering apparatus constructed according to the invention, certain parts being shown in section to better illustrate the construction thereof.

Referring to the drawing in detail, the numeral 10 generally indicates an internal-combustion engine having one or more cylinders as indicated at 12 mounted upon a crankcase 14 and supplied with combustible mixture through an individual intake pipe 16 leading from a supercharger diffuser chamber 18 into which intake air or combustible mixture is forced by a supercharger impeller 20 from an air intake conduit 22 provided with a throttle 24.

While a particular arrangement of engine

parts have been illustrated for the purpose of disclosing the invention, it is to be understood that the invention is in no way limited to the particular type of engine so illustrated and hereinabove described but that the improved fuel metering apparatus may be applied to various forms of internal-combustion engines.

Adjacent to the engine air intake there is provided a casing 26 enclosing two chambers 28 and 30 separated by a partition 32 through which extend two apertures or orifices 34 and 36. The chamber 28 is connected to some portion of the engine intake system between the throttle and the engine cylinders, such as the diffuser chamber 18, by a conduit 38 and the chamber 30 is connected to the engine air intake system through the conduit 40.

While the conduits 38 and 40 are shown connected with the diffuser chamber 18 they may, if desired, be connected with some other part of the intake system, such as the air intake duct 22 as indicated by the blanked off connections 42 and 44.

Intake air is forced through the casing 26 from one of the ducts 38 or 40, to the other, by suitable means such as the positive displacement fluid pump 46 driven by the constant-speed electric motor 48.

With this arrangement, the pump 46 will force a constant volumetric quantity of air through the casing 26 and through the orifice apertures 34 and 36. With aperture 36 closed the pressure drop across aperture 34 from one of the chambers 28 or 30 to the other chamber will constitute at all times a direct measurement of the density of the air in the engine intake system at the point where ducts 38 and 40 connect to the system.

The pressure drop between the chambers 28 and 30 is applied to a pneumatic device, generally indicated at 50, through the conduits 52 and 54 and this pneumatic device operates a valve 56 which controls a servo-motor, generally indicated at 58, which in turn regulates the stroke or capacity of a fuel pump, generally indicated at 60, which supplies fuel to an engine fuel injection device such as the injection nozzle, generally indicated at 62, of some form well known to the art, which nozzle may be inserted in chamber 22.

The pump 60 is driven in some definite proportion to engine speed by suitable means such as the drive shafts 64 and 66 and the gear connection 68.

If engine volumetric efficiency remained a fixed value under all operating conditions this arrangement would provide a substantially constant air-fuel ratio for the engine over the entire operating range. Further compensation, however, has been

found to be necessary for the reason that, volumetric efficiency of the engine changes due to variations in engine speed, therefore, the product of intake air density, engine displacement and engine speed is not necessarily an adequate measurement of the mass flow rate of engine intake air, as engine volumetric efficiency is an added factor variably affecting the mass flow rate. Also it is found desirable to change the fuel mixture ratio at both ends of the engine speed range to provide a somewhat richer mixture for cooling the engine to some extent and preventing detonation at the high speed end of the range, and for insuring proper ignition of the fuel mixture at the low speed end of the engine speed range.

Compensation for the change in volumetric efficiency and in the fuel mixture at the upper end of the engine speed range is accomplished by the provision of the second orifice 36, the area of which is controlled by a tapered plug 70 actuated by a governor 72 driven from the engine by suitable means, such as the shaft 64 and the gear connections 74 and 76. The governor 72 may be a conventional type of centrifugal governor having centrifugal weights 78 acting against the force of a compression spring 80.

The operation of this compensating mechanism is to increase the area of the orifice 36 at the upper end of the engine speed range. This permits a freer flow of air between the chambers 28 and 30 with a consequent drop in the pressure differential between these chambers. This drop in pressure differential has the same effect on the fuel regulating mechanism as would be accomplished by a decrease in specific density of the engine intake air and will result in a decrease in the amount of fuel supplied to the engine to compensate for the somewhat smaller weight flow of intake air to the engine, occasioned by the above mentioned decrease in volumetric efficiency at the upper end of the engine speed range. The shape of the plug 70 also may be so designed, that the decrease in amount of fuel supplied will not be as much as would be necessary to completely compensate for the decrease in volumetric efficiency so that a somewhat richer fuel mixture will be supplied to the engine at the upper end of the speed range thus providing an economizer action which will protect the engine at high speeds but will not result in excessive use of fuel in the intermediate portion of the engine speed range. The shape of plug 70 may also be such as to provide a richer mixture at low engine speeds for insuring proper ignition, as stated above.

A manually operated mixture control may be supplied by providing a bleed line 82 connected between the conduits 52 and 54 and a valve 84 in the bleed line controlled by suitable means such as the link 86 which may be connected to an independent manual control.

The pneumatic device 50 and the servo-motor 58 may be of some form already known to the art or may be specially designed for this particular application and are not necessarily restricted to the particular arrangement illustrated in the accompanying drawing. In the illustrated arrangement, however, the pneumatic device comprises a hollow casing 88 divided into two substantially equal chambers by a flexible transverse partition or diaphragm 90 secured at its center to the intermediate portion of a valve shaft 92. At each end of the casing the valve shaft 92 is sealed to the casing by respective flexible diaphragms 94 and 96 and at one end this shaft carries the valve member 56 which cooperates

with a valve seat provided at the end of a pressure fluid conduit 98. The valve is contained in a casing 100 from which a drain line 102 leads to a suitable sump or reservoir from which the fluid may be drawn by a pressure creating device, such as the engine lubricating oil pump, and returned through a pressure conduit 104 to the tube 98. At its end opposite the valve 56 the shaft 92 may be connected with a dash-pot comprising a piston 106 reciprocable in a closed cylinder 108 provided with restricted openings, as indicated at 110 and 112 respectively at opposite sides of the piston. The purpose of this dash-pot is to control the rate of change of the capacity of the pump 60 under conditions of rapid opening and closing of the engine throttle.

The servo-motor 58 is connected to the end of the tube 98 opposite the valve 56 and comprises a cylinder 114 connected at one end with the tube 98 and containing a piston 116 connected through a piston rod 118 with the displacement adjusting element 120 of the variable displacement fuel pump 60. A coiled compression spring 122 urges the piston 116 in a pump capacity decreasing direction opposed by the pressure fluid in the tube 98. A fixed restriction 124 is provided in the pressure line 104 so that the valve 56 may accurately control the fluid pressure in the tube 98 by adjusting the opening at the valve end of the tube.

When the bleed valve 84 is opened the bleed between the conduits 52 and 54 has the effect of reducing the pressure differential between the chambers 28 and 30 as determined by the fluid flow created by the pump 46 and on the opposite sides of the diaphragm 90. This decrease in the effective pressure differential will permit the action of the spring 122 to decrease the output capacity of the pump 60 and will result in a decreased quantity of fuel being supplied to the engine intake air to somewhat lean the fuel mixture.

With the above described apparatus the fuel supplied to the engine will be accurately metered in proportion to the mass flow rate of the engine intake air and in addition compensation will be made at the opposite ends of the engine speed range to somewhat enrich the mixture for improved operation and protection of the engine without permitting the mixture to become excessively rich at the upper end of the speed range because of the change in volumetric efficiency of the engine at this end of the range.

While a suitable mechanical embodiment has been hereinabove described and illustrated in the accompanying drawing for the purpose of disclosing the invention, it is to be understood that the invention is not limited to the particular embodiment so illustrated and described, but that such changes in the size, shape and arrangements of the various parts may be resorted to as come within the scope of the sub-joined claims.

Reference is made to my copending applications Serial Nos. 311,153 (filed December 27, 1939), 370,160 (filed December 14, 1940), 334,393 (filed May 10, 1940), and 417,266 (filed October 31, 1941), which show and claim subject matter shown but not claimed in the application.

Having now described the invention so that others skilled in the art may clearly understand the same, what it is desired to secure by Letters Patent is as follows:

1. A charge forming device for an internal-combustion engine having an air intake system and a fuel supply means driven at a fixed ratio to engine speed and having a controllable dis-

placement per operating cycle comprising, a fluid conduit connected at both ends with said air intake system, a pump in said conduit having a constant volumetric displacement per operating cycle, constant speed means for driving said pump, a restriction in said conduit, and means pneumatically connected with said conduit at opposite sides of said restriction and operated by variations in the pressure differential across said restriction to vary the displacement of said fuel supply means.

2. A charge forming device for an internal-combustion engine having an air intake system and a fuel supply means driven at a fixed ratio to engine speed and having a controllable displacement per operating cycle comprising, a fluid conduit connected at both ends with said air intake system, a pump in said conduit having a constant volumetric displacement per operating cycle, constant speed means for driving said pump, a restriction in said conduit, and means pneumatically connected with said conduit at opposite sides of said restriction and operated by variations in the pressure differential across said restriction to vary the displacement of said fuel supply means and speed responsive means for varying said restriction to compensate the variations in the pressure differential across said restriction for variations in the relation of the volumetric efficiency of said engine to engine speed.

3. A charge forming device for an internal-combustion engine having an air intake system and a fuel supply means driven at a fixed ratio to engine speed and having a controllable displacement per operating cycle comprising, a fluid conduit connected at both ends with said intake system, a pump having a constant displacement per operating cycle in said conduit for forcing a stream of sample intake air therethrough, constant speed means for driving said pump, a restriction in said conduit comprising a constant area orifice and a variable area orifice, means responsive to engine speed regulating the area of said variable area orifice to compensate the air pressure drop across said restriction for change in engine volumetric efficiency with a change in engine speed, and means connected with said conduit at opposite sides of said restriction and actuated by variations in the air pressure drop across said restriction to vary the displacement of said fuel supply means.

4. Apparatus for adding to a stream of gas a quantity of liquid sufficient to create a mixture in which the weight of liquid in a unit volume of gas bears a definite predetermined ratio to the weight of gas in said unit volume comprising, a variable displacement pump arranged to discharge into said stream for adding said liquid to said gas and operated at a speed proportional to the volumetric flow rate of said gas, means for continuously sampling said gas, said gas sampling device comprising a conduit having its inlet end in contact with said stream of gas, a pump in said conduit having a constant displacement per operating cycle, constant speed means for driving said pump, and a restriction in said conduit, said pump establishing across said restriction a pressure differential proportional to the density of said gas, and means actuated by variations in said gas pressure differential for varying the displacement of said liquid pump.

5. Apparatus for adding to a stream of gas a quantity of liquid sufficient to create a mixture in which the weight of liquid in a unit volume of gas bears a definite predetermined ratio to the

weight of gas in said unit volume comprising, a variable displacement pump arranged to discharge into said stream for adding said liquid to a gas and driven at said speed proportional to the volumetric flow rate of said gas, means for continuously sampling said gas and establishing across a restriction a pressure differential proportional to the density of said gas, and means actuated by variations in said gas pressure differential for varying the displacement of said liquid pump in accordance with variations in said gas pressure differential, said gas sampling device comprising a casing, a partition dividing said casing into two chambers, means connecting each of said chambers with said stream of gas, a pump having a constant displacement for each operating cycle disposed in one of said connecting means, constant speed means driving said pump, and a constant area orifice in the partition between said chambers.

6. Apparatus for adding to a stream of gas a quantity of liquid sufficient to create a mixture in which the weight of liquid in a unit volume of gas bears a definite predetermined ratio to the weight of gas in said unit volume comprising, a variable displacement pump driven at a speed proportional to the volumetric flow rate of said gas arranged to discharge into said stream for adding said liquid to said gas, means for continuously sampling said gas and establishing across a restriction a pressure differential proportional to the density of said gas, and means actuated by variations in said gas pressure differential for varying the displacement of said liquid pump in accordance with variations in said gas pressure differential, said gas sampling device comprising a casing, a partition dividing said casing into two chambers, means connecting each of said chambers with said stream of gas, a pump having a constant displacement for each operating cycle disposed in one of said connecting means, constant speed means driving said pump, and a constant area orifice and a variable area orifice in the partition between said chambers.

7. Apparatus for adding to a stream of gas a quantity of liquid sufficient to create a mixture in which the weight of liquid in a unit volume of gas bears a definite predetermined ratio to the weight of gas in said unit volume comprising, a variable displacement pump driven at a speed proportional to the volumetric flow rate of said gas arranged to discharge into said stream for adding said liquid to said gas, means for continuously sampling said gas and establishing across a restriction a pressure differential proportional to the density of said gas, and means actuated by variations in said gas pressure differential for varying the displacement of said liquid pump in accordance with variations in said gas pressure differential, said gas sampling device comprising a conduit, a restriction in said conduit, a pump having a constant displacement for each operating cycle disposed in said conduit producing said pressure differential across said restriction, constant speed means driving said pump, and a constant area orifice and a variable area orifice constituting said restriction, and speed responsive means for varying the area of said variable area orifice.

8. Apparatus for adding to a stream of gas a quantity of liquid sufficient to create a mixture in which the weight of liquid in a unit volume of gas bears a definite predetermined ratio to the weight of gas in said unit volume comprising, a variable displacement liquid pump driven at a

speed substantially proportional to the volumetric flow rate of said gas and arranged to discharge into said gas, means for continuously sampling said gas and establishing across a restriction a pressure differential proportional to the density of said gas, and means actuated by variations in said gas pressure differential for varying the displacement of said liquid pump in accordance with variations in said gas pressure differential, said liquid pump displacement varying means comprising, a hydraulic motor operatively connected with the displacement varying element of said pump, a valve for controlling said hydraulic motor and a pneumatic motor operatively connected with said valve and pneumatically connected with said gas sampling device at opposite sides of said restriction.

9. Apparatus for adding to a stream of gas a quantity of liquid sufficient to create a mixture in which the weight of liquid in a unit volume of gas bears a definite predetermined ratio to the weight of gas in said unit volume comprising, a duct for said gas, a constant speed constant displacement pump pneumatically connected with said duct for continuously withdrawing a sample quantity of gas therefrom, a restriction in the connection between said pump and said duct for establishing in said connection a pressure differential proportional to the density of the gas, a variable speed adjustable displacement liquid pump connected at its intake side with a supply of liquid and at its outlet side with an injecting device adjacent said gas stream, a hydraulically actuated variable volume mechanism operatively connected with said liquid pump for adjusting the displacement thereof, and a pneumatically actuated mechanism connected to said pump connection across said restriction and operatively connected with said hydraulically actuated mechanism to adjust the displacement of said liquid pump in accordance with variations in the gas pressure drop across said restriction through the intermediacy of said hydraulically actuated mechanism.

10. Apparatus for adding to a stream of gas a quantity of liquid sufficient to create a mixture in which the weight of liquid in a unit volume of gas bears a definite predetermined ratio to the weight of gas in said unit volume comprising, a duct for said gas, a constant speed constant displacement pump pneumatically connected with said duct for continuously withdrawing a sample quantity of gas therefrom, a restriction in the connection between said pump and said duct for establishing in said connection a pressure differential proportional to the density of the gas, a variable speed adjustable displacement liquid pump connected at its intake side with a supply of liquid and at its outlet side with an injecting device adjacent said gas stream, a hydraulically actuated variable volume mechanism operatively connected with said liquid pump for adjusting the displacement thereof, and a pneumatically actuated mechanism connected to said pump connection across said restriction and operatively connected with said hydraulically actuated mechanism to adjust the displacement of said liquid pump in accordance with variations in the gas pressure drop across said restriction through the intermediacy of said hydraulically actuated mechanism, said hydraulically actuated mechanism comprising, a cylinder, a piston reciprocable in said cylinder and operatively connected with

the capacity varying element of said liquid pump, a spring urging said piston in a direction to decrease the capacity of said pump, a fluid pressure line having a restriction therein connected to said cylinder in a manner to apply fluid pressure to said piston to increase the capacity of said fluid pump, and a bleed valve in said fluid line operatively connected with said pneumatically actuated mechanism to control the fluid pressure applied to said piston.

11. Apparatus for adding to a stream of gas a quantity of liquid sufficient to create a mixture in which the weight of liquid in a unit volume of gas bears a definite predetermined ratio to the weight of gas in said unit volume comprising, a variable displacement pump driven at a speed substantially proportional to the volumetric flow rate of said gas and arranged to discharge into said stream for adding said liquid to said gas, means for continuously sampling said gas and establishing across a restriction a pressure differential proportional to the density of said gas, and means actuated by variations in said gas pressure differential for varying the displacement of said liquid pump in accordance with variations in said gas pressure differential said liquid pump displacement varying means comprising, a hydraulic motor device including a cylinder, a piston reciprocable in said cylinder and operatively connected with the capacity varying element of said liquid pump, a spring urging said piston in a direction to decrease the capacity of said pump, a fluid pressure line having a restriction therein connected to said cylinder in a manner to apply fluid pressure to said piston in a direction to increase the capacity of said pump, a bleed valve in said fluid line for controlling the fluid pressure applied to said piston, and a pneumatic motor pneumatically connected to said gas sampling device at opposite sides of said restriction and operatively connected with said valve for controlling the same and a dash-pot associated with said pneumatic motor for stabilizing the operation thereof.

12. The device of claim 1, including manually operated means for varying said pressure differential.

13. The apparatus of claim 1, wherein the variable displacement pump discharges into said intake system at a point upstream of said gas sampling means.

14. In the combination of claim 1, a supercharger having a diffuser section in said air intake system, said conduit being connected with said diffuser section.

15. The device of claim 2, including means to automatically increase the fuel-air weight ratio of said charge at at least one end of the engine speed range.

16. In a charge forming device for an internal combustion engine having an air intake system and a variable delivery fuel pump discharging into said intake air, a conduit connected with said air intake system, a pump having a constant volumetric displacement per operating cycle in said conduit, constant speed means for driving said pump, a restriction in said conduit, and means connected with said conduit at opposite sides of said restriction and operated by variations in the pressure differential across said restriction to vary the delivery of said fuel pump.

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