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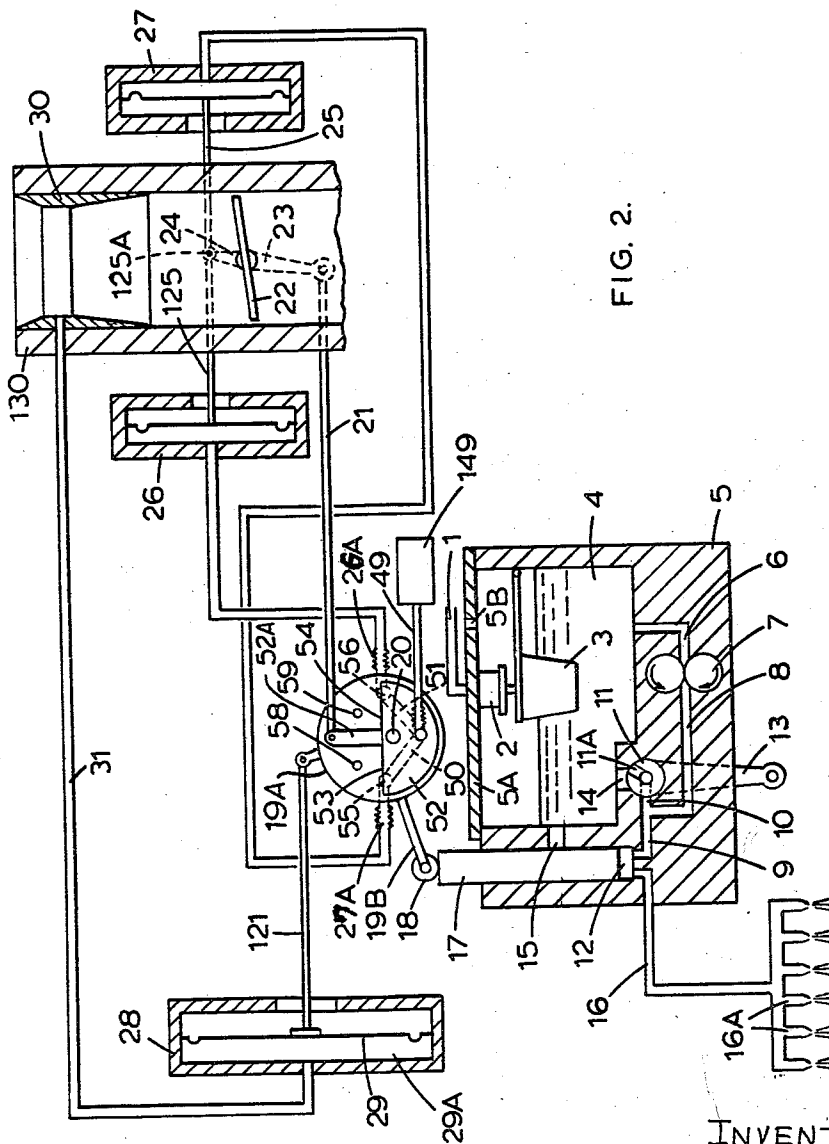


FIG. 2.

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APPARATUS FOR THE CONTROLLING OF THE SUPPLY OF FUEL AND AIR TO INTERNAL COMBUSTION ENGINES

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This invention relates to apparatus for controlling the supply of fuel and air to internal combustion engines and its main object is to achieve a predetermined substantially constant or varying fuel/air ratio over a large range of engine speeds by apparatus of comparatively simple construction which is not unduly expensive to manufacture. Apparatus as heretofore provided with the object of achieving a constant fuel/air ratio have proved too complicated and expensive and/or have failed to maintain the ratio constant and produced a fuel/air mixture which was too rich or too weak when not required. A weak mixture is desirable under conditions of low engine load and a further object of the present invention is to enable this weak mixture to be provided by simple means while providing the substantially constant richer mixture under conditions of high engine load.

For carrying out the invention an apparatus is provided comprising a fuel container, a pump for receiving fuel from said container and supplying the fuel to the engine, said pump having a maximum capacity exceeding the maximum fuel requirements of the engine, valve means for exhausting the fuel from the pump output in dependence upon the movements of the engine accelerator element, a pump output means to contain fuel coming from the pump, a control chamber coupled to the pump output means and containing a movable control member acted on by said fuel, means actuated by said control member for actuating the engine throttle valve to open the latter with increasing pressure, air controlled means for deriving a force proportional to the rate of flow of air in the engine air intake member, which flow is controlled by said throttle valve, means for applying said force to said control member in opposition to the fuel pressure thereon so as to maintain said control member in equilibrium when the fuel pressure is balanced by said force, and an exhaust opening for said chamber which opening is opened at substantially full throttle.

The fuel supply is directly controlled by the operator but the apparatus will always mix the correct amount of air with the fuel to give a constant air/fuel ratio unless special means are provided to vary this ratio. The pressure in the fuel line to the nozzles, due to the flow of fuel through the nozzles in the engine, is proportional to the square of the velocity through the nozzles. Thus, with the fuel line flowing full, the pressure is proportional to the square of the mass flow of fuel into the engine. The air supply may pass through a venturi to the throttle or air valve. The vacuum or suction in the venturi throat will be proportional to the square of the velocity of air in the throat, and hence to the square of the mass flow of air. The fuel pressure produces a force which opens the air throttle valve of the engine. The resulting flow of air causes a vacuum or suction in the venturi which produces a force. These forces can be made to balance at any engine speed.

If, for any one position of the accelerator pedal, these forces are equal when the air valve is in such a position that the air/fuel ratio for the engine is at a predetermined value; then, since both forces vary as the square of their respective mass/flow values, the balance will always occur at the chosen air/fuel ratio.

The square law, mass flow phenomena are commonly

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made use of in internal combustion engine fuel systems, but many existing systems control the air supply directly and the fuel supply is the dependent variable. The disadvantage with this direct control of air supply is that in transient conditions, particularly sudden acceleration of the engine, there is a lag in the response of the dependent variable, in this case the fuel, which results in a temporary weakening of the mixture at a time when enrichening is required, and necessitates a special device to overcome this deficiency. With the system used in the present invention, however, the opposite is the case and there is even a tendency for temporary enrichening of the mixture in sudden acceleration conditions.

A constructional form of the invention will now be described by way of example with reference to the accompanying diagrammatic drawings wherein:

FIGURE 1 shows an apparatus made in accordance with the invention for controlling the supply of fuel and air to internal combustion engines;

FIGURE 2 illustrates a modification involving servo actuation of a valve member by an internal fluid pressure;

FIGURE 3 shows a modified servo arrangement utilising the fuel pressure.

Referring first to FIGURE 1, fuel under pressure from a normal automobile fuel pump (not shown) is fed via a pipe 1, a needle valve 2, controlled by a float 3 to a chamber 4 formed in a fuel container or housing 5 closed by a cover 5A provided with a vent passage 5B. The action of this arrangement is to maintain a constant fuel level in the chamber 4. From the base of the chamber a channel 6 leads to a high pressure pump 7, preferably of the positive displacement type having an output substantially in excess of the fuel requirements of the engine at any speed. The pump outlet is connected via channels 8, 9 and 10 to a fuel control valve 11 and to a spill valve chamber or control chamber 12. The fuel control valve 11 is under the direct control of the driver by means of a driver operated member in the form of a lever 13 connected suitably to the accelerator pedal of the automobile. The lever 13 is connected to the rotary plug of the valve 11 which plug has outlet port 11A communicating with a discharge port 14 in the housing 5 leading to the chamber 4. The rotary plug valve 11 serves to control or regulate the pressure and the mass flow of fuel coming from pump 7 by bypassing a selected fraction of the pump's output back to the fuel chamber 4 by way of ports 11A and 14. The construction of the rotary plug valve 11 is conventional, and it may for example be formed as disclosed in either U.S. Patent No. 2,902,253, issued September 1, 1959, or in U.S. Patent No. 2,766,962, issued October 16, 1956. Similarly, the spill valve chamber 12 has a discharge opening 15 in the housing 5 also leading to the chamber 4. A discharge channel 16 is provided in the housing 5 and this channel 16 is connected to a series of jets 16A supplying the engine cylinders respectively. The channels 8, 9, 10, and 16 together with jets 16A constitute the pump output means for fuel pump 7. The opening 15 serves as an exhaust for the chamber 12, but this exhaust enters into actual operation only after full throttle conditions have been reached, as will be explained in detail hereinafter.

The channel 9 leads into the lower part of the spill valve chamber 12 and this lower part also communicates with the discharge channel 16, which supplies fuel to the jets 16A of the engine. The chamber 12 contains a spill valve piston 17. The pressure in the discharge channel 16 which is supplied via channel 9 acts on the piston 17 in the spill valve chamber 12. The force acting on the piston 17 is thus directly proportional to the pressure in the channels 9, 16. This force is communicated by the piston 17 to a roller 18 on one end of a bell crank lever

19 that is pivotally mounted at 20. The other end of the lever 19 is connected pivotally to a throttle rod 21 which serves to open and close a butterfly throttle valve 22 via throttle lever 23.

The valve 22 is mounted within an air intake pipe 130 which carries a venturi 30 on the atmospheric side of the valve 22.

A movable wall venturi-actuated device 28 contains a movable wall or diaphragm 29 in a chamber 29A which is connected by a pipe 31 to the throat of the venturi 30. The diaphragm 29 is connected to a rod 121 which is pivotally connected at 121A to the rod 21 and lever 19. The diaphragm 29 is therefore acted on by the vacuum or suction produced by the venturi 30. Air is supplied to an engine (not shown), wholly through the venturi 30 and pipe 130 and is consequently controlled by the butterfly valve 22. As is well known the vacuum or suction created by a venturi is substantially proportional to the square of the rate of flow of fluid. Consequently, the force produced by the diaphragm 29 on the rod 121 is proportional to the square of the rate of flow of air through the pipe 130. The parts 30, 31, 28, and 29 thus constitute air-controlled means deriving a force proportional to the rate of flow of air in the engine air intake pipe 130.

Fuel is supplied to the engine by one or more jets 16A from the channel 16, and since the rate of fuel delivery through an orifice obeys substantially the same law as that obtaining in the air venturi 30, the force acting on the piston 17 is related to the fuel flow in the same way as the force acting on the diaphragm 29 is related to the air flow.

Suitable choice of piston area, diaphragm area and lever lengths ensures that these two forces attain balance when the fuel/air mixture is correct for the engine in question.

The operation is as follows. Movement of the accelerator pedal opens or closes fuel control valve 11. Partial closure of this valve restricts the discharge of fuel to the chamber 4 and consequently raises the pressure in the above-identified pump output means and in chamber 12, and increases the fuel flow, through the nozzles 16A, to the engine.

The increased pressure acts on piston 17 moving it in an upward direction thus moving roller 18, lever 19, throttle rod 21, and lever 23 in such a direction as to open the butterfly valve 22, thus increasing the air flow through the venturi 30. This movement continues until the increased air flow which in turn increases the vacuum in the venturi 30 is sufficient to provide sufficient balancing force in the rod 121. This balancing force is provided by the vacuum in venturi 30 being communicated via pipe 31 to the venturi diaphragm device 28 and acting upon the diaphragm 29. When balance is obtained the piston 17 ceases to move and the system remains in equilibrium.

Opening of the fuel control valve 11 results in a lowering of pressure in the fuel channels 8, 9, 10, 16 and chamber 12, and eventual closure of the butterfly valve 22 until a position is reached where equilibrium is re-established.

It will be apparent that when the butterfly valve 22 has attained its fully open condition no further increase in air flow will occur at a given engine speed. Measures must be provided therefore to prevent further increase in fuel flow when this condition occurs. The exhaust port 15 is so placed in the wall of the spill valve chamber 12 that it is opened by movement of the piston 17 when the butterfly valve 22 attains almost the fully open condition. Additional fuel beyond that required to maintain a balance of force between the venturi diaphragm device 28 and the piston 17 is thus discharged from this port 15 to the chamber 4.

In certain circumstances it occurs that owing to the effects of friction, and of aerodynamic forces acting on the butterfly valve 22 external assistance may be required

to facilitate the attainment of equilibrium. For this purpose servo assistance devices 26, 27 may be provided in order to apply greater operating forces to the air throttle valve 22 than can be obtained by using only mechanical linkages, such as the members 19, 21, and 23 described above. The butterfly valve 22 carries a lever 24 which is pivotally connected at 125A to rods 125, 25 and these rods are connected, respectively, to two movable wall or diaphragm-type servo devices 26 and 27. The lever 19 of FIGURE 1 is replaced by an additional valve means comprising a disc or first valve member 19A carrying a lever 19B and provided with channels 50, 51 conjointly connected by flexible pipe 49 to a suitable vacuum source 149, for example the inlet manifold of the engine or a suitably evacuated chamber. The rod 121 connects the disc 19A to the diaphragm device 28 and rod 21 connects the lever 23 of the butterfly valve 22 to an arm 52A on a segmental plate 52 which forms a second valve member of the additional valve means, the plate 52 being pivotally mounted concentrically with disc 19A. The disc 19A and plate 52 are pivotally mounted on pivot 20. The radial edges 53, 54 of plate 52 are so placed as to coincide in its mid position with and close two holes 55, 56 in the disc 19A that communicate with passages 50, 51 respectively. These holes in turn communicate by flexible pipes 26A, 27A with the movable wall servo devices 26, 27. Opening of either hole in disc 19A causes the vacuum to act preferentially on the alternate movable diaphragm servo device, thus opening or closing the butterfly valve 22 as appropriate. The change of air flow thus caused causes the venturi diaphragm device 28 to operate so as to move rod 121, thus rotating disc 19A in a direction tending to restore symmetry between the disc 19A and the segmental plate 52, which itself responds to the movements of the throttle via lever 23 and rod 21. Such movements will cease so long as the force acting on the spill valve piston 17 remains in balance with the force acting on the venturi diaphragm device 28.

Any change in fuel pressure occasioned by movement of the fuel control valve 11 will result in displacement of piston 17, roller 18, lever 19B and disc 19A. This displacement will actuate the servo system above described and balance will be attained thereby. Two stop pins 58, 59 may be mounted on disc 19A to limit the relative movement of disc 19A and segmental plate 52.

In the modification shown in FIGURE 3 the servo devices 26, 27 are acted on by the fuel pressure instead of the external source 149 of air pressure. For this purpose the output from the pump 7 is fed to a channel 60 which communicates with the channel 8 via a spring pressed non-return valve 61. This channel 60 leads to a port 62, which is a subsidiary fuel inlet port entering the spill valve chamber 12. The valve 61 serves to maintain a predetermined minimum fuel pressure in channel 60, in the following manner: Assuming that non-return valve 61 is closed, then no through circuit is available for fuel coming from pump 7 which therefore must build up pressure in channel 60 to a value which overcomes the spring loading of valve 61. Until valve 61 is opened by this fuel pressure, no fuel can be fed to the engine. Therefore whenever the engine is operating, the minimum pressure possible in channel 60 is determined by valve 61, because any lower pressure would immediately permit this valve to close, cutting off the supply of fuel to the engine and stopping it. The maximum pressure in channel 60, on the other hand, is determined by the size of the jets 16A.

A piston 17' corresponding in function to piston 17 of FIGURES 1 and 2 has a land 63 which normally closes the port 62 and on opposite sides of the land 63 are parts of reduced diameter forming communicating spaces 65, 66 which are in communication with channels 67, 68. Ports 69, 70 can connect spaces 65, 66 to the chamber 4. Thus when the forces on the piston 17' are in equilibrium the piston will be in the mean position shown in which

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the port 62 is closed. If the piston is raised, fuel pressure will be transmitted through channel 68 to the servo device 26, thus opening the throttle while excess fuel from servo device 27 and channel 67 passes through port 69 to the chamber 4. Similarly, if the piston 17' descends the throttle is closed by device 27 while excess fuel from servo device 26 and channel 68 passes through the port 70 back to chamber 4. The diaphragm 29 is connected by rod 121 and pivot 121A to the bell crank lever 19, and applies a balancing pressure to the piston 17' in the same manner as described heretofore with reference to FIGURE 1. With the modification of FIGURE 3, a slightly different type of rotary plug valve 11' is employed in place of the valve 11 above to control the fuel pressure in the pump output means and in chamber 12. As shown in FIGURE 3, the valve 11' is located between the channels 8 and 9 of the pump output means, and this valve 11' is arranged to permanently interconnect channels 8 and 9 for all settings of the lever 13. Moreover, the rotary plug of valve 11' has an outlet port 11B which communicates to a variable degree with the section of valve 11' interconnecting channels 8 and 9. Thus, the valve 11' regulates the fuel pressure from pump 7 by bypassing a controlled fraction of the pump's output to the chamber 4 in a manner generally similar to the operation of valve 11. An example of a suitable construction for the rotary plug valve 11' is shown, for example, in U.S. Patent No. 1,249,837, issued December 11, 1917.

The device above described is readily adapted to give variable mixtures suitable for starting, idling, part and full throttle. Starting for example is readily performed by the use of the well known strangler valve so positioned as to close or partially close pipe 130 on the atmospheric side of the venturi 30. It is also well known to provide an adjustable orifice (or orifices) on the engine side of the butterfly 22. This may be connected via suitably sized atmospheric bleeds to the venturi diaphragm device 28, thus providing a variable degree of enrichment according to the manifold vacuum or suction and disposition of the orifice. Such an arrangement provides a graduated enrichment between part throttle weakened mixture strength and the enriched mixture required under idling conditions.

The volume and strength of the mixture during idling are usually required to be separately adjustable, and this is commonly done either by providing an adjustable throttle valve stop to prevent complete closure of the throttle or a separate adjustable throttle valve by-pass. Such methods have been found to be readily applicable to the present invention.

I claim:

1. An apparatus for controlling the supply of fuel and air to an internal combustion engine having an air intake member, an air intake throttle valve located within said air intake member and controlling the flow of air through said intake member, and a driver-operated member, said apparatus comprising a fuel container, a pump for receiving fuel from said container, said pump having a maximum capacity exceeding the maximum fuel requirements of said engine, a pump output means connected to said pump and containing fuel from the pump, valve means connected with the pump output means and operatively connected to the driver-operated member, said valve means controlling exhaust of the fuel from the pump output means to said fuel container in dependence upon the movements of said driver-operated member, a control chamber having a movable control member disposed therein, said control chamber being coupled to said pump output means so that the pressure of the fuel in said pump output means is applied to said movable control member to displace the latter in one direction of movement thereof, connecting means actuated by said movable control member and connected with the air intake throttle valve

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so as to open the latter with increasing fuel pressure, air controlled means for deriving a force proportional to the rate of flow of air in the engine air intake member, means for applying said force to said movable control member in opposition to the fuel pressure thereon so as to maintain said movable control member in equilibrium when the fuel pressure is balanced by said force, and an exhaust opening leading from said control chamber to said fuel container, said exhaust opening being controlled by said movable control member which opens said exhaust opening at substantially full throttle.

2. An apparatus as claimed in claim 1, wherein said air controlled means includes a venturi mounted within said air intake member through which the air passes to the air intake throttle valve, and a movable wall device in communication with the throat of said venturi and connected to said force-applying means.

3. An apparatus as claimed in claim 1, further comprising two servo devices each having a movable wall member, coupling means for connecting the movable wall members of both of said servo devices to said air intake throttle valve, and a separate source of fluid pressure, and wherein said connecting means actuated by the movable control member includes an additional valve means for supplying the fluid pressure of said separate source alternatively to said servo devices according to the movements of said driver-operated member.

4. An apparatus as claimed in claim 3, wherein said additional valve means comprises a first valve member and a second valve member coacting therewith, said first valve member being connected to said air controlled means by said force-applying means, said second valve member being connected to the throttle valve, said first valve member having channels therein connected to said separate source of fluid pressure and leading to said servo devices, said channels being alternatively exhausted by relative movements of said valve members upon any out-of-balance between said force and the fuel pressure.

5. An apparatus as claimed in claim 1, further comprising first and second servo devices each having a movable wall member therein, coupling means for connecting both of said wall members to said air intake throttle valve, said control chamber having a first port connected to the first servo device and a second port connected to the second servo device, said control chamber also having two exhaust ports leading to said fuel container and a subsidiary fuel inlet port, a channel leading from said pump to said subsidiary port, said movable control member having sections of reduced diameter on opposite sides of a land, said land disposed so as to close said subsidiary port for a mean position of said movable control member, all of said ports being selectively opened and closed by the movements of said movable control member so as to supply fuel pressure alternatively to said servo devices whenever said movable control member moves out of said mean position.

6. An apparatus as claimed in claim 5, further comprising a resiliently urged means mounted in the pump output means and acting on the fuel in said channel leading to the subsidiary port to maintain a predetermined minimum fuel pressure delivered to said servo devices.

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