Feb. 9, 1943. O. FUSCALDO 2,310,773

ELECTROMAGNETICALLY CONTROLLED FUEL INJECTION

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Fig. 2.

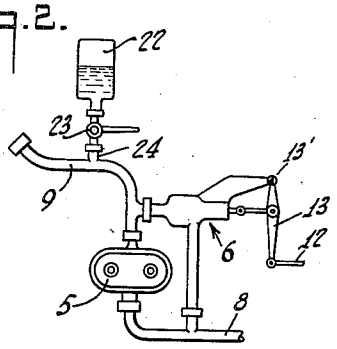


Fig. 1.

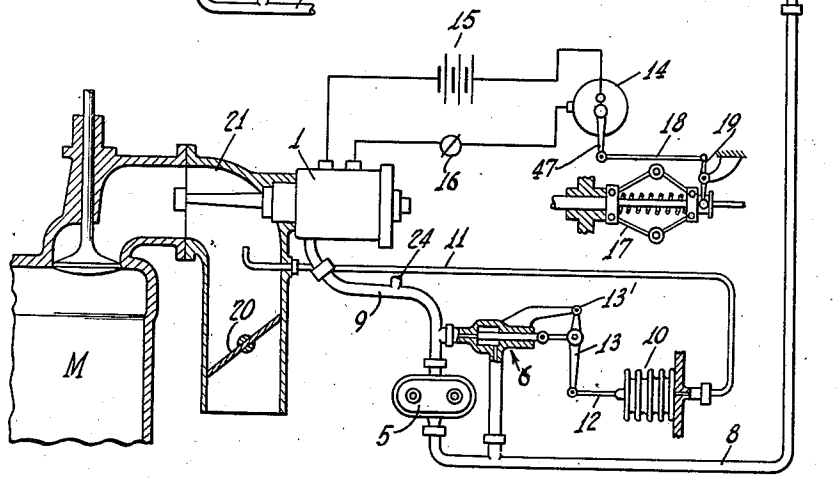
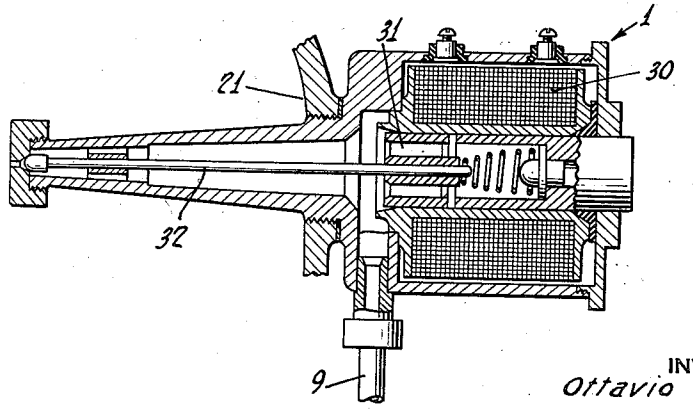


Fig. 3.



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Fig. 4.

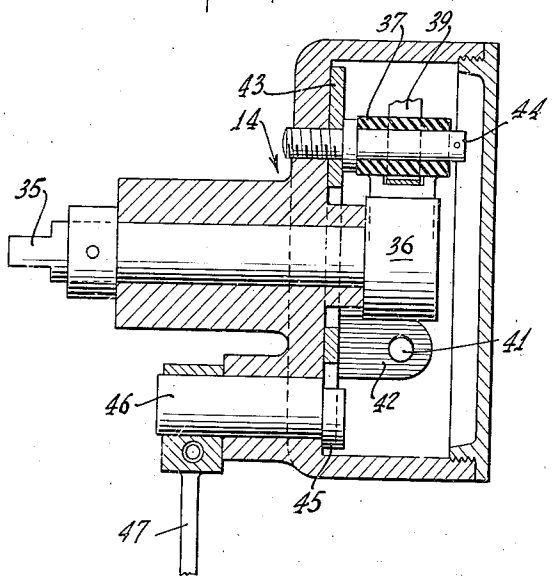
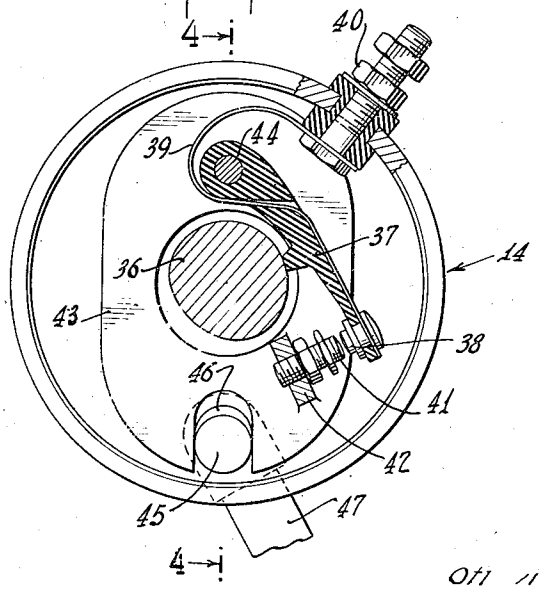


Fig. 5.



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UNITED STATES PATENT OFFICE

2,310,773

ELECTROMAGNETICALLY CONTROLLED FUEL INJECTION

Ottavio Fuscaldo, Milan, Italy; vested in the Alien Property Custodian

Application January 26, 1940, Serial No. 315,734
In Italy January 27, 1939

2 Claims. (Cl. 123—119)

This invention relates to electromagnetically controlled fuel injection, and its general object is to deliver automatically a constant air-fuel ratio under all operating conditions of explosion engines fed by electromagnetic fuel injection.

The mechanism of the present invention in its illustrated embodiment comprises in combination a series of electromagnetic injectors, at least one volumetric fuel-pump for feeding liquid fuel to said injectors, a device for gauging the fuel-flow placed as a bypass between the suction pipe and the pressure pipe of said pump, means for adjusting said gauging device through a pressure responsive instrument, and means which is controlled by the engine's speed for influencing the electric circuit breaker which controls the energizing of the winding of the electromagnetic injector.

The invention will now be described with reference to the attached drawings, given solely by way of an example.

Fig. 1 is a view, substantially diagrammatic, of an embodiment of the device as applied to an explosion engine.

Fig. 2 is a portion of Fig. 1, showing details.

Fig. 3 is a central section view of the electromagnetic injector of Fig. 1.

Fig. 4 is a longitudinal central section view of the current distributor of Fig. 1; and Fig. 5 is a right end view of Fig. 4 with the cover plate omitted.

Fig. 1 shows an electromagnetically controlled injector 1, which may be one of a series, energized from battery 15 and supplied under pressure from one or more fuel pumps 5, through pipes 9. Each injector may be constructed as in Fig. 3, wherein the solenoid winding 30, in circuit with the battery or current source 15 can attract the spring-resisted core 31 which pulls the injector valve and rod 32 to open the valve and cause each injection; the liquid flow and spring pressure closing the valve when the coil circuit is broken. This construction is the subject of copending applications, and is not herein claimed.

The pump 5 is preferably of the volumetric type, for instance a gear pump, driven by the engine M and, having consequently, a pump delivery proportioned to the engine's speed. Between the inlet pipe 8 and outlet pipe 9 of said pump extends a bypass passage back around the pump and adapted to permit backflow of fuel not passing to the valves 1; and in this passage is arranged a controller 6 for varying the delivery, independently of the pump speed. Pump 5 draws the fuel from the tank 7 through the pipe 8 and sends it to the injector 1 or to the series of injectors feeding the various cylinders of the engine. The bypass controller or valve 6 is varied in its action by a pressure responsive device, as a manometric Sylphon-capsule or bellows 10, the interior of which is in constant communication by a small pipe 11 with the engine intake conduit 21, leading to the usual inlet valves. The bellows device, thus responsive to intake pressure or suction, controls the bypass 6 by means of a link 12, pivoted to a lever 13, fulcrumed at 13', so as to reduce the fuel volume flow, by discharging into the inlet pipe 8 from pipe 9 in increased fraction of the fuel pumped, with the decrease of the absolute pressure of feed-air, i. e. with the increase of suction; and vice versa.

The timing of current distribution to the injectors 1 may be by means of a distributor 14 of a type that contains means for varying the angular closing time of the contacts, as for instance that shown in Figs. 4 and 5 containing features disclosed in copending applications and not herein claimed. The distributor 14 has a shaft 35 which is driven from and in time with the engine shaft and carries a cam 36 of shape to swing a contact arm 37 in proper coordination. The arm carries an insulated contact 38 which is connected by a conducting strip 39 to a terminal post 40. The strip may be also a spring pressing arm 37 to close contact 38 against an opposing contact 41. The cam 36 therefore causes the contact 38 to separate from and return to the contact 41, to break and make the circuit. The contact 41 while relatively fixed is operatively adjustable, for which purpose it is mounted on an extension or ear 42 outstanding from an adjustably movable plate 43. This plate may swing slightly and for convenience is shown pivoted to the same stud or pin 44 about which the contact arm 37 oscillates. Adjustments of plate 43 and contact 41 are effected by an eccentric 45 on a shaft 46, the eccentric occupying snugly a slot in the plate. The shaft 46 carries an arm 47 for effecting these adjustments, and this arm, as shown in Fig. 1, is adjustably swung under control from the engine speed so that the higher the speed the longer the angular period of current flow in each cycle.

The electric current may flow through the circuit from battery 15, when the master switch 16 is closed. A centrifugal regulator 17, driven by the engine, operates through a lever 19 and link 18 to swing the arm 47 of the distributor 14, thereby to vary the angular period of closure of the contacts in each cycle in direct relation to

the speed of the engine which period is therefore made substantially constant in point of time.

It is manifest that if the angular timing of closure of the contacts remains constant at all speeds, the actual timing, or period of time, varies evidently in inverse ratio to the engine running speeds; consequently in that case an increase in speed of the engine increases also the fuel pressure in the injectors, as the actual time during which the injection is operative diminishes, while the volume flow in the pump must increase, the latter being of the volumetric type. Therefore, while the fuel feed pressure is very low at the start, it becomes very high at the highest speeds of the engine; this causes an excessive drop in the volumetric efficiency of said pump (because the leakage increases in all existing gaps and crevices), and causes also a rapid wear of the pump (with consequent increase in said gaps and leakage), resulting in a great reduction in the flow factor of the injection nozzles and a quicker erosion of the same (owing to the increase of the discharge velocity), as well as too penetrating an injection (causing the atomised fuel to strike against the walls and build up large drops) and a greater difficulty in keeping the pipes and fixtures perfectly tight. These difficulties it is an object of the present invention to overcome.

The inclusion of a centrifugal governor in the present combination of elements substantially eliminates all of the stated inconveniences, by annulling their cause, namely the undue increase in injection pressure. In fact, while the volumetric pump provides automatically a volume of fuel which is proportional to the engine's speeds, the centrifugal governor provides automatically a way to maintain the time of injection substantially constant, so that the pressure of the fuel also remains constant.

The device of this invention operates as follows: When changes in the engine's speed (with air throttle **20** constantly open) are imposed by load changes, as is the case with the power curve, the amount of fuel and of air for each feed stroke of the engine remain constant and therefore the fuel-air ratio remains constant, as desired.

The slight decrease in the intake of air into the cylinders which unavoidably occurs on increasing the speed of the engine, caused by the increase of friction in the intake pipe **21**, causes in its turn a slight increase in the depression in said inlet pipe and therefore also in the manometric bellows or capsule **10**, which responsively shortens and, acting on the by-pass **6** of the pump, causes its delivery to decrease.

When the changes in the speed of the engine are brought about by changes in the volume of feed-air, through the adjusting action of the throttle **20**, as the case may be when working on the utilization curve, then the manometric bellows **10** undergoes an extreme action, because in this case the change in the depression is very great. The more the throttle **20** is closed, the greater is the increase of the depression in the intake pipe **21** and the shorter the capsule grows and the more it opens by-pass **6** and decreases the volume of fuel fed to the engine.

In a case where the engine is supercharged by a compressor, the principles of the apparatus remain unchanged; the responsive bellows is subject both to depressions and to compressions, which means simply that the range is more extended of the variations of the absolute air feeding pressure. In order to fulfill the general requirement that the entire range of variation in the length of the bellows may cause in the distributor the complete range of variation in the length of time of contact closure, it is sufficient that the bellows should be of proper dimensions and properly adjusted for the purpose.

Considering now the performance of the system in sudden changes of engine speed (accelerations or decelerations) it should be noted that upon a quick opening of the throttle, whereupon the cylinders are immediately and completely filled with air, the fuel feed tends to lag, as it can only increase in consequence of the engine's acceleration, that is, of the pump's and governor's increase in speed. But this lag is somewhat reduced because the simultaneous decrease of pressure in the intake pipe **21** is very sharp and the bellows **10** acts fairly quickly to close the by-pass **6**. But this action is not wholly sufficient and the acceleration will be rather doubtful due to the excessive reduction of the ratio of fuel to air.

In order to prevent this special drawback, and perfect the performance of the invention, it is sufficient to connect to the pipe **9** feeding the pumped fuel under a certain pressure, an airtight chamber **22**, shown in Fig. 2 as an inverted vessel of liquid fuel, its lower end communicating with the pipe **9**. During the normal running conditions the fuel in said chamber maintains a certain level above which there is a cushion of compressed air at the same pressure. The action of this refinement will now be explained.

Supposing the engine to be running at slow speed, on opening quickly the throttle, the air inflow to the engine is complete and rapid as stated above, and the reserve of fuel contained in chamber **22**, urged by the air pressure above it, feeds partly into pipe **9** and so provides the fuel needed to allow the engine to accelerate sufficiently to allow in turn the pump to increase its delivery, while the automatic closure of the by-pass helps out. When conditions become settled the fuel reserve in chamber **22** refills automatically and rapidly, affording a cushioned auxiliary supply.

If the air throttle be closed suddenly, what happens is that, while the feed of the air ceases immediately and almost completely, the pumped fuel goes on feeding in a large measure, as it can decrease only in consequence of the engine's speed deceleration, namely, by a decrease in the speed of the pump and of the centrifugal governor. Such a condition is sufficiently offset by the fact that the depression in the engine **21** increases very greatly, and the bellows quickly acts to open in full the pump's by-pass, almost annulling the fuel feed.

Let us now consider the operation of chamber **22** when the engine is stopped, and when it is subsequently started. The stoppage of an engine with electromagnetic injection is exclusively obtained by cutting-off the current from the injectors. At this exact moment, the fuel pressure in the piping **9** rises, because the injectors have closed, while the pump goes on running awhile, although at a decreasing speed. In the connection from inverted chamber or flask **22** to the pipe **9** is a cock **23** to cut off the communication. Now, if at the instant the engine stops the cock **23** is closed, cutting off the communication of chamber **22** with pipe **9**, it will be possible to keep stored in the chamber a quantity of fuel under pressure; and this will prove useful for an

easy restarting of the engine, even after a rather long stop, and without any other outside help. It will be sufficient to open at the proper moment the cock **23** while the engine is running only slowly, or is driven by the starting motor, and while the pump has yet too small a delivery for full operation.

It should be understood that the details of construction, arrangement, design and application of the invention may be varied in many ways without thereby exceeding the scope of the invention.

Having now described my invention and how the same is to be carried out, what I claim as my invention is:

1. Fuel injection apparatus for explosion engines, comprising a series of valved fuel injectors for the engine cylinders, each electromagnetically operable for timed quick opening and closing of its valve, an engine-driven electric distributor adapted for adjustably predetermining the angular timing and the duration of opening of the several injector valves, an engine-driven speed-responsive regulating centrifuge device having connection to the distributor for adjusting the latter for regulation by the centrifuge of the angular duration of each injection and arranged to increase such angular duration with faster engine speed and vice versa thereby to maintain a substantially steady actual time duration of each injection; an engine-driven volumetric fuel pump delivering by its pressure pipe to the series of injectors, adjustable means associated with the pump for modifying the rate of flow of pumped fuel to the injectors, and a pressure-responsive capsule instrument in communication with and operated from the air pressure in the engine intake for adjusting said fuel-flow-modifying means and arranged to reduce the rate of fuel flow to the injectors with decrease of intake air pressure and vice versa; whereby the fuel injected into each cylinder in each cycle is proportioned substantially to the air inflow to maintain substantially steady the air-fuel ratio under varying intake pressures and engine speeds.

2. In an explosion engine fuel injection apparatus as in claim 1, a fuel passage extended laterally from the pump pressure pipe, a closed fuel reserve vessel to which said passage extends adapted to contain compressed air above the reserve fuel therein, and a cock in said passage to shut off and isolate said vessel and contained fuel and air; whereby on stopping the engine the cock may be closed to seal and confine under pressure the liquid and air in the vessel, thereby to provide initial fuel pressure by opening the cock on restarting the engine.

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