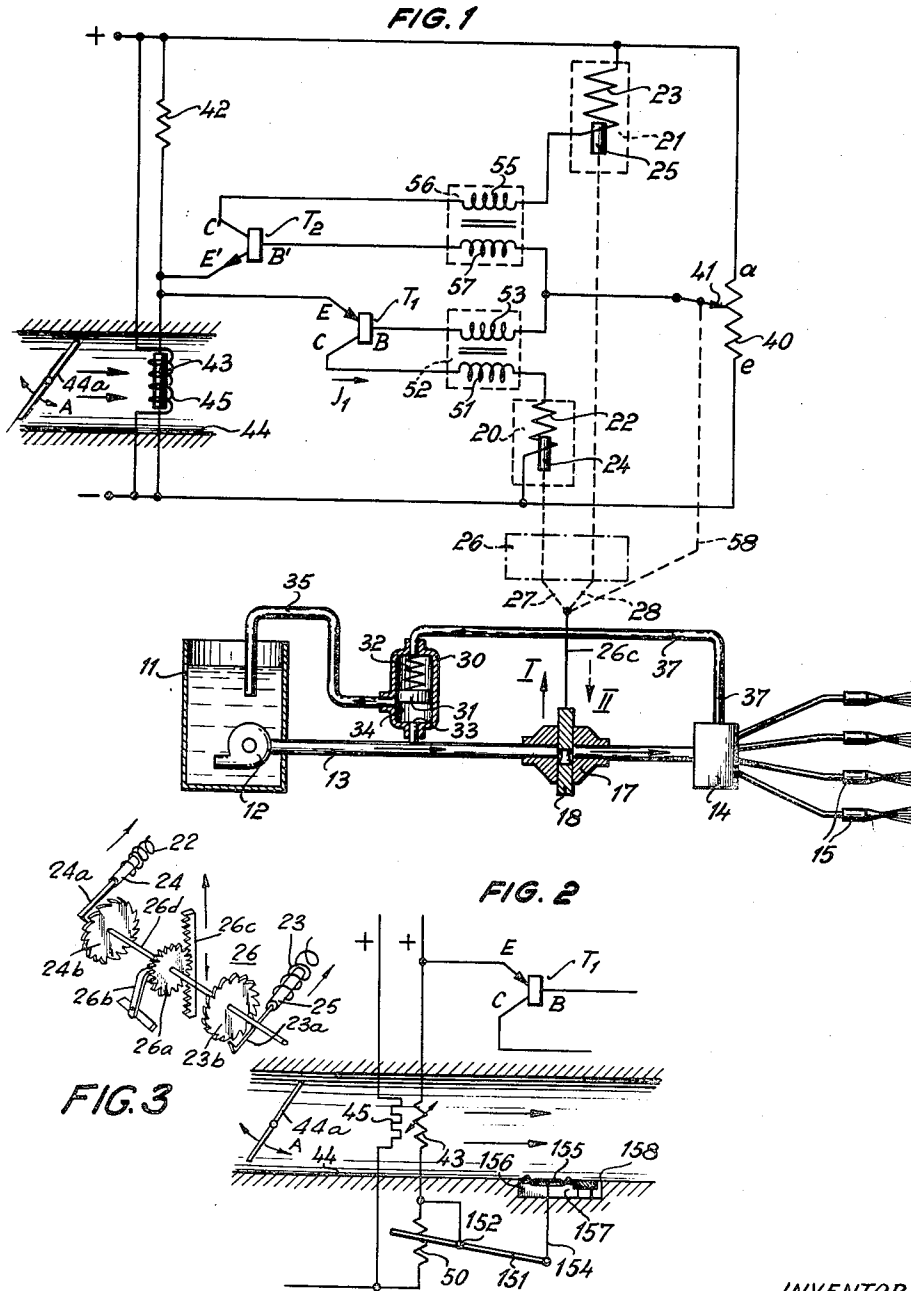


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FUEL INJECTION CONTROL DEVICE

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1

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FUEL INJECTION CONTROL DEVICE

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The present invention refers to fuel injection devices for internal combustion engines, and more particularly to a fuel injection arrangement incorporating electrical control means.

In the operation of internal combustion engines it is desirable to adjust automatically the amount of fuel which is preferably continuously injected into the engine so that it is in a predetermined proportion to the amount of air drawn-in by the engine at the particular time.

The amount of fuel which is injected during each operational cycle of an internal combustion engine, either directly into the cylinder or cylinders, or into the intake manifold of the engine, must be kept in a definite proportion to the amount of air drawn-in at the same time during the particular operational cycle. This proportion is determined by the so-called stoichiometrical ratio. In case the amount of fuel injected is too small then the engine cannot deliver its maximum power. On the other hand, if too much fuel is injected then a very rich mixture is created so that the fuel that is being used does not burn completely and therefore the fuel spent is only incompletely utilized.

It is therefore a main object of this invention to provide a fuel injection arrangement which is capable of adjusting the fuel supply and of maintaining the desired ratio as set forth.

It is another object of this invention to provide for a fuel injection control arrangement of the type set forth in which the automatic control is carried out by electrical means which control and adjust a throttle valve located in the fuel supply line between the fuel supply pump and the injection means.

With above objects in view the fuel control arrangement according to this invention mainly comprises electrical control means capable of adjusting the quantity of preferably continuously injected fuel depending upon the simultaneously drawn-in air used for operating an internal combustion engine, a throttle valve being arranged in the fuel supply line between a fuel supply pump and the injection nozzles, said valve being adjusted by an electrical control device.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

Fig. 1 is a diagrammatic illustration of a fuel supply system including injection means, supplemented by an electric circuit diagram for illustrating the electrical control means; and

Fig. 2 is a diagrammatic enlarged illustration of certain elements of the arrangement of Fig. 1, including an additional component for controlling the arrangement; and Fig. 3 illustrates by way of example a drive mechanism forming part of the system shown in Fig. 1.

2

For illustrating an embodiment of fuel injection control arrangement according to the invention it did not appear to be necessary to show the whole engine. Fig. 1 shows in a diagrammatic way the important elements of the fuel supply system. Submerged in the fuel tank 11 is a fuel pump 12 which feeds through a pressure line 13 and a distributor 14 the fuel to four injection nozzles 15 which are individually connected to the distributor 14. Suitably mounted in the supply line 13 between the fuel pump 12 and the distributor 14 is a throttle valve 17 the cross sectional passage area whereof can be altered by means of a slide plate 18 which can be moved in transverse direction in such a manner that the opening in the slide plate can assume various positions more or less in register or even out of register with the supply line 13. The movement of the slide plate 18 is effected by means of two electro-magnets 20 and 21, respectively, the solenoid coils whereof are indicated by the numerals 22 and 23, respectively. The movable armatures 24 and 25, respectively, are mechanically connected with a stepwise operating unidirectional drive mechanism 26 which is illustrated in Fig. 1 only by a diagram symbol in the form of a block. The mechanical connection between the armatures 23, 24, respectively, and the mechanism 26 is illustrated in Fig. 1 diagrammatically by a broken line since any suitable mechanical connection for transmitting unidirectional stepwise movement will be found suitable for this purpose. Similarly a mechanical connection between the mechanism 26 and the slide plate 18 is likewise indicated only by broken lines 27, 28, respectively. It must be understood that every stroke of the armature 24 will produce a step movement in the mechanism 26 in one direction which is transmitted to the plate 18 in such a manner that it is moved in the direction of the arrow I, while every stroke of the armature 25 causes the mechanism 26 to move in such a way one step that the valve plate 18 is moved in the reverse direction indicated by the arrow II in other words, each step in the mechanism 26 produced by movement of the armature 24 causes the plate 18 to move a certain amount in direction of arrow I thus increasing the flow of fuel through the valve 17, while every stroke of the armature 25 causes in a similar way a movement in the direction of arrow II so as to reduce the flow of fuel through the valves 17.

Fig. 3 will serve to illustrate, by way of example, one of the many possibilities of providing the above mentioned stepwise operating unidirectional drive mechanism 26. A shaft 26d carries a first ratchet wheel 24b and a second ratchet wheel 23b having its teeth facing in a direction circumferentially opposite to that of wheel 24b. The armature 24 carries as forward extension a pawl 24a cooperating with wheel 24b, and armature 25 carries a similar pawl 23a cooperating with wheel 23b. In normal position of the armatures, as shown in Fig. 1, the pawls 23a, 24a are out of engagement with the teeth of the respectively associated wheel 23b, 24b. Whenever one or the other solenoid 22, 23 is energized, the displacement of the respective armature 24, 25 in direction of the arrow causes the pawl 24a, 23a, respectively to move the associated ratchet wheel 24b, 23b, respectively, a certain rotational step in one direction, counter clockwise in the case of wheel 24b, clockwise in the case of wheel 23b.

The shaft 26d carries a gear 26a which will follow the turns of the ratchet wheels, in either direction. A resilient holding finger 26b engages the gear 26a for holding the wheel assembly in any position reached by the step one action of the pawls on the ratchet wheels. The control rod 26c diagrammatically shown in Fig. 1 carries rack teeth in driving engagement with gear 26a so that any turning step of the gear and wheel assembly in either

direction will be transformed in a translatory step of the control rod 26c.

The fuel supply system further comprises an overflow valve 30 which is connected with the fuel line 13 between the fuel pump 12 and the throttle valve 17 and comprises a cylindrical housing in which a piston 31 is axially movable. The pressure existing in the fuel line 13 acts through the connection 33 against one face of the piston 31 thus tending to move it in upward direction as seen in Fig. 1 against the action of a spring 32 inserted between the opposite end of the cylinder and the rear face of the piston 31. In the position shown in Fig. 1 the piston 31 has cleared the outlet opening from the lower part of the valve 30, this opening leading into a return flow pipe 35 so that in the case of excessive pressure in the line 13 the fuel will return to the fuel tank 11. Ordinarily the spring 32 tends to move the piston 31 into its lower position in which the return flow through the pipe 35 is blocked. The action of the spring 32 is supplemented by the action of a partial amount of fuel branched off from the distributor 14 through an auxiliary pipe line 37 which is connected with the rear end of the valve 30. The overflow valve 30 serves in generally known manner to maintain in the fuel line 13 a constant fluid pressure disregarding whatever may be the adjusted cross sectional flow area in the valve 17 and whatever may be the amount of fuel that is continuously injected by the nozzles 15 into the engine.

The electrical control means for adjusting the throttle valve 17 depending upon the amount of drawn-in air comprises mainly two transistors T1 and T2 which form parts of a blocking oscillator arrangement. The transistor T1 is a silicon transistor of the PNP type, while the transistor T2 is a NPN type transistor and may also be of the silicon type. The control means further comprises a bridge circuit one branch of which is constituted by a potentiometer 40 having an adjustable tapping contact 41. The other branch of the bridge circuit is constituted by a fixed resistor 42 and a series connected heatable resistor 43 which latter is located within the air intake tube 44 of the engine in such a manner that the air continuously flows around this resistor in contact therewith. A heater coil 45 is wound around the heatable resistor 43 and is connected with the source of energy supplying the electrical control arrangement and indicated by the conventional plus and minus symbols in the diagram. The current continuously flowing through the heating coil 45 serves to heat up the heatable resistor 43 to a substantial temperature provided that the amount of air flowing through the suction duct 44 is comparatively small. Under these conditions the resistance of the heatable resistor 43 is low. If however the amount of air drawn in by the engine increases then the heatable resistor 43 is considerably cooled down to a lower temperature in which case its resistance is comparatively high.

The collector electrode C of the transistor T1 is connected with the solenoid coil 22 of the electro magnet 20 via the primary winding 51 of a feed back transformer 52 the secondary winding 53 of which is arranged in the connection between the potentiometer tapping contact 41 and the base electrode B of the transistor T1. The pertaining emitter electrode E is connected with the junction point between the fixed resistor 42 and the feedable resistor 43.

The same junction point is connected also with the emitter electrode E' of the other transistor T2 while the pertaining collector electrode C' is connected with the solenoid coil 23 of the second electro magnet 21 via the primary winding 55 of a second feed back transformer 56. The secondary winding 57 of this transformer is arranged in a connection between the tapping contact 41 of the potentiometer 40 and the base electrode B' of the transistor T2. It can be seen that the solenoid coil 22 is connected at its other end with the minus terminal of the source of electric energy, while the solenoid coil

24 is connected with its other terminal to the plus terminal of said source.

The tapping contact 41 of the potentiometer 40 is movable by mechanical connections indicated by a broken line 58 through the movement of the slide plate 18 of the throttle valve 17 in such a manner that the contact 41 is positioned in the neighborhood of the one end *e* of the potentiometer 40 when the valve 17 is in its minimum opening position, while contact 41 is positioned in the neighborhood of the opposite end *a* of the potentiometer 40 when the valve 17 is in its maximum opening position. By means of the above described mechanical interconnection between the slide plate 18 and the tapping contact 41 of the potentiometer an auxiliary control is established with the result that the two transistors T1 and T2 will interrupt their self-excited oscillation only when the above mentioned bridge circuit is in a balanced condition and at the same time the slide plate 18 of the valve 17 is so positioned that the amount of fuel ejected by the nozzles 15 is in the proper proportion to the amount of air measured by means of the heatable resistor 43.

In practice, the above described arrangement operates as follows: For the purpose of this explanation it may be assumed that at the start the bridge circuit is in balanced condition and that at the particular moment the proper amount of fuel which is to be supplied to the engine has been predetermined and fixed by a corresponding adjustment of the position of the slide plate 18 in the throttle valve 17. Under these conditions the combustion engine operates approximately in the middle area of its entire range of possible speeds, and at half load.

It has to be further assumed that in the air suction of supply channel or in connection with the manifold a butterfly valve 44a or the like is arranged for increasing or decreasing the stream of air into the engine. These means being entirely known are shown only diagrammatically in the drawing. If now by operating said butterfly valve 44a in the air supply duct the amount of air drawn into the machine to the engine increases the heatable and heated resistor 43 in the duct 44 is cooled down to a greater degree and a greater portion of the heat produced therein by the heating coil 45 is carried away. Thus the electric resistance of the heatable resistor 43 increases. Now the potential at the emitter electrode E of the transistor T1 is shifted towards more positive values until finally a positive potential differential is established between the emitter electrode E and the base electrode B of this transistor and in this direction, so that a small control circuit can flow from the emitter electrode to the base electrode of the transistor T1. Simultaneously a collector current J1 is generated which flows from the collector electrode C through the primary winding 51 and the solenoid coil 22 to the minus terminal. This collector current J1 induces during its rise a feed back voltage in the secondary winding 53 which latter is so polarized that with increasing collector current J1 the effective control voltage between the emitter electrode and the base electrode increases. It can be seen that on account of this feed back effect the collector circuit rapidly increases to substantial values and is capable to cause attraction of the armature 24 of the electro magnet 20. As explained above, this movement or stroke of the armature 24 causes via the mechanism 26 the slide plate 18 of the valve 17 to move a small distance in the valve 17 in direction of the arrow I whereby the cross sectional flow area in the valve is increased. Simultaneously, however, the movement of the plate 18 causes the tapping contact 41 of the potentiometer to move a small distance to the end *a* of the potentiometer 40.

As soon as the increase of strength of the current J1 has reached its maximum which is determined by the dimensions of the transistor T1 so that no feed back voltage can be induced any more in the secondary winding 53, the control current flowing from the emitter E to

5

the base B decreases and so does the collector current J1 which is proportional to said control current. The result of this is that in the secondary winding 53 a feed back voltage is induced which is directed in opposite direction and therefore returns the transistor T1 completely to its non-conductive condition. However as soon as the collector current J1 has decreased to approximately zero also the negative feed back voltage in the feed back winding 53 disappears.

It can be seen that if at this moment the movement of the tapping contact 41 of the potentiometer 40 has not sufficed to compensate an increase of resistance in the heatable resistor 43 due to an increase in rotational speed of the engine, then the above described cycle of operations may start again until finally with every such cycle the transistor T1 finally has injected so many impulses into the solenoid coil 22 that due to the corresponding consecutive steps carried out by the mechanism 26 and the plate 18, the tapping contact 41 is located again in a position in which the bridge circuit is balanced whereby the now again increased cross sectional flow area of the valve 17 is adjusted for furnishing the amount of fuel required for the now prevailing operating conditions of the engine.

If however the drawn-in amount of air, for instance by turning the above mentioned butterfly valve 44a in the air supply duct in direction A, has been reduced and therefore the heatable resistor picks up more heat due to a lesser cooling effect from the air stream with the consequence of decreasing resistance therein, then the bridge circuit is again changed into an unbalanced condition. In this case the transistor T1 remains in non-conductive or blocked condition. However the transistor T2 is now able to become conductive and in the same manner as described above in reference to the transistor T1 self-excited current impulses are supplied by this transistor to the solenoid coil 23 of the electro magnet 21 which impulses cause through the movements of the armature and the steps of stepping mechanism 26 the slide plate 18 of the valve 17 to move step by step in the direction of the arrow II and thus to reduce the cross sectional flow area of the valve, while simultaneously the tapping contact 41 of the potentiometer 40 is gradually moved towards the end e. The just mentioned current impulses repeat until the potentiometer tapping 41 reaches a position in which the balanced condition of the bridge circuit is reestablished and the slide plate 18 is in a position in which the amount of fuel ejected from the nozzles 15 has been adjusted to the changed amount of air passing in the duct 44.

Necessarily the heatable resistor 43 has a certain thermal inertia which prevents the above mentioned auxiliary control from following and responding immediately to a change in the amount of air drawn into the machine. Therefore it is advisable to provide an additional control element which would respond to changes in vacuum in the air duct, as is illustrated by Fig. 2. In this auxiliary device a variable resistor 50 is connected in series with the heatable resistor 43. The sliding contact 151 of this variable resistor is constructed at a two-arm lever and is tiltable about a pivot point 152 which is preferably adjustable. The free end of the lever 151 is connected by a connecting rod 154 with a vacuum-sensitive diaphragm 155 mounted in a window 156 of the suction duct 44. The air stream passes over the inner face of the diaphragm 155. However the diaphragm forms a partition between the duct 44 and a vacuum chamber 157 which is connected with the duct 44 by a small bypass and throttling slot 158.

If for instance the above mentioned butterfly valve 44a is suddenly turned in direction A into its closing position so that the amount of air streaming through the suction duct 44 suddenly decreases, then simultaneously the amount of vacuum in the duct 44 is greatly increased. Therefore the diaphragm 155 is bound to bulge in direction towards the interior of the duct 44 and thereby

6

causes by transmission of the connecting rod 154 a movement of the control lever 151 in such a manner that the effective resistance of the resistor 50 is decreased. Only when the pressure on both sides of the diaphragm 155 has been equalized due to the effect of the bypass slot 158 then the lever 151 returns into its normal position shown in Fig. 2. In the meantime the heatable resistor 43 could be reheated by the heater coil 45 to the extent that its resistance corresponds to the lower value corresponding to the amount of air now passing through the duct 44. It can be seen that by means of this differential arrangement the delay in response by the heatable resistor is compensated.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of fuel injection control devices differing from the types described above.

While the invention has been illustrated and described as embodied in electrically controlled fuel injection control devices, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

While the invention has been illustrated and described as embodied in electrical heating apparatus, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. Fuel injection device for internal combustion engines for adjusting the amount of preferably continuously injected fuel depending upon the drawn-in amount of air, comprising a fuel supply line including a fuel pump and at least one fuel injection nozzle and further including an overflow valve arranged in said fuel supply line and capable of maintaining constant pressure in said fuel supply line; an adjustable throttle valve arranged in said supply line between said pump and said nozzles; electrical control means for automatically adjusting said throttle valve, said control means comprising two electronic amplifiers capable of generating self-excited oscillations, the oscillation starting condition of said amplifiers being determined by the corresponding operative position of said throttle valve, one of said amplifiers being capable of moving said throttle valve into its closed position, the other one of said amplifiers being capable of moving said throttle valve into its open position; and variable resistor means connected in the control circuits of said amplifiers and operatively connected with said throttle valve for being adjusted to various resistance conditions depending upon the operative adjustment of said throttle valve.

2. Fuel injection device as set forth in claim 1, including a stepwise operating unidirectional drive mechanism operatively connected with said throttle valve for stepwise changing the position of the latter, said mechanism being actuated by either one of said two amplifiers.

3. Fuel injection device as set forth in claim 2, wherein said electric control means include a bridge circuit, one branch of said bridge circuit being constituted by said variable resistor means operatively connected with said throttle valve, the other branch of said bridge circuit including a second variable resistor means capable of being varied depending upon the operational condition of the internal combustion engine as determined by the in-

7

tensity of the air supply stream of said engine, and the bridge terminals carrying its diagonal potential being connected with the control circuit of at least one of said electronic amplifiers operatively connected with said throttle valve.

4. Fuel injection device as set forth in claim 3, in which said variable resistor means operatively connected with said throttle valve is constituted by a potentiometer.

5. Fuel injection device as set forth in claim 4 wherein said second variable resistor means is a heat responsive resistor located within the air supply stream of said internal combustion engine.

6. Fuel injection device as set forth in claim 5, including a heating coil assembled with said heat sensitive second variable resistor means for heating said second variable resistor means.

7. Fuel injection device as set forth in claim 6, wherein said heating coil is connected with a constant source of electric energy, and means for changing the intensity of the heating current passing through said heating coil depending upon the intensity of the air supply stream of said internal combustion engine.

8

8. Fuel injection device as set forth in claim 7 including a third variable resistor means connected in series with said heat sensitive second variable resistor means and capable of responding to the varying intensities of the air supply stream of said internal combustion engine.

9. Fuel injection device as set forth in claim 8, wherein said electric control means include, for each of said amplifiers, a respectively associated feed back transformer having a primary winding and secondary winding, said primary winding being arranged in the output circuit of the associated electronic amplifier, and said secondary winding being arranged in the control circuit of said associated amplifier, said means further including an electro magnet connected in series with said primary winding.

10. Fuel injection device as set forth in claim 9 wherein one of said amplifiers is a PNP-type transistor, the other one of said amplifiers being a NPN-type transistor.

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