

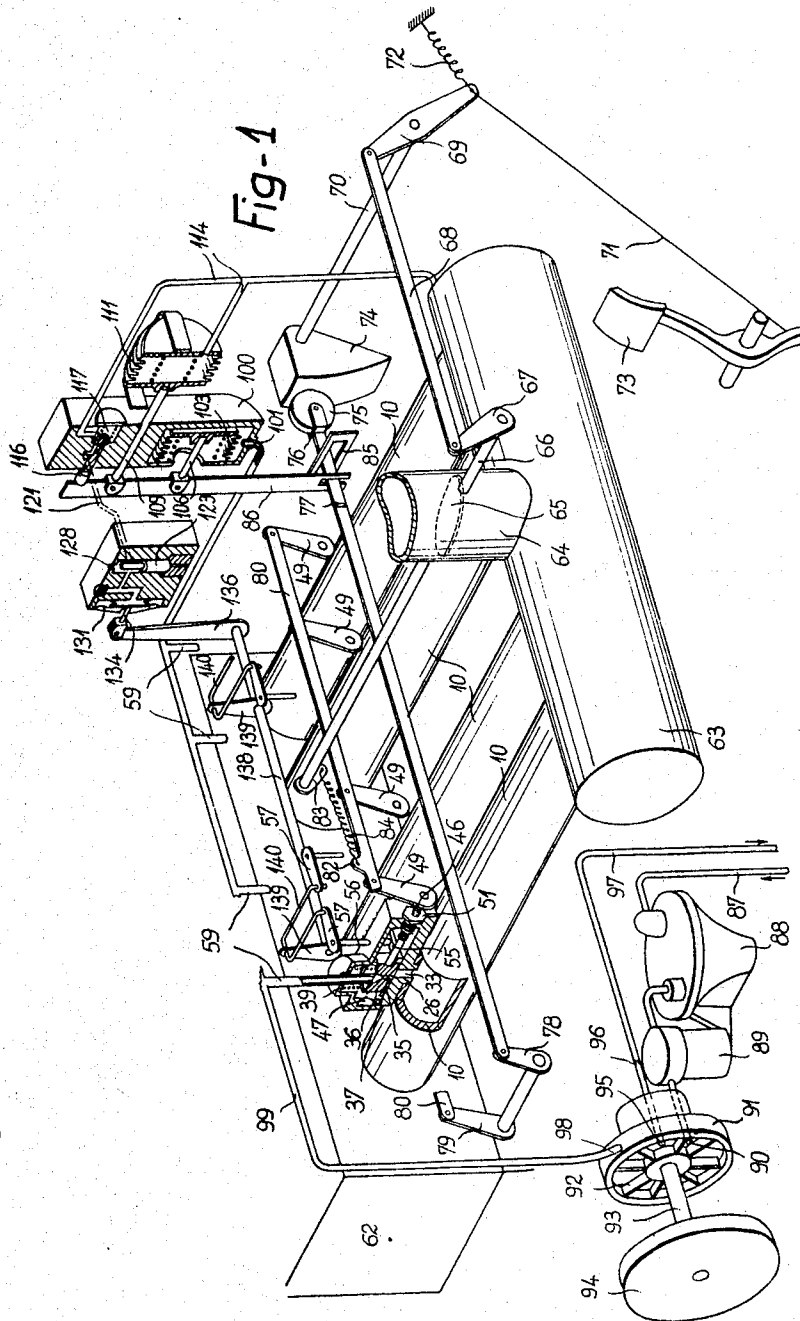
Jan. 17, 1967

G. DE COYE DE CASTELET  
LOW-PRESSURE FUEL INJECTION METERING DEVICES FOR  
INTERNAL COMBUSTION ENGINES

3,298,335

Filed Oct. 5, 1964

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig-2

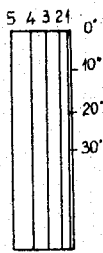


Fig-3

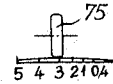
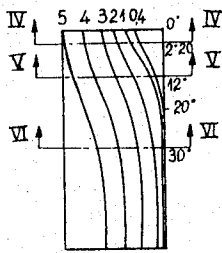


Fig-4

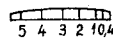


Fig-5

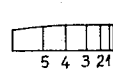


Fig-6

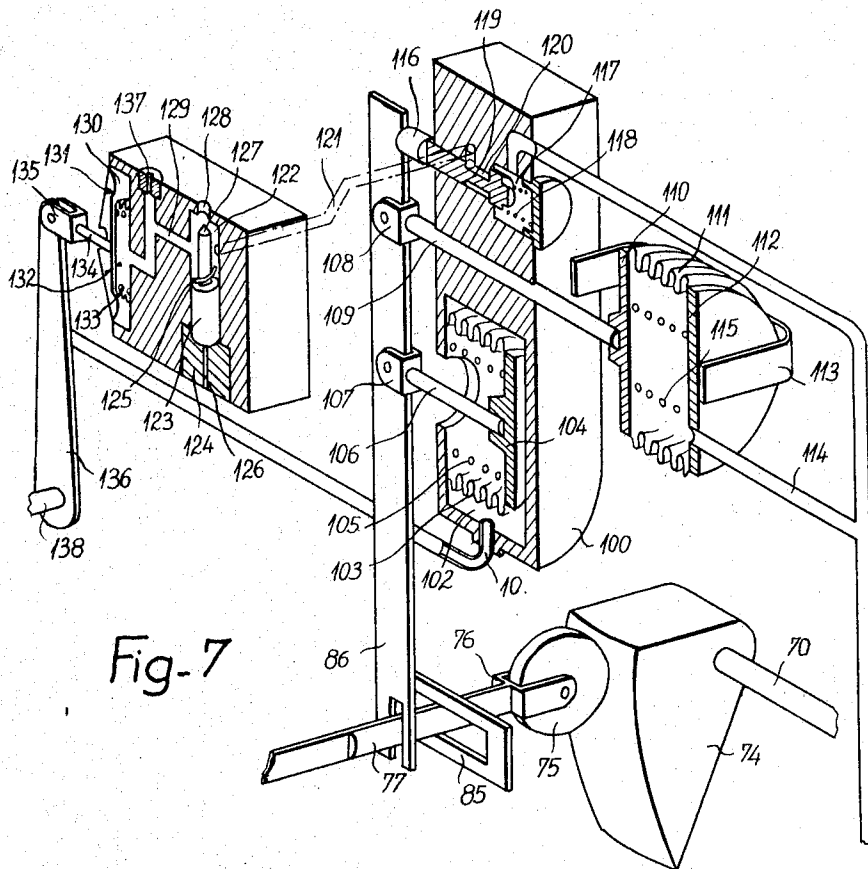


Fig-7

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3,298,335

**LOW-PRESSURE FUEL INJECTION METERING DEVICES FOR INTERNAL COMBUSTION ENGINES**

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Claims priority, application France, Oct. 14, 1963,

950,563, Patent 1,418,780

8 Claims. (Cl. 123—119)

It is already known to utilize low-pressure metering systems comprising a centrifugal pump for providing a pressure proportional to the square of the engine speed, whereby the flow rate through a calibrated hole is made proportional to the engine speed, and comprising also means for varying the cross-section of said calibrated hole as a function of the engine load. The combination of two separate speed and load laws will not always permit of precisely satisfying engine requirements, so that recourse has also been had to devices which, instead of combining two separate functions of these two "speed" and "load" variables, utilize a single function

$$Z=f(x \cdot y)$$

of these two variables, which variables are introduced into a three-dimensional cam, one of said variables controlling the rotation thereof, the other its translation, and the function being obtained by the displacement of a pushrod or a roller riding over the surface of said cam. Heretofore, this function has been utilized for controlling the adjustment element of a fuel injection pump, namely the toothed rack, the piston stroke, or the associated distributor.

Exclusive of these known general arrangements, the present invention relates essentially to a new low-pressure fuel injection metering device for internal combustion engines, comprising a feed pump supplying a centrifugal pump which continuously delivers the fuel, through an injection system of adjustable passageway cross-section, into the engine inlet tract downstream of a regulating butterfly-valve and upstream of the cylinder valves, characterized in that said passageway cross-section is adjusted by a control element co-operating with a three-dimensional cam whose rotation is linked to the control means of said air regulating butterfly-valve, said control element and said three-dimensional cam additionally co-operating by a relative translating motion governed by means responsive to the fuel pressure applied to the injection system and by means responsive to the negative pressure prevailing in the inlet tract downstream of said butterfly-valve, these latter-mentioned means being intended to provide a correcting effect at low engine speeds on the adjustment governed by the fuel pressure.

It will be manifest that, in such an arrangement, by a judicious choice of the centrifugal pump characteristics and without the need to segregate the injection orifice from negative pressures in the engine, i.e. without recourse to a secondary air inlet, it is possible, having regard for the resultant pressure through the injection orifice (which is the sum of the fuel pressure and the negative pressure in the inlet tract) and while at the same time using the negative pressure to correct variations in the fuel pressure (which is little affected by low engine speeds), to use a three-dimensional cam whose surface is substantially cylindrical. This facilitates execution of the cam and reduces sideway reactions to virtually negligible proportions, thereby permitting and justifying, precisely, the introduction of the speed parameter without any form of servo-control, preferably by utilizing the fuel pressure of the centrifugal pump.

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Such a form of execution is particularly well suited to injection systems operating individually on each engine cylinder but in which a common control element may be used.

Independently of the aforesaid adjustment control means, the present invention provides means for automatically and instantaneously shutting off the fuel injection under certain specific conditions which will be set forth in greater detail hereinbelow.

The invention further relates to the use of an injection system specifically adapted to such a control means and which was the subject of patent application in U.S.A., Ser. No. 377,932, filed by the applicant on June 25, 1964.

An embodiment of the invention will now be more particularly described, by way of example, with reference to the accompanying drawing, in which:

FIGURE 1 is a perspective overall view of the subject device of this invention, as used to equip an internal combustion engine;

FIGURE 2 is a developed view of the surface of the three-dimensional cam used in the specific instance where the regulating factor is the butterfly-valve rotation angle and the fuel pressure;

FIGURE 3 is a developed view of the surface of the three-dimensional cam in the case of utilization of the depression as an auxiliary adjustment factor;

FIGURES 4, 5 and 6 show in section through the radial planes IV—IV, V—V and VI—VI of FIGURE 3, the extra thicknesses of the three-dimensional cam over and above its basic cylinder; and

FIGURE 7 is a detail view on an enlarged scale of the device of FIGURE 1.

Upon an internal combustion engine cylinder head 62, shown as being of the four-cylinder type but which could be for any number of cylinders, is mounted an inlet manifold 63 having four separate inlet tracts 10 (one per cylinder) and an inlet pipe 64 bearing the butterfly-valve 65 mounted on its pivot 66. This pivot is rotated by a lever 67 connected through a link 68 to an equipollent beam-lever 69 mounted on a shaft 70 and itself controlled by the accelerator pedal 73 through a cable 71 in conjunction with a return spring 72.

The shaft 70 of lever 69 additionally supports a three-dimensional cam 74 over the surface of which rides a follower 75 carried in a clevis 76 secured to the end of a fairly long control rod 77. This rod 77 is guided as close as possible to the cam 74 by a slideway 85 arranged parallel to the shaft 70 and allowing the contact point of follower 75 to move over the entire width of the three-dimensional cam under the control of a lever 86 mounted on an adjustment corrector device 100 which will be described hereinafter. At its other end the rod 77 is pivotally connected to a lever 78 which is rigidly united with a motion amplifying lever 79 connected through a link 80 to four equipollent levers 49. These levers regulate the flow through the four fuel metering valves 26 which are of the type described in the applicant's patent application cited precedingly.

For a proper appreciation of the present invention it should be recalled that with this particular type of metering valve, the levers 49 rotate pushrod-screws 46 which, rotating inside locknuts 51, move the slide valves 36 (hereinafter referred to as "slides") against return springs 47, said slides being thrust against the faces 35 of the valve castings 26 by a spring 39. The calibrated orifice 37 of each slide 36 is more or less obturated by the edge of the port 33 according to the position of said slide. These orifices are supplied with fuel under pressure through flexible lines 59. These lines are connected to a main fuel line 99 extending tangen-

tially at 98 from a centrifugal pump 91 whose impeller 92 mounted on the shaft 93 is driven by a pulley 94 at a speed proportional to the engine speed. This pump is supplied from a conventional feed pump 88 (or from a centrifugal pump immersed in the fuel tank), via a filter 89 and an orifice 90 which is offset with respect to the impeller shaft. The orifice 95 of a fuel, gas, or air return line 97 is located at the center of the pump 91; this line is fitted with an adjustable jet 96 and leads back into the tank.

After joining with the lines 89, the fuel delivery line 99 opens by its orifice 101 into the lower chamber 102 of corrector 100. In this chamber 102 a bellows 103 sustains the fuel pressure on its outside, its inside communicating with the atmosphere. The bellows end 104 bears against a spring 105 and is connected through a rod 106 and a clevis 107 to the lever 86. A second clevis 108 pivotally connected to lever 86 a little higher up is connected through a rod 109 parallel to rod 106 to the movable end 110 of a second bellows 111 whose other end 112 is held rigidly connected to the main casting of the corrector 100 by a yoke 113. This fixed end communicates through a pipe 114 with the inlet manifold 63 in which prevails the depression created by the butterfly-valve 65. This depression also prevails inside bellows 111 and is countered by a spring 115. Still further up the lever 86, a piston 116 bears thereagainst, its associated rod sliding in a cylindrical hole formed in corrector 100. Piston 116 extends into a cylindrical cavity 117 of larger diameter than that of the piston housing and within which a return spring 118 thrusts the piston 116 against the lever 86. This cavity 117 is maintained at the same negative pressure as the inlet manifold, through a pipe 114. The piston 116 comprises a reduced section 119 substantially midway along its length that consequently bounds a further cavity 120 which communicates through a duct 121 with a third cavity 122 formed in a block associated to the corrector 100. Inside the cavity 122 a differential piston 123 is normally applied against the plug 124 by its return spring 125, atmospheric pressure being continuously exerted against the end of this piston through the duct 126. The piston 123 has its upper end terminating in an obturator 127 which, when the piston rises, is adapted to seal the hole 128 in response, say, to a pressure below the atmospheric pressure prevailing in the cavity 122. This cavity 122 also communicates through a duct 129 with a chamber 130 which is closed by a diaphragm 131 clamped by two plates 132 which bear on the one hand against a spring 133 and are connected on the other hand by a rod 134 and a clevis 135 to a lever 136. The chamber 130 is continuously vented to the open atmosphere via a calibrated jet 137. Through a shaft 138, the lever 136 controls further levers 139 which, through the agency of hairpin links 140, act upon levers 57 and ultimately upon the levers 55 through the medium of the shafts 56. The ends of the levers 55 are adapted to thrust against the slides 36 concurrently with the screws 46 and in opposition to the springs 47.

The system hereinbefore described functions in the following manner:

As the engine runs, it rotates its feed pump 88 and its centrifugal pump 91. The fuel is drawn from the tank and delivered by the feed pump at a moderate pressure (of the order of one meter of fuel, say) into the centrifugal pump. By virtue of the non-central location of the outlet 90, there is formed, above a certain speed of about 1500 r.p.m., a cylindrical separation surface which bounds in the center of the centrifugal pump a cylinder devoid of liquid and in which collect air and fuel vapour which is evacuated through the central hole 95 and the pipe 97 back into the tank. Below said speed the centrifugal pump fills up with fuel to a greater or lesser extent and the jet 96 inserted into the return pipe 97 maintains a minimum pressure in the pump. This jet does not

hinder the passage of the gas under normal running conditions.

A certain fuel pressure is thus established in the distribution line 99, and this pressure is the sum of the feed pump and centrifugal pump pressures and is consequently strictly determined for any given engine speed. The law of variation of the pressure as a function of the speed is not quite a square law because of the relatively high and fairly constant pressure of the feed pump; this, however, is not unduly important, since to come as close as possible to a square law is useful only insofar as it enables the three-dimensional cam to be made fairly flat.

The pressure in the line 99 is transmitted through the connecting pipes 59 to the metering valves and to the free sections of the orifices 37. By design, these injection cross-sections are always equal to one another; indeed, constantly equal flow rates can be ensured by initially adjusting the locknuts 51. When the system is operating the slides 36 are always displaced by an equal amount since the screws 46 have rigorously equal pitches and their control levers 49 rotate through rigorously equal angles. Lastly, the diameters and flow coefficients of the orifices 37 are made exactly equal.

Under given operating conditions these equal flow rates must bear a determinate relationship to the air flows, though this relationship need not necessarily be the same under all operating conditions.

The parameters affecting the respective flow rates are the following:

Fuel—

- (a) The fuel pressure on the injection orifices.
- (b) The absolute air pressure beneath the injection orifices.
- (c) The viscosity of the fuel.
- (d) The injection cross-section.

Air—

- (a) The butterfly-valve setting.
- (b) The engine speed.
- (c) The air pressure ahead of the butterfly-valve.
- (d) The air temperature ahead of the butterfly-valve.
- (e) The relative humidity of the air ahead of the butterfly-valve.

When the vehicle is running the driver exerts instantaneous control over the butterfly-valve setting. On the other hand, the instantaneous balance achieved between engine torque and road reactions affects the engine speed. The butterfly-valve setting and the engine r.p.m. are consequently independent of each other.

Moreover, environmental conditions of pressure, temperature and relative humidity never vary instantaneously in the case of propulsion on land and will therefore at first be assumed to be constant. In addition, the viscosity of gasoline is very low and varies very little under the anticipated conditions of use and will therefore also be assumed to be constant.

The remaining variables are therefore:

- (a) The fuel pressure  $P$ .
- (b) The depression  $\Delta H$ .
- (c) The injection cross-section  $X$ .
- (d) The butterfly-valve setting  $\alpha$ .
- (e) The engine speed  $\omega$ .

$X$  must be determined such that

$$X = f(P, \Delta H, \alpha, \omega)$$

But  $\alpha$  and  $\omega$  are independent variables; also, as has already been seen,

$$P = f'(\omega), \text{ or } \omega = \phi(P)$$

It is further known that, on the previous assumption of constant environmental conditions, the depression  $\Delta H$  will depend on  $\alpha$  and  $\omega$ .

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Thus

$$H=f''(\alpha, \omega)$$

Whence

$$X=F(\alpha, \omega)$$

or

$$X=\phi(\alpha, P)$$

This justifies the use of a mechanism which defines the injection section as a function of the butterfly-valve setting and the fuel pressure, by means of a three-dimensional cam 74 whose angular displacement  $\alpha$  is the same as that of the butterfly-valve 65 and in which the transverse position of the follower 75 is determined by the fuel pressure P by means of the bellows 103 and the amplifying lever 86, the pivotal connection thereonto of the clevis 108 being assumed to be provisionally fixed. As FIGURE 1 clearly shows, the depthwise displacement of the follower 75 is faithfully transmitted to the slide 36. The injection section X is therefore an exact function of the degree of penetration of the follower 75 and hence of the variables  $\alpha$  and P, or, again, of  $\alpha$  and  $\omega$ . Since P and  $\Delta H$ , which act on either side of the injection orifice, are clearly defined, the fuel flow rate must also be clearly defined.

By causing  $\alpha$  and  $\omega$  to vary separately it is then possible to define all points on the three-dimensional cam, thereby enabling the same to be constructed. Reference to FIGURE 2 shows the development of such a cam, on which the reference numerals 1 through 5 designate the engine speed grid from 1000 to 5000 r.p.m. and on which the angle of rotation of three-dimensional cam, which is a function of  $\alpha$  is indicated in degrees. This particular profile reveals low sensitivity at the lower speeds, resulting in accentuated slopes, sideway reactions on the follower 75, and consequent poor definition in the region of idling speeds.

A notable original complementary feature of the invention consists in distorting this speed grid by characterizing the speed variable not merely by the variable P which depends on it alone, but also by adding to P a more or less large fraction of the variable  $\Delta H$  which depends on both  $\alpha$  and  $\omega$ . For each value of  $\alpha$  it is possible to represent  $\omega$  by

$$KP+K'\Delta H$$

which, as FIGURE 3 shows, gives a greatly improved cam surface development wherein the sensitivity in the idling zones is extremely good and wherein sections taken through radial planes reveal only very slight bulge, as FIGURES 4, 5 and 6 clearly show. This addition is effected in simple manner by placing the depression-sensitive bellows 111 in circuit, which bellows displaces the previously stationary clevis 108 in such manner that provided that the sections of the bellows 103 and 101 are equal, that the springs 105 and 115 have the same flexibility, and that the elongations produced are  $a$  and  $b$ , the speed abscissae of the three-dimensional cam be

$$\frac{a}{b}P+\frac{a-b}{b}\Delta H$$

for each value of  $\alpha$ . It can be seen that sideway reactions of the cam on the follower are very small and that the equilibrium of the lever 86 remains for all practical purposes undisturbed by these reactions.

It is to be noted that the follower 75 is continuously biased against the three-dimensional cam by the spring 84, one end of which is attached to a lobe 82 on the link 80 interconnecting the fuel valve control levers and the other end of which is attached to the end of a lever 83 mounted on an extension of the air butterfly-valve shaft 66. The movements sustained by the ends of this spring differ very little from each other, so that the length of the spring 84 varies very little and it is thus possible to choose a cam follower contact pressure that varies very

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little between the limits of operation. In addition, any backlash in the various pivotal connections is consequently automatically taken up.

As is well known, it is preferable to cut off the fuel flow when the foot is lifted from the accelerator and to allow only a trickle flow for idling. This can also be worthwhile in cases of very poor efficiency, an example being for a small butterfly-valve opening and high speed (without realizing it, the driver is then obliged to open the butterfly-valve a little more). Naturally, all these points are materialized on the three-dimensional cam and such fuel shut-offs could be achieved by thinning down the cam at these points until total closure of the slides is obtained through the medium of their control screws 46. However, there are a number of drawbacks attached to this method: firstly, it would be necessary to lengthen the travel of the screw 46, which would be detrimental to its sensitivity in normal operation; secondly, it is absolutely indispensable that such shut-offs be instantaneous, as incorrect combustion would otherwise occur at shut-off and when opening up once more; this in turn would result in the surface of the cam being too sharply indented at the fuel shut-off point, thus causing the follower to become jammed against this indent when the driver wishes to accelerate the engine once more.

Accordingly, an energetic servo-motor is utilized wherein the driving impulse is the depression itself (which is always strong when the power is cut off) and in which the criterion is a further combination

$$K''P+K'''\Delta H$$

in which the depression is in this case preponderant. This is the reason why the sensing function is again effected on the lever 86, though above the clevis 108, by the piston 116 whose axis is at a distance  $c$  from the axis of the rod 109. Said piston, which is continuously biased against lever 86 by return spring 118, consequently moves in obedience to the law:

$$\frac{b+c}{b}\Delta H+\frac{c}{b}P$$

in which  $\Delta H$  is invariably preponderant and in which the greater the value of  $c$  the greater the influence of the fuel pressure (and hence of the speed). The choice of the value  $c$  will therefore be determined firstly by the need not to shut off (or restore) the flow below a certain speed (1200 or 1500 r.p.m.) and also by that area of the table of engine equiconsumption curves which it is desired to eliminate.

The piston 116 initiates shutting off or restoring of the flow in the following manner:

The depression  $\Delta H$  normally prevails in the cavity 117 and atmospheric pressure prevails on both sides of the diaphragm 131, and notably in the chamber 130 and the compartments 122 and 120. The spring 133 normally urges the diaphragm 131 rearwardly and, through the agency of the intermediate members 134, 135, 136, 138, 139, 140, 57, 56, the levers 55 are kept well clear of the slides 36 in all slide positions normally adjusted by the screws 46 and the springs 47.

As the depression  $\Delta H$  and the speed increase, the piston 116 is thrust further inward. A stage is ultimately reached wherein the thinned down section 119 protrudes slightly into the cavity 117. Nothing happens however for a time, since the slight suction effect into the cavity 122 is easily satisfied through the hole 128 and the depression produced therein is therefore very small and does not destroy the equilibrium of the piston 123 or of the diaphragm 131. If, however, the sum

$$\frac{b+c}{b}\Delta H+\frac{c}{b}P$$

continues to increase, the piston 116 moves still further inward and opens the passageway between the cavities 120 and 117 a little more, resulting in the equilibrium

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position of the piston 123 being displaced slightly through an increase in the depression. As the piston 123 rises it closes the hole 128 to some extent, which further increases the depression, which in turn closes the hole 128 a little more, and so on, as a result of which the hole 128 is finally closed sharply by the obturator 127. This in turn produces a sudden increase in the depression behind the diaphragm 131 which, through the agency of the various intermediate members, causes the levers 55 to move the slides 36 from their positions adjusted by their respective screws 46 and to compress their springs 47 until they reach stops positioned so that the holes 37 be hermetically sealed off by the valve faces 35. Fuel is then no longer admitted into the engine. A small auxiliary air intake, however, remains regulated by the calibrated jet 137 which for all practical purposes leaves the depression unaffected as long as the piston 116 is thrust inward sufficiently to uncover an adequate passageway section between the cavities 117 and 120.

Conversely, as soon as the piston 116 reduces the passageway between cavities 117 and 120 sufficiently, due to a diminution of the function

$$\frac{b+c}{b}\Delta H + \frac{c}{b}P$$

the air introduced through the jet 137 becomes preponderant and the depression is reduced in the cavities 130 and 122. A stage is then reached when the spring 125 thrusts away the piston 123 slightly, thus uncovering the hole 128 and destroying the equilibrium, which in turn causes the piston 123 to drop and atmospheric pressure to suddenly prevail in the chamber 130. Through the agency of the various members referred to preceding, this causes instant withdrawal of the levers 55 and the immediate return of the slides 36 by their springs 47 against the screws 46 which, having at all times followed a pattern of motion set by the three-dimensional cam 74, will instantly locate the slides 36 in their correct adjustment positions.

I claim:

1. In a low-pressure fuel injection metering device for internal combustion engines having a feed pump supplying a centrifugal pump which delivers the fuel continuously through an injection system of adjustable passageway section which injects the fuel into the engine inlet tract at a point located downstream of an air regulating butterfly-valve and upstream of the cylinder valves, the improvement comprising control means for adjusting said passageway section, a three-dimensional cam cooperating with said control means for regulating same, the control for said butterfly-valve being operatively connected to said cam to control the rotation thereof, first responsive means responsive to fuel pressure applied to said injection systems, second responsive means responsive to the negative air pressure prevailing in the inlet tract downstream of said butterfly-valve, said first responsive means and said second responsive means adapted to control a relative translational motion between said cam and said first control means in response to changes in said fuel pressure and said negative air pressure.

2. The improvement of claim 1 wherein said translatory motion is effected by movement of said control means with respect to said cam.

3. The improvement of claim 1 further comprising an adjustment member operatively connected to each of said responsive means and to said control means to effect said translatory motion.

4. The improvement of claim 1 wherein said injection system comprises, independently of said control means, a second control means for instantaneously covering and uncovering said passageway section as a function of said negative air pressure and of said fuel pressure, said second control means being activated by a release member on which said first and second responsive means act jointly.

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5. The improvement of claim 1 wherein said second control means comprises a depression type control chamber having means for venting the same to the atmosphere under the control of an equilibrium-destroying obturator responsive to the depression susceptible of prevailing in said chamber, which chamber is sealed off by said obturator at a negative pressure determined by said release member.

6. The improvement of claim 1 wherein an injection system is provided for the inlet tract of each engine cylinder, said injection systems having a common control element.

7. The improvement of claim 1 wherein said injection system comprises a slide-valve which comprises a calibrated jet supplied with fuel and which slides over a stationary valve face having formed therein an orifice of larger cross-section for fuel injection into the inlet tract and of which the degree of overlap by said jet determines the fuel flow cross-section, the translation of said slide-valve being controlled by a threaded pushrod against a countering spring and said threaded pushrod being rotated through the agency of said control element governed by said three-dimensional cam.

8. In a low-pressure fuel injection metering device for internal combustion engines having a feed pump supplying a centrifugal pump which delivers the fuel continuously through an injection system of adjustable passageway section which injects the fuel into the engine inlet tract at a point located downstream of an air regulating butterfly-valve and upstream of the cylinder valves, the improvement comprising control means for adjusting said passageway section, a three-dimensional cam cooperating with said control means for regulating same, the control for said butterfly-valve being operatively connected to said cam to control the rotation thereof, first responsive means responsive to fuel pressure applied to said injection systems, second responsive means responsive to the negative air pressure prevailing in the inlet tract downstream of said butterfly-valve, said first responsive means and said second responsive means adapted to control a relative translational motion between said cam and said first control means in response to changes in said fuel pressure and said negative air pressure; said injection system comprising independently of said first control means, a second control means for instantaneously covering and uncovering said passageway section as a function of said negative air pressure and of said fuel pressure, said second control means being activated by a release member on which said first and second responsive means act jointly; said injection system further comprising a slide-valve which comprises a calibrated jet supplied with fuel and which slides over a stationary valve face having formed therein an orifice of larger cross-section for fuel injection into the inlet tract and of which the degree of overlap by said jet determines the fuel flow cross section, the translation of said slide-valve being controlled by a threaded pushrod against a countering spring and said threaded pushrod being rotated through the agency of said first control means governed by said three-dimensional cam at the same time as said slide valve is subjected to said second control means.

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