FUEL-AND-AIR CONTROLS FOR INTERNAL-COMBUSTION ENGINES

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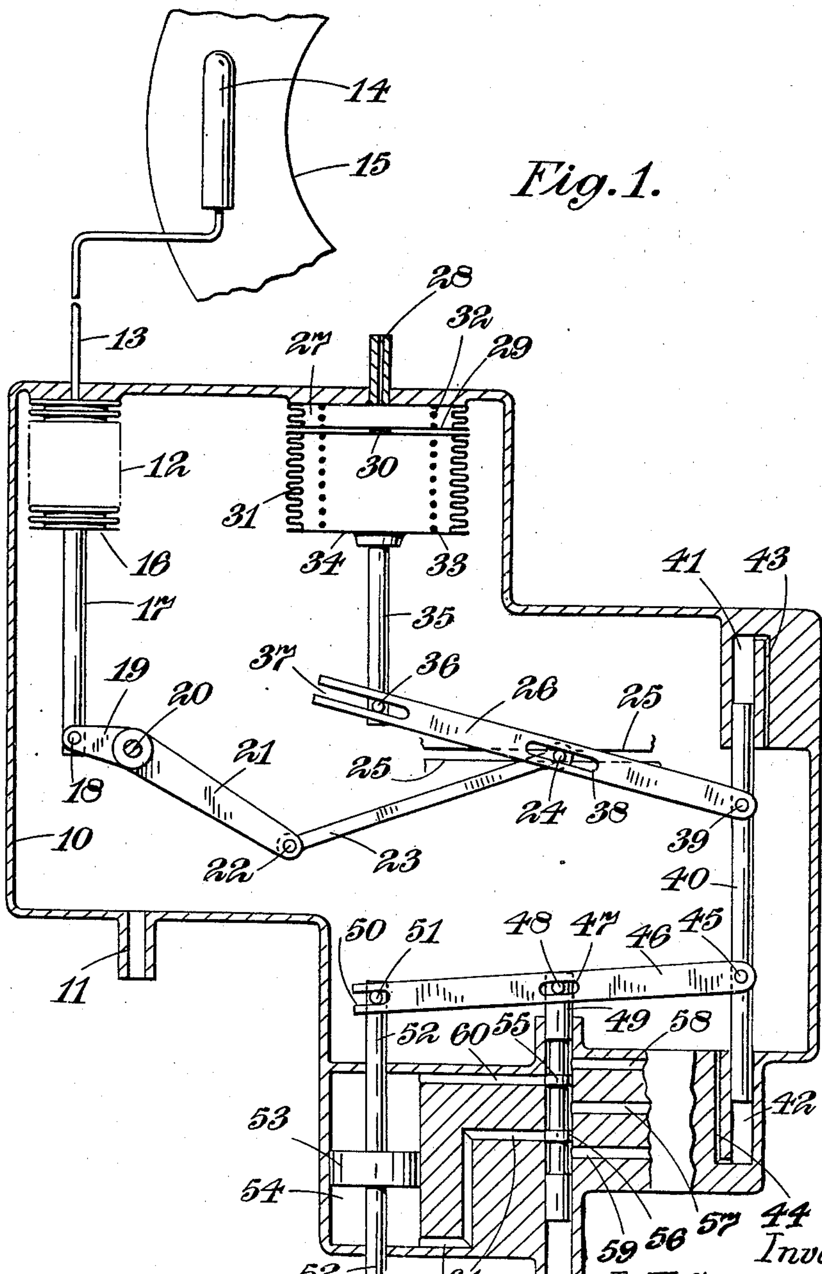
Fig. 1.



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Dec. 15, 1942. L. F. G. BUTLER ET AL 2,305,070

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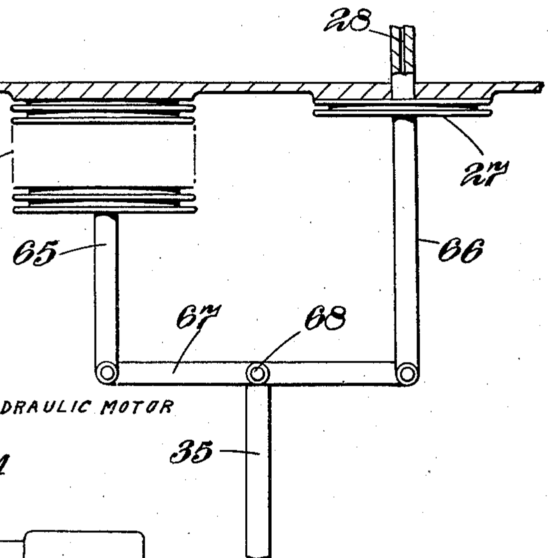
Fig. 2.



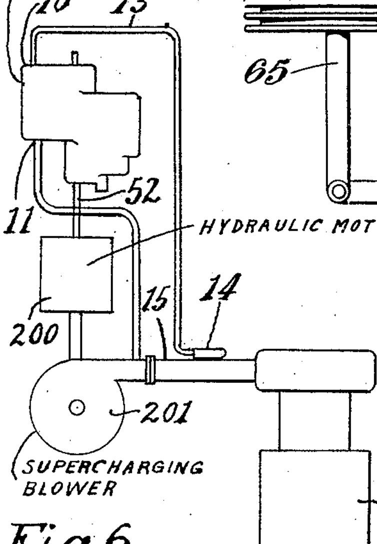
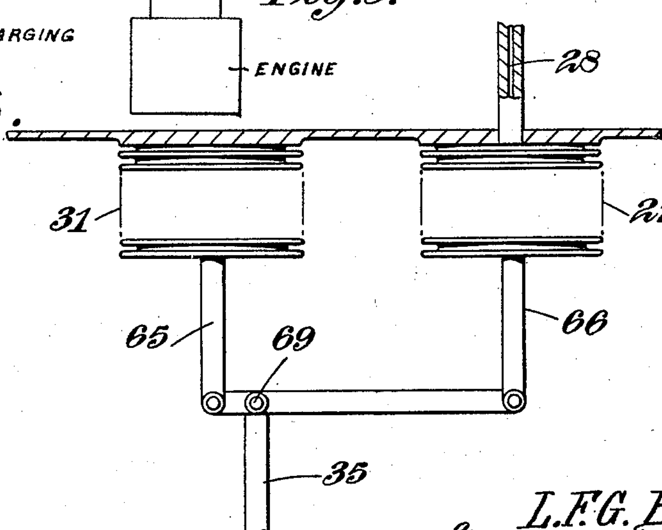


Fig. 6.

Fig. 3.



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FUEL-AND-AIR CONTROLS FOR INTERNAL-COMBUSTION ENGINES

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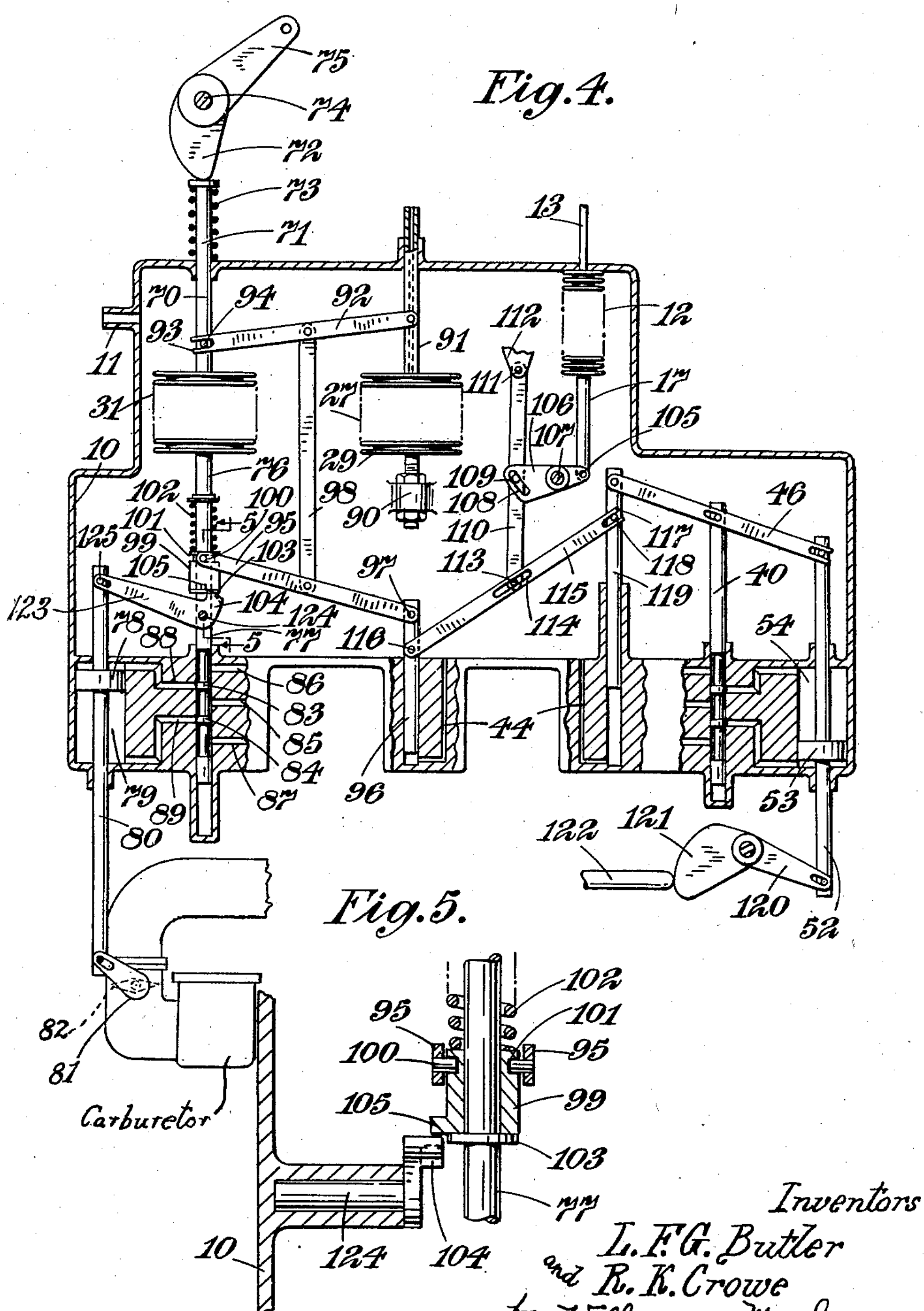
Fig. 4.

Fig. 5.



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Patented Dec. 15, 1942 2,305,070

UNITED STATES PATENT OFFICE

2,305,070

FUEL-AND-AIR CONTROL FOR INTERNAL-COMBUSTION ENGINES

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Application May 20, 1940, Serial No. 336,302
In Great Britain August 17, 1939

10 Claims. (Cl. 123—119)

This invention relates to fuel-and-air controls for internal-combustion engines and has for its object to maintain the proper ratio between the mass of fuel and the mass of air admitted to the cylinders of the engine despite variations in the density of the air in the induction system of the engine. The invention is thus of particular application to aircraft engines and, moreover, is primarily concerned with engines of the kind in which liquid fuel is delivered either to the cylinders or into the induction system near the cylinder-inlet ports by a metering pump driven by the engine. Alternatively, the fuel may be injected into the intake of a supercharging blower.

In order that the ratio between the mass of fuel and the mass of air admitted to the engine cylinder shall have a predetermined value, it is necessary that the mass of fuel should be proportioned in relation to the mass of the air taken into the cylinder during the induction stroke of the piston.

The mass of the air taken into the cylinder depends upon the pressure and temperature of the air supplied to the inlet ports and upon the mass of residual gas remaining in the cylinder from the preceding power stroke, which depends upon the back-pressure against which the exhaust gases are discharged. This back-pressure, for a given design of engine and exhaust system, will depend upon the circumambient atmospheric pressure.

According to one feature of the invention, means for automatically maintaining a predetermined ratio between the mass of fuel and the mass of air admitted to the cylinder of an internal-combustion engine comprises a temperature-responsive device exposed to the air delivered to the cylinder, a pressure-responsive device exposed to the pressure of the air admitted to the cylinder, a pressure-responsive device exposed to the pressure of the circumambient atmosphere, and an operative connection between the three said devices and means for adjusting the fuel-to-air ratio, whereby a predetermined mixture strength is automatically maintained despite the variables hereinbefore referred to.

The ratio between the mass of the residual gas in the cylinder and the mass of fresh air admitted depends not only upon the pressure of the circumambient atmosphere but also upon the pressure of the air admitted to the cylinder. The pressure-responsive device exposed to the atmosphere and referred to above is therefore preferably exposed also to the pressure of the air admitted to the cylinder so as to respond to the difference between these pressures. The pressure of the air admitted to the cylinder is not necessarily equal to, and will ordinarily differ from the atmospheric pressure, particularly in the case of a supercharged engine. The pressure of the air admitted to the cylinder is hereinafter termed the "boost-pressure." The temperature of the air admitted to the cylinder is termed the "boost-temperature."

It is to be understood that the expression "a predetermined mixture strength" does not necessarily mean that the mixture strength remains constant for all working conditions of the engine. For example, it is found in aircraft engines that a comparatively rich mixture is desirable for idling conditions and for conditions of maximum power, a weaker mixture being more suitable for intermediate or cruising conditions. Moreover, a control may be superimposed upon the automatic control in order to weaken the mixture during cruising conditions.

The degree of control required in respect of the residual gases is proportional to the unswept volume or compression space of the cylinder whereas the degree of control required in respect of variations in the boost-pressure is proportional to the swept volume. The pressure-responsive device exposed to the difference between the atmospheric pressure and the boost-pressure is therefore so arranged, according to the invention, as to have an effect, in relation to the degree of control exerted by the responsive device exposed to the boost-pressure, which is equal to the ratio between the unswept and swept volume of the cylinder. Various means, whereby the necessary difference between the effects of the two responsive devices is obtained, are described below.

According to another feature of the invention, a pressure-responsive device exposed to the boost-pressure may also constitute the pressure-responsive device of a servo-actuated throttle-control in which a pressure-responsive device exposed to the boost-pressure is connected through a relay to the engine throttle-valve so that, for a given datum-setting of the pressure-responsive device, any departure of the engine boost-pressure from a predetermined value causes movement of the device which, through the relay, adjusts the position of the throttle-valve whereby the boost-pressure is corrected. The corrected boost-pressure acts upon the pressure-responsive device to restore it and the part of the relay it controls to their datum positions. The datum position of the pressure-responsive device may be adjusted by a manually-operated cam or other means. Thus, for a given setting of the cam, the servo-control maintains a definite boost-pressure irrespective of the altitude at which the engine is operating, for all altitudes up to what is termed the "rated" altitude at and above which, at full-throttle, increase of altitude will produce a drop of boost-pressure.

According to another feature of the invention, movements of the pressure-responsive device produced by changes of boost-pressure are transmitted to the means for adjusting the mixture strength through a floating linkage.

According to another feature of the invention, the said pressure-responsive device is connected at one end to one member of the linkage and at the other end, through a resilient connection which provides lost-motion, to another member of the linkage and an abutment obstructs the movement of the said member when the datum of the device is shifted so as to open the throttle. The consequent increase of boost-pressure, after a short delay, restores the second member of the linkage, and therefore the mixture-strength setting, to a position depending upon the boost-pressure. The consequent relative movement between the two members of the linkage which occurs before the boost-pressure has had time to build up to the value determined by the setting of the datum-varying cam produces an early enrichment, as is desirable during acceleration, and the usual "accelerator pump" is thus dispensed with. The said abutment is preferably interconnected with the throttle-valve so as to be inoperative when the valve is fully open. Thus the automatic control of mixture strength is maintained for all throttle conditions above the rated altitude.

In view of the necessity for exposing at least two pressure-responsive devices to the boost-pressure, the said devices, according to the invention, are preferably enclosed within a sealed casing the interior of which is connected to the engine induction system. To reduce to a minimum the number of external connections from the interior of the said casing, the casing may also include the linkage through which the pressure-responsive devices act upon a servo-motor which effects adjustments of the mixture strength, and also the servo-motor itself. The said casing may also include the moving part of the temperature-responsive device. Where, as above described, the boost-pressure responsive device also constitutes the pressure-responsive device of the servo-actuated throttle-control, the hydraulic relay through which the said device operates the throttle may also be contained in the same casing.

Alternatively, the linkages referred to may be situated outside the sealed casing.

Two specific embodiments of the invention will now be described, by way of example, with reference to the accompanying diagrammatic drawings, of which:

Figure 1 shows mixture-control apparatus, according to the invention, for use in conjunction with a supercharged aircraft engine in which the fuel is injected by metering pumps either into the cylinders or into the induction pipes adjacent the inlet ports,

Figures 2 and 3 are diagrams showing alternative arrangements of the boost-pressure capsule and atmospheric capsule,

Figure 4 is a diagram of an arrangement alternative to Figure 1 in which the apparatus incorporates a variable-datum boost-control,

Figure 5 is a section on the line 5—5 of Figure 4, to an enlarged scale, and

Figure 6 is a diagrammatic view showing the control unit coupled in the engine fuel system.

As shown first in Figure 1 the apparatus comprises a sealed casing 10 of suitable shape to enclose the parts hereinafter described, the interior of the casing being connected through a union 11 to the discharge side of the supercharging blower 201. Thus, the "atmosphere" within the casing is at a pressure which is always equal to the boost-pressure.

The casing contains a "temperature-capsule" 12 the interior of which is connected by a capillary tube 13 to a phial 14 in the outlet conduit 15 from the supercharging blower. The capsule 12 is an expansible receptacle anchored at its top end to the casing 10. The capsule, capillary tube 13 and phial 14 are filled with a suitable liquid such as alcohol, ether, or benzol so that the free lower end 16 of the capsule takes up a position which, at all times, corresponds to the boost temperature. The bottom end 16 of the temperature capsule 12 is connected by a rod 17 to a pin 18 carried by one arm 19 of a lever pivoted about an axle 20, the other arm 21 of the lever being pivoted at 22 to a link 23 of which the other end carries a pin 24 which is constrained by means of suitable guides 25 to move in a straight horizontal line. The pin 24, which forms a fulcrum for a lever 26, thus takes up a position in the guides 25 which at all times corresponds to the boost temperature.

The casing 10 also contains an atmospheric capsule 27 the upper face of which is anchored to the casing and the interior of which communicates through a vent 28 with the circumambient atmosphere so that the bottom face 29 of the atmospheric capsule takes up a position corresponding to the difference between the atmospheric pressure within it and the boost-pressure outside it.

Connected by a short rod or link 30 to the lower face 29 of the atmospheric capsule 27 is a boost-pressure capsule 31 which is evacuated so as to be influenced only by the boost-pressure by which it is surrounded. The capsules 27 and 31 may be of a resilient nature or they may be provided with internal springs 32, 33, respectively.

As has already been explained, it is necessary that the effect of the atmospheric capsule 27 should be less than the effect of the boost-pressure capsule 31 in the same ratio as the ratio of the unswept volume of the engine cylinder to the swept volume. The necessary effect may be obtained, as shown in Figure 1, by making the capsule 27 smaller than the capsule 31 in the required ratio. For example, where the engine has a compression ratio of 7, the boost-pressure capsule 31 may have a volume six times as great as that of the atmospheric capsule 27. Alternative arrangements are described below with reference to Figures 2 and 3. In any event, the arrangement is such that a variation in boost-pressure produces a displacement of the bottom end 34 of the boost-pressure capsule 31 which is greater than the displacement produced by the same variation in the difference between atmospheric pressure and boost-pressure, by the same ratio as the ratio of the swept volume to the compression space. It will be seen that this ratio is less by unity than the compression ratio of the engine.

The bottom 34 of the boost-pressure capsule 31 is connected to a rod 35 to the lower end of which a pin 36 is affixed to engage the forked end 37 of the lever 26. This lever is slotted at 38 to engage the pin 24 already described, and the other end of the lever is pivoted at 39 to a vertical sliding-rod 40 the upper end of which slides in a bore 41 and the lower end in a bore 42, the bores being formed in integral parts of the casing and each being connected with the interior of the casing by a conduit 43, 44, respectively, to permit the rod 40 to slide freely in them.

As has already been explained, the rod 35 moves in such manner that its position corresponds at all times to the absolute boost-pressure. The fulcrum-pin 24 moves so that its position corresponds to the boost temperature; the sliding-rod 40 therefore takes up a position which at all times corresponds to the mass of fresh air contained in the engine cylinder at the end of the induction stroke.

At another point on the sliding-rod 40 it is connected by a pivot-pin 45 to a lever 46 which is slotted at 47 to engage a pin 48 on the upper end of a control-valve 49; the rod 46 is forked at its left-hand end 50 to engage a pin 51 carried by the piston-rod 52 of a hydraulic motor 200 of which the piston 53 slides in a cylinder 54. The valve 49 has lands 55, 56, which co-operate with a pressure-port 57, drain-ports 58, 59, and motor-ports 60, 61, the ports 60 and 61 leading respectively to the top and bottom of the motor-cylinder 54. The piston-rod 52 passes out of the casing at the lower end and is connected by a mechanical linkage (not shown) to any known means for controlling the delivery-per-stroke of a fuel-injection pump or pumps.

For stable conditions of operation the lands 55, 56, close the ports 60 and 61 whereby the piston 53 remains stationary and is prevented from moving by the oil or other hydraulic liquid contained in the cylinder 54. If, for any reason, the boost temperature rises, the capsule 12 expands, the lever 19, 21, is rotated in a counter-clockwise direction, the pin 24 is moved to the right, the lever 26 rocks about the pin 36 so as to raise the sliding-rod 40. The piston-rod 52 being held stationary for the time being, the lever 46 rotates about the pin 51 so as to raise the valve 49. Consequently, the port 60 is opened to pressure oil from the port 57 and the port 61 is placed in communication with the drain 59. The piston 53 is therefore driven down, the mechanism to which it is connected being so arranged that downward movement of the piston decreases the mass of fuel injected per stroke so as to compensate for the decrease in density of the air which the rise in temperature has caused. Such downward movement of the piston 53 rocks the lever 46 about the pivot 45 so as to restore the valve 49 to the position shown in Figure 1 in which the ports 60 and 61 are closed. Conversely, a fall in the boost temperature would cause the piston 53 to rise and thereby increase the mass of fuel injected per stroke.

Any change in the density of the air admitted to the engine cylinders resulting from a change in the altitude of flight or a change in the throttle-opening similarly causes a suitable correction to the adjustment of the fuel pumps by rotation of the lever 26 about the fulcrum-pin 24 and the consequent movement of the valve 49, corresponding movement of the piston 53 and follow-up movement of the lever 46 and valve 49 as already explained above. The piston 53, valve 49 and link 46 constitute a servo-motor of known form, follow-up movements being transmitted from the piston to the valve by tilting movements of the lever 46 about the pin 45, whereby the motor-piston 53 assumes at all times a position corresponding to the position of the sliding-rod 40.

Instead of connecting the atmospheric capsule 27 and the boost-pressure capsule 31 together end-to-end, as shown in Figure 1, the capsules may have separate rods 65 and 66, as shown in Figure 2, each pivotally connected to one end of a floating link 67 of which the mid-point is pivoted by a pin 68 to the rod 35 of Figure 1. In Figure 2 the capsules 31 and 27 have volumes of which the ratio is equal to the compression ratio of the engine minus one.

In yet another arrangement, as shown in Figure 3, the capsules 31 and 27 may be identically similar so that the movement of the rod 65 due to a change in boost-pressure is equal to the movement of the rod 66 due to a change in the difference between boost-pressure and atmospheric pressure. In order that the displacement of the rod 66 shall be reduced in the required ratio with respect to movements of the rod 65, the operating-rod 35 is pivoted to the floating link 67 at a point 69 which is six times as far from the right-hand end of the lever 67 as it is from the left-hand end, assuming that the compression ratio of the engine is seven, as before.

In the alternative form of the invention shown in Figures 4 and 5 the sealed casing 10, boost-pressure union 11, temperature-capsule 12 and hydraulic-motor 53, 54, are provided as before. The boost-capsule 31, however, is formed with two rods one extending from each end. From its upper end a rod 70 extends through a suitable gland in the casing 10 to constitute a tappet 71 which is spring-pressed upwardly against a datum-varying cam 72 by a compression spring 73. The cam is rotatable on a shaft 74 by means of a lever 75 manually operable by the pilot. From the lower face of the capsule 31 a rod 76 (termed the "valve-rod") extends downwardly to constitute the controlling valve 77 of a hydraulic relay comprising a piston 78 reciprocable in a cylinder 79. The piston-rod 80 of the relay is connected by suitable mechanism 81 to the throttle-valve 82 of the engine. The valve 77 is formed with lands 83, 84, co-operating with a pressure-port 85, drain-ports 86, 87, and motor-ports 88, 89, which lead to the top and bottom respectively of the cylinder 79.

The boost-capsule 31, cam 72 and relay 77, 78, constitute a servo-system which operates to maintain constant the boost-pressure for any given setting of the cam 72. For example, if the boost-pressure should fall, the capsule 31 will expand, the rod 76 will move down, the valve 77 will open the motor-port 89 to the pressure-port 85 and the motor-port 88 to the drain-port 86 so that the piston 78 will be driven upwardly. Such movement will be transmitted through the mechanism 81 to open the throttle-valve 82 whereby the boost-pressure will be increased and the capsule 32 collapsed to its original size, whereupon the valve 77 will be restored to its original closed position. A different controlled boost-pressure is obtainable at the will of the pilot by appropriate adjustment of the cam. However, at altitudes above what is termed the "rated altitude" of the engine, the boost-pressure obtainable at full throttle will decrease with increase in altitude. The atmospheric capsule 27, in this movement, is anchored to the casing by being fixed at its bottom face 29 to a suitable lug or bracket 90. The top face is connected to a tube 91 which extends through a suitable gland in the casing 10, the tube 91 admitting atmospheric pressure to the interior of the capsule 27. The capsules 31 and 27 are of such relative volume, or their springs are of such rate, that the effects of the two capsules bear the same ratio to one another as the ratio of the swept volume of the engine cylinder to the unswept volume. Any of the methods above described for ensuring that this ratio is obtained can be used in the arrangement of Figure 4.

A link 92 is pivoted to the tube 91 and at its other end 93 is forked to engage a pin 94 on the tappet-rod 70. A similar link 95 extends between the valve-rod 76 of the boost-pressure capsule 31 and a guide-rod 96 which slides in a suitable bore in an integral part of the casing 10, the link 95 being connected to the guide-rod 96 by a suitable pivot-pin 97. In a manner explained below the guide-rod 96 is connected, through a suitable relay, to means for varying the mass of fuel injected into the engine cylinder or induction system. The mechanism has superimposed upon it the action of the temperature-capsule 12 as in the case of Figure 1. The midpoints of the links 92 and 95 are interconnected by a third link 98.

The link 95 is not directly connected to the valve-rod 76 of the boost-pressure capsule but is formed with pins 100 to engage a peripheral groove 101 in a collar 99 which is slidable on the rod 76, being pressed downwardly by a compression spring 102, movement in this direction being limited by a flange 103 on the rod 76. An abutment 104 (described more fully below) obstructs movement of the collar 99 downwardly beyond a position corresponding to the closed position of the valve 77, by engaging with a tooth 105 carried by the collar 99 as shown in Figure 5.

The two links 92 and 95 are always approximately parallel with one another so that bodily movement of the boost-pressure capsule 31 in either direction merely rocks the link 92 about the pivot on the tube 91 and the link 95 about the pivot 97. But expansion or contraction of the boost-pressure capsule rocks the links 92 and 95 with respect to one another whereby the guide-rod 96 is moved up or down, the altitude capsule 97 constituting the abutment for such movement.

When the datum-varying cam 72 is adjusted in such sense as to increase the throttle-opening, the boost-pressure capsule 31 is shifted bodily downwards, as above explained, the link 92 being thereby rotated. But the collar 99 is held against movement by the abutment 104 so that the links 92 and 95 experience relative movement. The fuel-and-air mixture is thus disproportionately enriched for the time being. However, the consequent increase in boost-pressure restores the valve 77, after a short interval, to its original position whereby the mixture strength is again controlled in accordance with boost-pressure, boost-temperature and atmospheric-pressure. As is known, such enrichment of the mixture strength during acceleration is desirable and the arrangement above described has the advantage, already explained, of enabling the usual "accelerator pump" to be dispensed with.

Any convenient arrangement may be used for imposing the effect of the temperature-capsule upon the relay-piston 53. As shown in Figure 4, the rod 17 of the temperature-capsule is pivoted at 105 to a lever 106 rotatable on a fixed axle 107 and formed with an arcuate slot 108. The slot co-operates with a pin 109 carried on a swinging link 110 pivoted at 111 to a fixed part 112. The lower end of the link 110 carries a pin 113 engaging a slot 114 in a lever 115, the left-hand end of which is pivoted at 116 to the guide-rod 96. The right-hand end of the lever 115 is forked at 117 to engage a pin 118 on a sliding-rod 119 which operates in exactly the same manner as the sliding-rod 40 of Figure 1, being pivoted to the follow-up lever 46 of the hydraulic relay which comprises a control-valve 49 and the necessary ports and conduits already described with reference to Figure 1. The piston-rod 52 may operate a lever 120 which controls a cam 121 and follower 122 such that movements of the follower towards the left increases the supply of fuel and vice versa.

It will be understood that the angular position of the link 110, and thus the position of the fulcrum-pin 113, depends upon the boost temperature. As explained above, the vertical position of the guide-rod 96 corresponds to the pressure of the air existing in the engine cylinder at the end of the induction stroke and thus the sliding-rod 119 and relay-piston 53 always assume positions corresponding to the mass of the fresh air existing in the engine cylinder at the end of the induction stroke.

The abutment 104, above referred to, is constituted by the end of a lever 123 having an axle 124 borne in the casing 10 as shown in Figure 5. The other end of the lever engages by a pin-and-slot connection 125 with the piston-rod 80. The portion 104 is of such shape that when the piston 78 is at its uppermost position, corresponding to full throttle-opening, the tooth 105 is free to move down with the rod 76 under the action of the spring 102. It will be understood that, for conditions above the rated altitude of the engine, the follow-up action of the boost-pressure capsule 31 on the valve 77 is suspended when the throttle is fully open since the boost-pressure cannot be increased to such value as would restore the parts to the position shown in Figure 4. Thus, the valve 77 can assume a position in which the underside of the piston 78 is permanently open to pressure-liquid. In this condition of the parts, if the abutment 104 were to remain operative upon the tooth 105, the disproportionate enrichment of the mixture strength above referred to would be continuously maintained. By rendering the abutment automatically inoperative as above described, the automatic control of mixture strength is maintained for all throttle conditions including throttle conditions above the rated altitude.

It may be necessary to compensate for the difference which occurs between the temperature of the air delivered by the supercharger to the cylinder and the temperature of the air in the cylinder at the end of the induction stroke. If so, the temperature-capsule 12 may be interconnected with the fulcrum-pin 24 (Figure 1) or 113 (Figure 4) through the intermediary of suitable cam-mechanism. For example, the slot 108 in Figure 4 may be so designed as to provide the necessary compensation.

In each of the embodiments above described, the desired fuel-to-air ratio for each working condition of the engine is obtained by suitably designing the connection between the servo-motor **53** and the fuel-pumps. Manually-controlled departures from the automatic control may be obtained by means of a manually-adjustable ported sleeve surrounding the valve-member **49**.

The datum-varying cam **72** in Figure 4 may be of the form described in British patent specification No. 482,441.

We claim:

1. Apparatus for automatically maintaining a predetermined ratio between the mass of fuel and the mass of air admitted to the cylinder of an internal-combustion engine, comprising a temperature-responsive device exposed to the air delivered to the cylinder, a pressure-responsive device exposed to the pressure of the air admitted to the cylinder, a pressure-responsive device exposed to the difference between the atmospheric pressure and the boost-pressure and so arranged as to have an effect, in relation to the degree of control exerted by the responsive device exposed to the boost-pressure alone, which is equal to the ratio between the unswept and swept volumes of the cylinder, means for adjusting the fuel-to-air ratio and an operative connection between said temperature-responsive device, said pressure-responsive devices and said adjusting means.

2. Apparatus for automatically maintaining a predetermined ratio between the mass of fuel and the mass of air admitted to the cylinder of an internal-combustion engine, comprising a temperature-responsive device exposed to the air delivered to the cylinder, a pressure-responsive device exposed to the pressure of the air admitted to the cylinder, a pressure-responsive device exposed to the pressure of the atmosphere, means for adjusting the fuel-to-air ratio, an operative connection between the three said devices and the said adjusting means, and a servo-operated throttle-control of which the pressure-responsive device is constituted by the first said pressure-responsive device.

3. Apparatus for automatically maintaining a predetermined ratio between the mass of fuel and the mass of air admitted to the cylinder of an internal-combustion engine, comprising a temperature-responsive device exposed to the air delivered to the cylinder, a pressure-responsive device exposed to the boost-pressure, a pressure-responsive device exposed to the difference between the atmospheric pressure and the boost-pressure, means for adjusting the fuel-to-air ratio, and an operative connection between the three said devices and the said adjusting means and a sealed casing pressure within which is maintained by the boost-pressure of the engine, the said pressure-responsive devices being enclosured within the said casing.

4. Apparatus for automatically maintaining a predetermined ratio between the mass of fuel and the mass of air admitted to the cylinder of a supercharged aero engine comprising a supercharging blower, a sealed casing, a conduit connecting said casing to the discharge side of the supercharging blower, a temperature capsule (with one end fixed in said casing) the temperature-responsive element of which is disposed in the discharge of the supercharging blower, an atmospheric capsule with one end fixed in said casing, a conduit connecting said capsule with the atmosphere, a boost pressure capsule disposed within said casing, a linkage operatively connected to the moving parts of each of the three capsules, adjusting means for controlling fuel delivery to the engine and an operative connection between the said linkage and said adjusting means.

5. Apparatus for automatically maintaining a predetermined ratio between the mass of fuel and the mass of air admitted to the cylinder of a supercharged aero engine comprising a supercharging blower, a sealed casing, a conduit connecting said casing to the discharge side of the supercharging blower, a temperature capsule (with one end fixed in said casing) the temperature-responsive element of which is disposed in the discharge of the supercharging blower, an atmospheric capsule with one end fixed in said casing, a conduit connecting said capsule with the atmosphere, a boost pressure capsule disposed within said casing, a linkage operatively connected to the moving parts of each of the three capsules, adjusting means for controlling fuel delivery to the engine, an operative connection between the said linkage and said adjusting means and a servo-operated throttle control of which the pressure-responsive device is constituted by the said boost pressure capsule.

6. In combination, a control means for the fuel-injection pump of an internal combustion engine, temperature-response means subject to the air constituent, density-response means also subject to the air constituent, and connections between said temperature and density response means and the control means including a common member coupled at one side positively to the control means and at the other side loosely to both response means independently.

7. In combination, a control means for the fuel-injection pump of an internal combustion engine, temperature-response means subject to the air constituent, density-response means also subject to the air constituent, and connections between said temperature and density-response means and the control means including a common lever coupled at one side positively to the control means, lost-motion couplings between said connections and said lever to enable the operation of the control device through said lever independently from either of said connections.

8. In combination, a control means for the fuel-injection pump of an internal combustion engine, temperature-response means subject to the air constituent, density-response means also subject to the air constituent, connections between said temperature and density response means and the control means including a lever coupled at one side positively to the control means, lost motion couplings between said connections and said lever acting as variable fulcrums for the lever coacting conjointly to shift either fulcrum independently by its respective response means and thereby alter the effective throw of the lever in its operation by the other response means.

9. In combination, a control means for the fuel injection pump of an internal combustion engine, density-response means subject to the air constituent, atmospheric-response means, and connections between said density and atmospheric response means and the control means so constructed and arranged that the control means is operable from either response means independently of the other response means, datum-varying means for shifting said density-response means with reference to its connection, said last mentioned connection being loosely connected to said density-response means.

10. In combination, a throttle valve of an internal combustion engine, a control means for the throttle valve, a hydraulic relay coupled to the fuel-injection pump of the engine, temperature-response means subject to the air constituent, connections between said temperature-response means and said hydraulic relay, density-response means also subject to the air constituent, atmospheric-responsive means, connections between the density and atmospheric response means and the throttle valve control means, said connections having a loose coupling to the density-response means, resilient means for taking up normally said loose coupling, and datum varying means for shifting said density-response means in respect to said loose coupling.

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