

July 16, 1935.

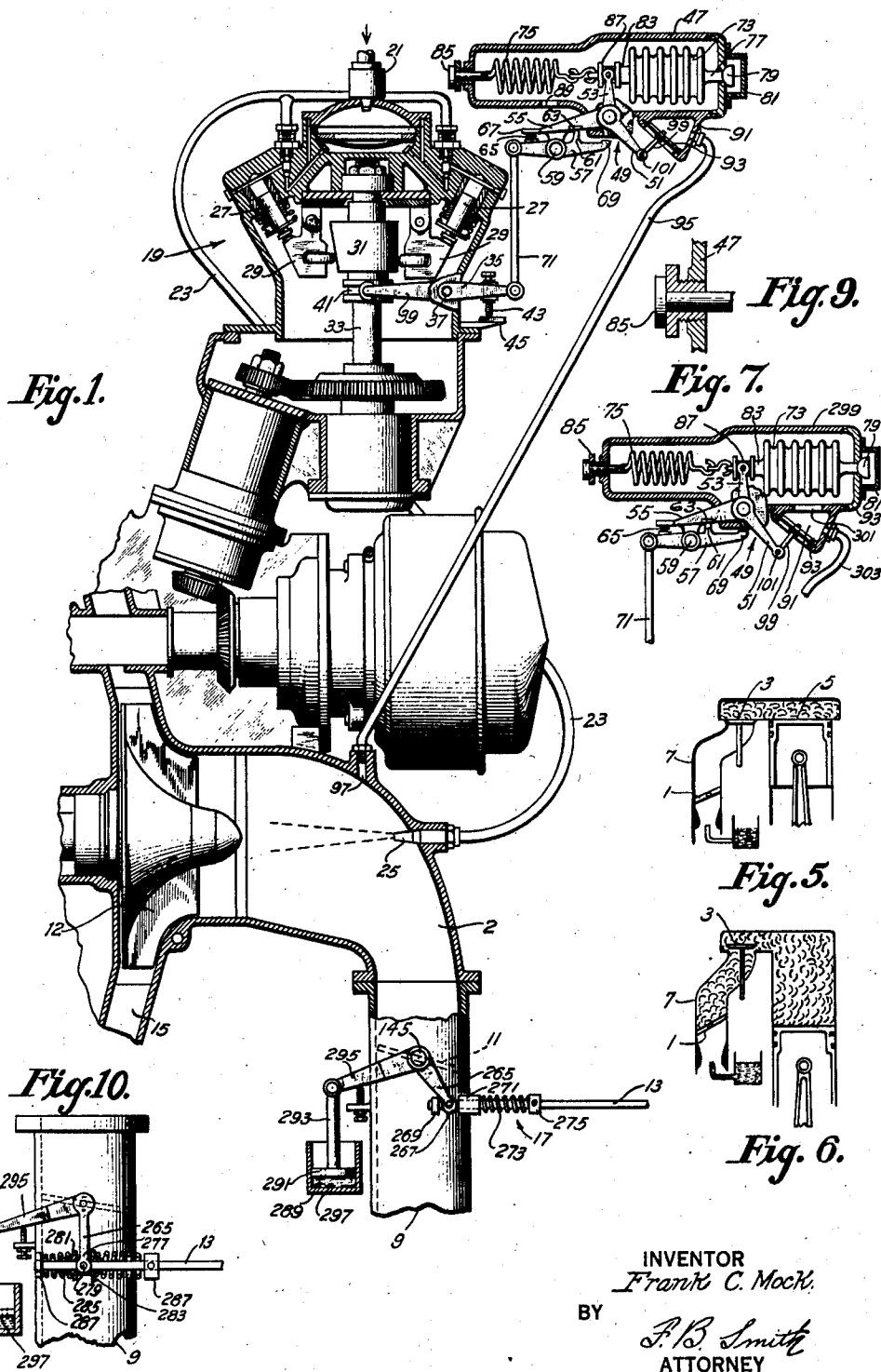
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2,008,143

FUEL FEED CONTROL

Filed June 22, 1931

4 Sheets-Sheet 1



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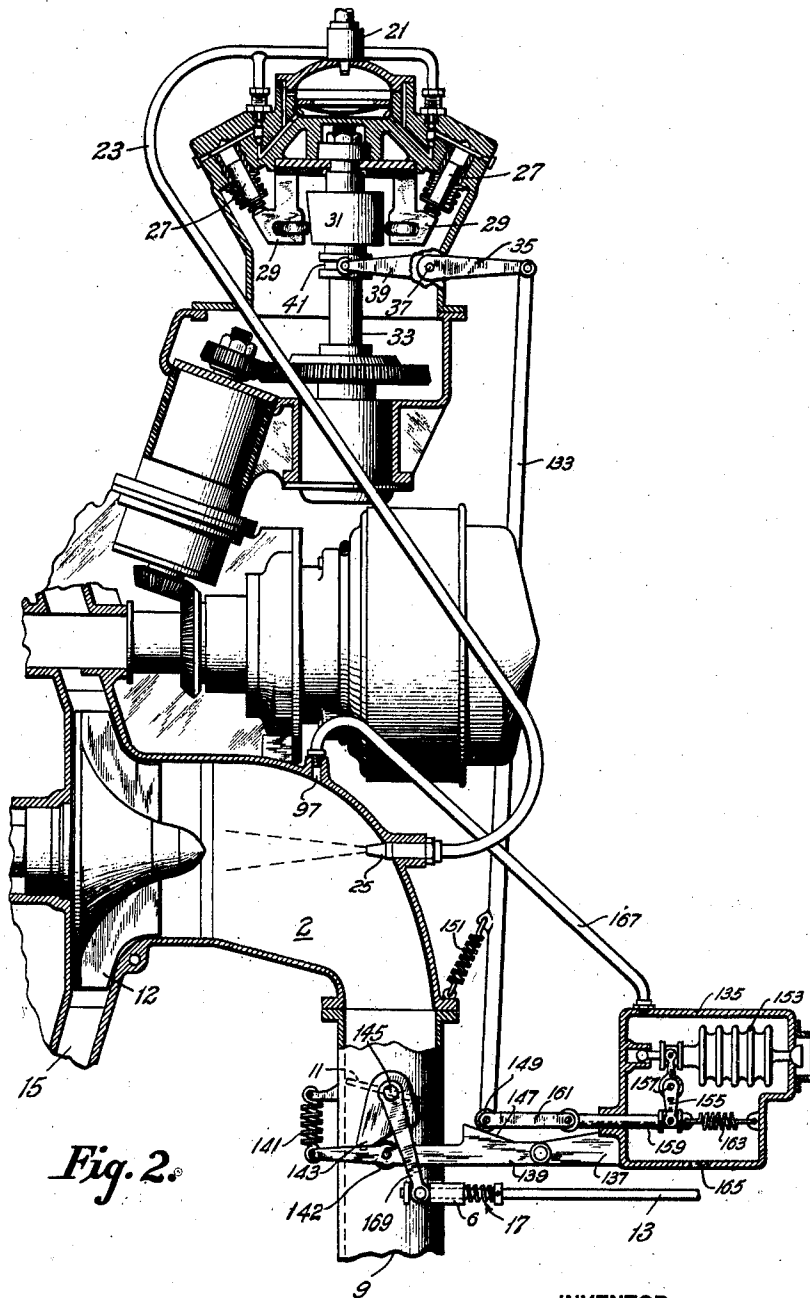
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Filed June 22, 1931

4 Sheets-Sheet 2



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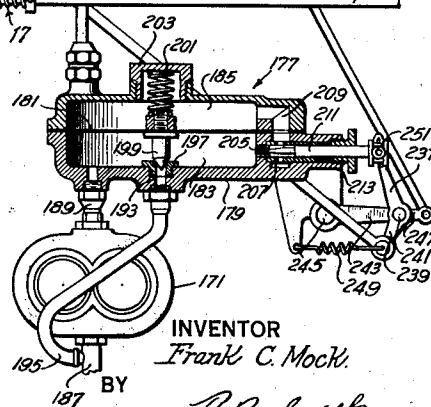
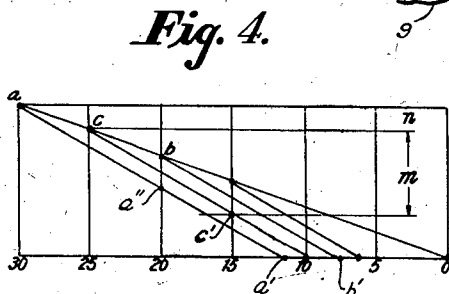
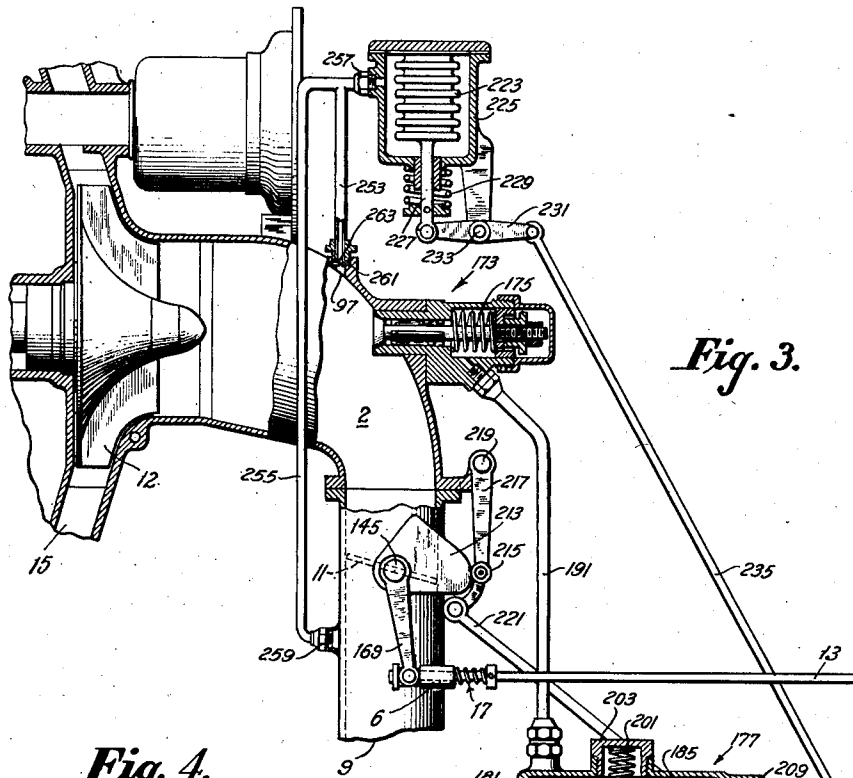
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FUEL FEED CONTROL

Filed June 22, 1931

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July 16, 1935.

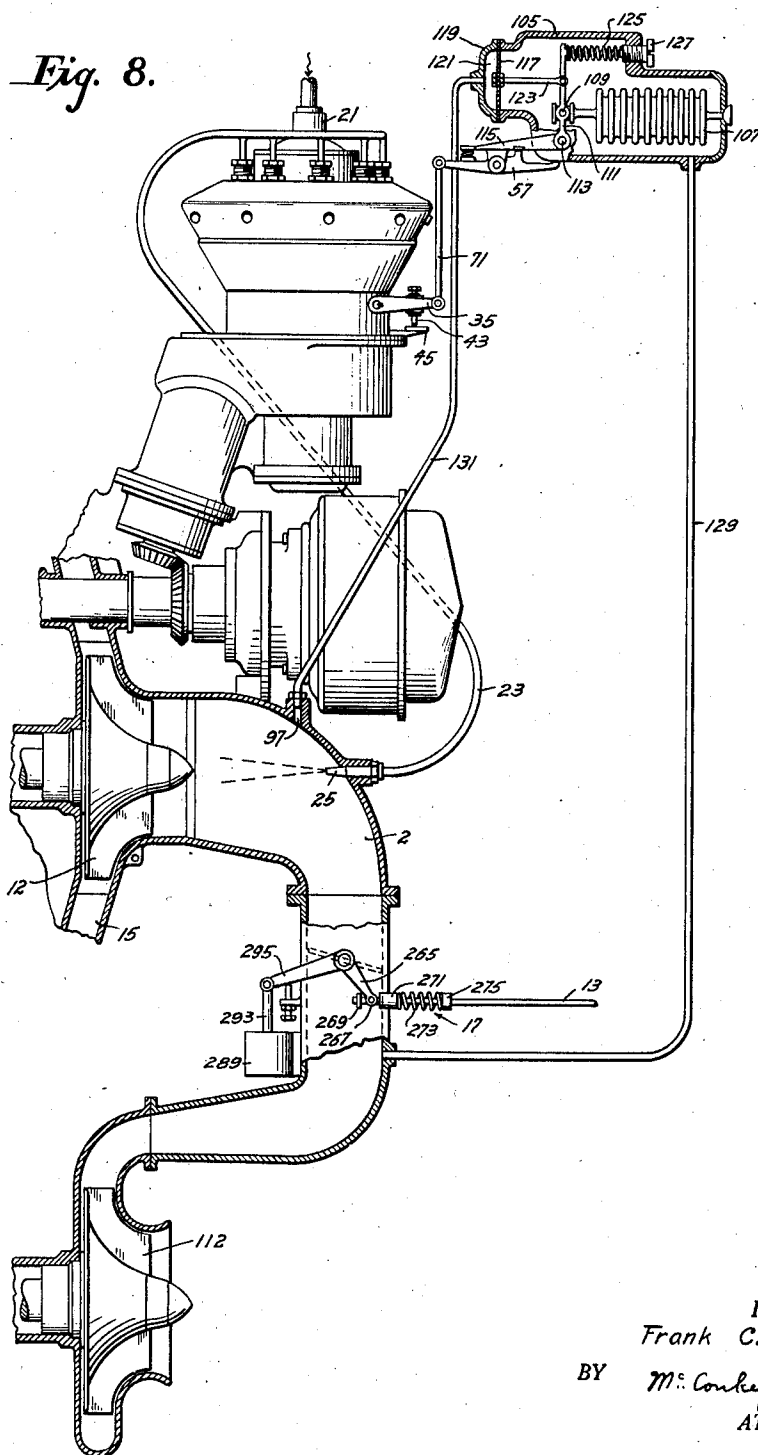
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FUEL FEED CONTROL

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4 Sheets-Sheet 4



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2,008,143

FUEL FEED CONTROL

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Application June 22, 1931, Serial No. 546,122

48 Claims. (Cl. 123—75)

The invention relates generally to fuel-feeding systems or apparatus for internal combustion engines, and more especially to novel and improved means or systems for supplying liquid fuel to the air charge by pressure positively applied to the fuel, in distinction from carbureting the intake air in a carburetor. A principal use contemplated is in connection with engines of types in which the mixture is formed externally of the cylinder, and is ignited by spark, in distinction from compression-heat ignition, although the mode of ignition per se does not affect the invention-devices.

Although not limited to such uses, the invention is especially valuable in application to aircraft engines, wherein the problem of properly metering fuel delivered by pump or like action to the intake air at a point anterior to the combustion chamber, is greatly complicated by the air pressure variations caused by changes in elevation of the aircraft from sea level to high altitudes, as well as by air pressure variations in the mixing space or "manifold" caused by changes of throttle position, both of which factors affect the weight of the air charge in different ways, as will appear.

The general object of the invention is to supply to such engines under the varying operating conditions, a mixture of combustible proportions, to maintain the air-fuel ratio approximately constant when so desired, and/or to vary the proportions as is desirable under certain conditions.

Typical suction operated carburetors have the capacity to proportion the mixture approximately satisfactorily under the various air-service conditions; but in the absence of a suction operated carburetor and with pump or analogous fuel supply, an inventive problem is involved in practically controlling the air-fuel proportion.

A principal object of the invention is to provide in fuel supply systems of the character defined, fuel proportioning means which will operate automatically and keep the mixture approximately uniform, and/or to vary the proportions within the desired ranges in some cases, thus largely or entirely relieving the operator of the necessity to arbitrarily manipulate or readjust the fuel mechanism while flying, and making this general mode of fuel supply commercially practical.

In a system of the stated character, in attempting to automatically control the fuel supply, in the absence of a carburetor and the inherent capacity of air flowing through such an instrument to take up fuel in approximately proper proportions, it is necessary to utilize other forces than air-flow to effect fuel proportioning; and a prin-

cipal feature of the invention is the utilization of variations of pneumatic pressure occurring at different altitudes and at different throttle settings to proportion the fuel properly to the air charge. This general principle of pneumatic control is utilized in the present embodiments in different ways.

In preferred cases, the fuel pump action, or the rate of fuel flow from a pressure source, is controlled more or less directly by an instrumentality which is itself directly responsive to altitude-pressure-variations. In other cases, this fuel control is effected or affected by an instrumentality responsive to pressure in the mixing space or mixture duct between the throttle and the engine; i. e., as commonly expressed, in the "manifold". Also, in some cases, these principal controlling methods or means may be employed cooperatively. In some cases, also, the instrumentality which is responsive to pressure in the mixing space may be, at the same time, more or less directly responsive to external atmospheric pressure.

In some cases, also, the apparatus or system may include, in addition to one or more such pressure-responsive instrumentalities, means of more mechanical character, which may cooperate with or modify the action of such pressure-responsive, or pneumatic means. An example of such a mechanical instrumentality is a device positioned by variations in throttle setting and connected more or less directly in a mechanical sense to the fuel-supply-regulating element, and which is itself acted upon, or cooperates with, a pressure-responsive instrumentality to affect the position of the fuel-controlling element.

In some preferred forms, a principal feature of the invention consists in a novel and improved fuel-supply apparatus, including a continuously feeding or non-metering pump, fuel chambers, and fuel-flow control means constructed and arranged to maintain a desired high fuel feed pressure and at the same time to meter the flow to the mixing space at or in an orifice which is subjected at its opposite ends to a fuel pressure difference of a relatively or definitely small amount, thus providing high injection pressure with a low metering pressure; or, in other words, it is thus possible to provide a metering orifice and needle valve of substantial diameters which can practically be produced with necessary accuracy; whereas when the full supply pressure, of the order, for example, of four hundred pounds per square inch, is applied to the metering orifice, in order to keep the total flow down to the necessary maximum, the orifice must be extremely small

and the needle valve of correspondingly small size and delicate character, so that practical commercial production is difficult and expensive, or impossible.

5 This fuel supply apparatus, while especially applicable to fuel supply regulating systems of present character, is not limited to such uses, but is evidently available, with or without modification, in a great variety of cases where fuel is to be
10 supplied under more or less analogous conditions, against substantial back pressure; as, for example, that afforded by the spring of an injection valve, or by internal pressure in the vessel or chamber into which the fuel is introduced.

15 The invention is based largely upon determination, by study and experiment, of the fact that in an engine of the subject character, variation in the weight of the air charge caused by altitude variation is at a different ratio from that caused
20 by variations in the throttle opening; and in devising means or apparatus to effect the desired control of fuel, in certain of the preferred forms, as here disclosed, such means or elements are designed to act responsively to both of these variation ratios in a manner to provide a substantially uniform mixture, or when desired, also to
25 vary the fuel proportion substantially under certain conditions, as will appear.

While a principal utility of the invention is in
30 connection with aircraft engines, it is also applicable to engines of other types or those used for other purposes, too numerous to mention, but some of which are briefly referred to hereinafter.

The characteristics and advantages of the invention are further sufficiently referred to in
35 connection with the following detail description of the accompanying drawings, which represent certain preferred embodiments. After considering these examples, skilled persons will understand that many variations may be made without departing from the principles disclosed; and I
40 contemplate the employment of any structures, arrangements, or modes of operation that are properly within the scope of the appended claims.

45 Fig. 1 is partly in elevation and partly in section, and also of somewhat diagrammatic character, showing certain sufficient appurtenances of an internal combustion engine and elements included in the invention, as embodied in one preferred form.

Fig. 2 is a similar view of a modified structure or arrangement.

Fig. 3 is a similar view of another modification.

55 Fig. 4 is a diagram explanatory of the principles of air-charge weight variation, previously referred to.

Figs. 5 and 6 are diagrams for explanation of pressure conditions in a conventional engine and its intake passage.

60 Fig. 7 illustrates a modification of the construction or arrangement of the barometric device of Fig. 1.

Fig. 8 is a view similar to Fig. 1, illustrating, however, important variations or modifications
65 including as a principal item what is called, for convenient identification, an anterior supercharger; i. e., one in the air supply line anterior to the throttle.

70 Fig. 9 is an enlarged view showing the spring adjustment of the aneroid of Fig. 1.

Fig. 10 is a view in elevation showing a modified throttle control.

75 The principles of construction and operation of the invention devices will be better understood after first considering some of the fundamentals

of pressure variation causing charge weight variations.

When fuel supply means such, for example, as a displacement type of pump, is employed, which
5 can be made to give equal fuel charges per cylinder when the engine speed is varied, it is preferred in accordance with the invention to coordinate the fuel pump delivery per charge with the pressure of the air in the intake manifold beyond the
10 throttle, because when this pressure is constant the air charge per cylinder is also approximately constant at different engine speeds at constant altitude.

Referring first to a simple engine with conventional carburetor, fuel supply and throttle, as illustrated in Fig. 5, where the piston is about to
15 start its suction stroke, with the throttle valve 1 entirely closed, before the intake valve 3 opens, the combustion space 5 is filled with gas which was equalized, during the previous opening of the
20 exhaust valve, to approximately atmospheric pressure. After the intake valve opens, this exhaust gas fills both the cylinder and its combustion space, and the intake manifold 7 between the throttle and the intake valve, so that, as shown
25 in Fig. 6 with no air (or a negligible amount) entering the intake passage, the pressure in the intake manifold will be to atmosphere as the volume of the gas space in Fig. 5 is to that in
30 Fig. 6 (temperature effects being disregarded). Therefore, referring to Fig. 4, if at sea level there is a full air charge corresponding to the point *a*, that is, 30" Hg. absolute pressure, there will be
35 a zero air charge with the throttle entirely closed, as indicated at *a'*, and the pressure corresponding to any fractional air charge will be shown by the line *a-a'*. This is found to hold true through
40 quite a large range of speeds, although the actual value of *a* may vary between 28½" and 30", and of *a'* between 10" and 12", depending on the individual characteristics of the engine and intake system. If the engine be taken to an altitude where the air is rarer, approximately the same ratio holds true for throttling; for instance,
45 at a level where the external pressure is *b*, or 20" Hg., (disregarding temperature), the air charge at full throttle opening will be 20/30 of that at sea level. If the throttle be closed entirely, the intake pressure will be 11/30 of 20, or 7.3" Hg. as shown at *b'*, and the relation of air
50 charge to the absolute pressure will be shown by the line *b-b'*. On the other hand, if the throttle be held full open as the altitude and air pressure around the engine are changed, the relation of air charge weight to the pressure in the manifold is
55 direct, as shown by the line *a-b-o*.

As otherwise stated, the invention may be said to depend, in certain of its principal aspects, upon the following theory, which is stated largely
60 for convenience of explanation and understanding of operation of the invention structure, although dependence is not necessarily placed upon correctness of this or other theoretical explanations herein contained:

In an ordinary aircraft engine, assuming it to
65 have a simple main air intake opening, a throttle in the air line, and a mixture space (manifold or the like) between the throttle and the engine heads, and disregarding or eliminating the usual carburetor, (and also disregarding a supercharger
70 anterior to the throttle which may be provided in some cases as later referred to), the pressure variations caused by altitude changes and tending to modify the charge weight, take effect at or through the air intake opening and tend to 75

vary the charge weight at a constant rate. The total force available for controlling fuel supply rate by utilization of pneumatic pressure, in accordance with the invention, is the difference between normal pressure at sea level and hypothetical zero pressure (as if the engine could be flown above atmosphere, or obtainable by placing the engine in a vacuum chamber).

The charge weight variations caused by throttling are effective in the manifold or equivalent chamber between the throttle and the engine, at or from which general location these pressure variations are utilized in the invention to effect a fuel control appropriate to these variations. The total force exerted or available at the stated location for the stated purpose has not a range from zero to the maximum obtainable by altitude variation, namely, 30" Hg. absolute, but this range commences at a minimum which is approximately 11" Hg. with fully closed throttle at sea level and, of course, with zero air charge, this minimum with closed throttle decreasing with increase of altitude; and from the stated varying minimum, the range of variation of course runs to the maximum available at full throttle opening, that is 30" Hg. absolute at sea level, and decreasing to zero at some hypothetical altitude or in a vacuum.

It thus appears that the force available for fuel adjustment by altitude directly varies in a simple ratio, while that available for adjustment in accordance with throttling varies in a more complex ratio; that is, the manifold pressure variation may be said to be simple at each altitude, and for any throttle setting the manifold variation with respect to different altitudes is also simple, but the combined ratio which is effective under flying conditions on account of continual changes in elevation and variations in throttle setting, is quite complex.

In certain of the preferred practical embodiments, in order to obtain optimum advantages of the invention, the fuel adjustment is affected by a first device directly responsive to external atmosphere, and at the same time the adjustment is effected by a second device, which is primarily responsive to the manifold pressure, and without further provision will, in coordination with the first-named device, attain a fuel adjustment which is fairly accurate and satisfactory in all cases. If preferred, the second-named device may be made at the same time responsive to direct atmospheric pressure, thus introducing into fuel adjustment by this second device what may be called a correction for altitude; and when the two devices, having characteristics as last stated, are coordinated, the fuel-adjustment accuracy is very close to the severest practical requirements.

In some cases, the system organization may include, in addition to other items mentioned previously to the preceding theoretical explanation, a supercharger, or supercharging blower, delivering its output to the air supply passage in advance of the throttle, thus creating in the air passage at this point, that is, between the main supercharger and the throttle, a pressure above atmosphere, which may be considered for the present purpose as an artificial atmosphere anterior to the throttle; and in the just stated system organization, this pressure is momentarily applied in lieu of the actual atmospheric pressure to effect the desired fuel regulation; or, in other words, the fuel adjustment is in this case made in accordance with a pressure equal to atmosphere-

plus, the "plus" representing the additional pressure to to the supercharger.

Some or all of the previously stated facts or principles are utilized in a practical way for the invention purposes in the structures disclosed, of which Fig. 1 shows a preferred form, representing an embodiment of the nature just above discussed in general terms; that is, one having an instrumentality responsive directly to atmospheric pressure and another instrumentality responsive to manifold pressure and also to atmospheric pressure, although the latter function may in some cases be eliminated; and these instrumentalities are arranged to control the fuel supply adjusting device.

As here shown, a main air intake duct or pipe 9 leads to a rotary distributor or supercharger 12 of an internal combustion engine which, as here sufficiently illustrated, is of a radial aircraft type. The intake air passage 9 contains the throttle 11 which is operated by a rod 13 extending from the pilot's cockpit. The pilot thus controls directly the air charge of the engine while the fuel charge, as will be described in detail, is automatically controlled by the engine speed (or intake manifold pressure as effected by the throttle opening and speed) and/or by altitude. In some cases, as further referred to below, a main supercharger or supercharging blower may be employed to supply air at higher than atmospheric pressure to the air passage leading to the throttle; and in such cases an instrumentality such as the rotary distributor 12 just above mentioned, if used, will generally be employed principally as a distributor or fuel mixer.

The invention structure as shown in Fig. 1 and elsewhere is associated with a radial aircraft engine, since its advantages are fully utilized in such an adaptation. An instrumentality such as the blower 12 is not essential to the invention, but is here shown as representing approved practice in aircraft engines, and serves to or assists in atomizing and properly distributing fuel introduced into the air line in the manner presently referred to. The blower discharges into a generally annular chamber 15 from which pipes lead to the intake parts of the various cylinders, as usual in this type of engine.

A yieldable device such as 17 is desirably interposed in the manual throttle control as described in detail below.

It is to be understood that the entire air passage between the throttle and the engine heads represents broadly an intake manifold, and the pneumatic connection for fuel control in accordance with throttle positioning is at a convenient point in this manifold or air space between the throttle and the engine proper.

Any known or suitable fuel pump 19 is provided. As illustrated, this pump is of a known form, details of the pump structure being unimportant, except as presently mentioned. Fuel is supplied to the pump at 21 and is delivered from it through a pipe 23 to an injection orifice or nozzle 25 in the air conduit arranged to deliver the fuel to the intake of the blower 12, in accordance with the selected fuel-supply, mixing and distributing arrangement although obviously it may be injected into the engine at any other desired point. In the pump are plungers 27 operated by bell cranks 29 and the bell cranks are actuated by a tapered sliding cam 31 mounted on a shaft 33 which is driven in any suitable way, the drive arrangement shown being typical and its details immaterial to the invention. The ver-

tical positioning of the cam varies the stroke of the bell cranks and of the plungers 27 and thus regulates the pump charge per revolution of the engine. In a broad sense, this represents any suitable mode of regulating the amount of fuel, or the rate at which fuel is supplied to the mixing point at a suitable pressure.

The cam 31 is operated by means such as a lever structure in any manner suitable to the purposes of the invention, and in some cases a simple lever, linkage or like mechanism may be employed. As shown, the cam is positioned principally by a lever structure which involves several elements, mainly for the purpose of obtaining variations in charge proportioning, as will appear; although the cam control can be greatly simplified if it is sufficient to maintain substantially uniform mixture proportions. The stated mechanism includes a lever 35 fulcrumed at 37 in casing part and having a fork 39 engaging in a shifting channel 41 on the cam, and also having an adjustable stop screw 43 engaging a fixed stop 45 to establish minimum-charge position of the cam. At a convenient position, as shown, adjacent the pump, is a fixed frame or supporting structure including a casing 47 for purposes below mentioned. On a part of this frame or casing structure is fulcrumed a lever mechanism 49 having three arms 51, 53, and 55. A secondary or floating lever 57 (so called for convenient reference) is fulcrumed at 59 on lever arm 55. The floating or auxiliary lever has a stop member or lug 61 cooperating with a shoulder or stop member 63 on lever arm 55 and is urged in a direction such that the lug 61 engages the shoulder 63 by a spring 65 acting between an extension of 67 of lever arm 55 and lever 57. The floating lever also desirably has a member or extension 69 (conveniently called a "toe") to cooperate with a fixed abutment such as a part of the casing 47. The outward end of lever 35 is connected by a link 71 to the inward end of lever 57.

In casing 47 is any known or suitable pneumatic-pressure-responsive device of the general nature of a barometric element or aneroid. As shown, this device 73 is an axially-extensible sheet metal bellows of known form, and evacuated to a desired degree, so that it tends to contract. This element is conveniently referred to in some cases as an evacuated aneroid. The contractile tendency of this element is resisted, or in other words it is normally elongated, by suitable means such as a spring 75. In a convenient physical arrangement, one end of the aneroid element has an extension 77 with a ball fitting 79 engaging in a socket in the casing end and enclosed, if necessary, by a cap 81. The other end of the element has an extension 83, and to one end of this extension, one end of the spring 75 is connected, while the other end of the spring may have an adjustable connection to the casing end, as by a screw 85 which engages in the casing wall. The spring is calibrated and/or adjusted to exert a suitable pull on the aneroid element. The extension 83 is formed as with an annular channel 87 for engagement by the end of lever arm 53 previously referred to.

In the present embodiment of the invention, the aneroid element is subjected to full atmospheric pressure, the casing for this purpose having an aperture 89 through which external air enters. By the devices and arrangements described, the natural contractive tendency of the aneroid element is resisted by the spring, which, at a certain maximum elevation, will elongate it

to its maximum, while the atmospheric pressure always tends to compress or shorten the aneroid. These movements are communicated to lever arm 53 so that, disregarding any other forces tending to effect the stated movements and also for the present disregarding the floating lever 57, the movements of the aneroid element caused by altitude variations act through lever 35 to position cam 31 in such manner that, as the pressure applied to the aneroid increases, (as when the craft is descending), the aneroid is compressed and the lever mechanism operates to move the cam 31 downward on its shaft, thus increasing the stroke of the pump plungers and the amount of fuel delivered into the intake air, the fuel supply being of course decreased as the craft rises; and when the various factors of design are correct the air-fuel ratio is maintained substantially constant, so far as correction for elevation alone is concerned.

Additional control in accordance with throttle positioning is also provided in accordance with Fig. 1, as follows: In a convenient location, which may be on casing 47, a pneumatic chamber 91 is provided, having at one face a flexible diaphragm 93 of a suitable diameter, the chamber being in this instance sealed except for a connection through a pipe 95 to the mixing space or manifold at 97; that is, as previously referred to, this connection is made at some suitable point in the air line between the throttle and the engine heads. The chamber 91 and its diaphragm 93 or equivalent element, represent broadly any known or suitable instrumentality responsive to pneumatic pressure and which is by the pipe connection 95 made responsive to the pressure in the manifold. This instrumentality, or at least a part of it, namely the diaphragm 93 or equivalent, is also in the present example subjected and responsive to an extent largely controllable by factors of design, to atmospheric pressure, since its outer face is directly exposed to atmosphere. The movable element of this second pneumatic instrument, namely, the diaphragm 93, is connected, as by a pin or stud 99 and pivot 101 to the end of the arm 51 of the three-armed lever previously mentioned.

This second pressure responsive instrument such as 93, disregarding for the present the aneroid element 73, tends to and will position lever arm 55, lever 35, and cam 31, in accordance with pressure variations in the manifold at the point 97, in such manner that the delivery of the pump per revolution is decreased as the pressure in the manifold decreases or, as more accurately stated with reference to this particular arrangement, fuel delivery is decreased in accordance with the pressure difference between the manifold and external air.

When the two pressure-responsive instrumentalities are connected in the manner shown and described, so that both act upon the lever arm 55, it is apparent without lengthy repetition of previous explanation of operative characteristics, that the cam 31, and therefore the amount of fuel delivered, is regulated mutually by the two pressure-responsive devices, in accordance with all the conditions connected with altitude and throttle position, to maintain a substantially constant mixture proportion; so that, to give a single example, if the pressure in the manifold 2 is brought from the point *a* of Fig. 4 corresponding to 30" Hg. with full open throttle at sea level, to a pressure of 20" Hg., by closing the throttle, the air charge will be brought to the

point a'' in the diagram, and the fuel charge will be regulated solely by the pressure differential acting to expand aneroid 73. Further, if the surrounding air pressure be brought to the point c, or 25" Hg. by changing the altitude, and then the pressure in the intake passage be brought to 15" Hg. corresponding to the point c' , by closing the throttle, the change in air charge will bring the two sets of pressure values to bear on the mechanical controlling elements, one represented by the value n due to increased altitude, and the other represented by the value m , due to the result of closing the throttle; these two, m and n combined, being in the same proportion to the air charge as would be obtained, first by getting this first air charge weight at sea level by closing the throttle sufficiently to produce a manifold pressure of 16.7" Hg., or second, by leaving the throttle wide open and going to an altitude of 9" pressure.

There is thus secured a uniform mixture proportioning of fuel and air. Actually, it is desirable in many cases to increase the richness of the mixture slightly as the air charge is decreased, which may be accomplished by varying the effective action of diaphragm 93 (or equivalent element) in relation to the "strength" of spring 75. For this purpose, for example, the area of the diaphragm may be varied, or specifically, made smaller than is required for practically uniform proportioning. The result of this is equivalent, with reference to the diagram, to changing the slope of the line $a-a'$.

It is also desirable in many cases to increase the richness of the mixture at from about 28" to 30" Hg. absolute pressure, because under these high air charge weights the engine tends to overheat, and a richer mixture assists in cooling it. This effect is obtained in the described structure by the floating lever 57 and its appurtenances, the action of which has heretofore been disregarded. Through most of the range of movement of lever arm 55 the floating lever remains in fixed relation to said lever arm, that is the position shown in Fig. 1, spring 65 holding lug 61 in contact with stop 63; but as the lever arm 55 approaches its uppermost position, corresponding to high air pressure and densities, the lever toe 69 engages the casing; and then in the further movement of the lever arm 55 the upward tilting of the outward end of the floating lever 57 gives the same effect as a magnified movement of the main lever arm; or, in other words, multiplies the upward movement of connecting link 71 and provides the desired increase in the proportion of fuel to air.

It will now also be apparent that, while the invention in this form, providing what may be called the full fuel mixture proportion control contemplated by the invention, has been described as applied to and acting in cooperation with an aircraft engine, and with such an engine of a more or less specialized type, it is evidently applicable to aircraft engines of other types or to various internal combustion engines used for other purposes, although of course its greatest utility will be with an engine subjected to considerable variations of speed and load, as well as altitude; so that the invention is applicable, for example, to vehicle engines where the vehicle is driven in mountainous country, and where heretofore fuel control in relation to altitude has been absent or of a rudimentary character, and there has been notable lack of efficiency in land vehicles when required to climb to high altitudes.

With reference to this usage, the invention by including pump or equivalent fuel supply in combination with a blower or the like, which may have a supercharging action, and suitable fuel controlling devices accurately responsive to speed and load variations as well as altitude variations, will greatly increase the utility and efficiency of a land vehicle in mountainous country.

Fig. 8 shows a modification based largely on the fundamentals involved in Fig. 1, as above discussed, but including in the air supply system a supercharger or supercharging blower which supplies its output to the air conduit 9 at some convenient point anterior to the throttle 11. In this case a device similar to the rotary distributor 12 of Fig. 1 may also be employed when desirable or necessary and, when used, will function principally as a distributor or mixer, since the blower is intended to serve as the supercharger. There is thus produced in the air line between the main supercharger and the throttle a pressure generally higher than that of surrounding atmosphere. This is one example of invention embodiments above mentioned in which there is produced or exists in the air line anterior to the throttle what has been referred to as an "artificial atmosphere"; that is, a pressure equal to surrounding atmosphere plus the added pressure produced by the action of the blower at the moment. It will now be evident that this artificial atmospheric pressure may be utilized for the invention purposes in the same general manner that actual atmospheric pressure is utilized in the example of Fig. 1, to obtain the desired fuel regulation with respect to altitude. The pressure-responsive means or devices are in the case of Fig. 8 associated with or contained in a casing 105 which may be considered a sealed casing except for pneumatic-pressure-connection-openings to be mentioned. The pressure-responsive device 107 substantially similar to the device 73 of Fig. 1 is arranged in substantially the same manner, being connected at 109 to a lever arm 111 fulcrumed on a shaft 113 which passes out through a casing wall (with suitable packing, not necessary to illustrate) and has outside the casing an arm 115 operatively equivalent to the lever arm 55 of Fig. 1, and other devices affording a mechanical connection to lever 35, in order to position a fuel-regulating member such as the cam 31 of Fig. 1, in accordance with the movements of arm 115. Also mounted and sealed at an aperture in the casing is a diaphragm 117, the inner face of which is subjected to the pressure condition existing in the casing and the outer face is enclosed by cap 119 forming a pneumatic chamber 121. The diaphragm is connected as by a stem 123 to an extension of lever arm 111. A further extension of this lever arm is also engaged by a spring 125, which acts between it and a properly spaced abutment on the casing, as, for example, against the inner end of an adjusting screw 127. From the main interior space of the casing 105 a pipe connection 129 leads to the air conduit at a suitable point between the main blower 112 and the throttle 11. From the chamber 121 a pneumatic connecting conduit 131 leads to the manifold at a point between the throttle and the engine.

The artificial atmospheric pressure above referred to is thus applied through the pipe 129 into the main interior space of the casing 105 and thus to the barometric device 107 in such manner that increase of pressure tends to collapse it against the effort of spring 125, which tends to extend it. At the same time, this artificial atmosphere pres-

sure, or atmosphere-plus pressure, is applied to the inward face of the diaphragm 117 while through the pneumatic conduit 131, manifold pressure is applied to the outward face of the diaphragm, thus practically reproducing the operative characteristics of Fig. 1 except that in this instance the altitude control takes into account in a proper manner the action or effect of the supercharger located or arranged in the system, as here shown.

Fig. 2 shows a modification of the invention structure, involving in some respects a simplification and also introducing what I have hereinabove referred to as a mechanical controlling instrumentality or means, in cooperation with pressure-responsive means.

In this arrangement the pump, pump cam and cam-controlling lever are operated by a single aneroid responsive to both manifold pressure and altitude changes, while the link 133 operating lever 35 is itself arranged to be operated as an incident to the movement of the throttle 11, thus providing the before-mentioned mechanical controlling feature. Specifically, as here shown, a fixed structure or frame, here represented by a casing 135, has an arm 137 to which is fulcrumed at one end a lever 139 normally urged upward by a spring 141, and having a roll or follower 142 cooperating with a cam 143 on the throttle shaft 145. The lever has a cam face 147 of suitable design, and this is engaged by a roll or cam follower 149 at the lower end of link 133, and when necessary a spring 151 may be applied at a suitable place, as to link 133, tending to retain the roll 149 in contact with the cam 147, and at the same time to normally maintain the pump cam 31 in upward position. In the casing 135 is located a pressure-responsive instrumentality 153 substantially similar to evacuated aneroid 73 of Fig. 1, and this is connected by any suitable means such as a rock-lever 155 fulcrumed at 157, to a rod 159 which reciprocates in the casing wall. This lever is connected by a link 161 to link 133, conveniently at its lower end. A spring 163 is applied in a manner tending normally to move the cam follower 149 to the right, as viewed in the drawings, and also tending to extend or expand the aneroid element.

This mechanism is capable by simple modifications or rearrangements to operate in different manners, for example, the aneroid 153 may in some cases be exposed to external atmospheric pressure, as by providing an aperture in the casing 135, and will then tend to effect a fuel adjustment in accordance with altitude variations or the like. Otherwise, and as specially illustrated, the casing may be connected to the external atmosphere by a restricted opening 165, and also through a pipe 167 to the manifold or intake passage at a point 97; that is, a pneumatic connection located as in Fig. 1; the relative sizes of the openings 165 and passage being so chosen that a change of manifold pressure exerts the same force upon the aneroid 153 as would a change of altitude giving the same manifold air density. Thus, it is responsive to changes of both throttle position and altitude; and in either case, when pressure applied to the aneroid increases, it tends to contract and to move the cam follower 149 to the left, as viewed in Fig. 2, with the result, so long as the throttle is in stationary position, that link 133 is moved upward and the pump cam 31 is moved downward, increasing the fuel supply; and when pressure decreases the aneroid expands, and spring 163 moves the follower 149 in the

opposite direction, causing a decrease in fuel supply.

Further, as a minor control, when the throttle is moved toward open position by rod 13 acting on arm 169, spring 141 moves the outward end of lever 139 upward to an extent permitted by the positioning of the cam 143, thus moving link 133 and lever 35 in a direction to increase the fuel supply; and similarly, in the closing movement of the throttle the fuel supply may be decreased through this mechanical means. At the same time the action of the aneroid element 153 or the equivalent pneumatic control, in either of the cases referred to, positions the follower 149 in relation to the cam element 147, thus effecting a fuel regulation in accordance with both throttle position and a pressure condition, which may be one controlled by altitude or by throttle position.

Fig. 3 shows the general principles so far explained, embodied in a different form. Especially this embodiment includes in place of a positive feeding or metering pump of the character heretofore described, a novel and improved fuel supply means including a continuously-feeding non-metering pump 171, an injection valve 173 controlled by a spring 175 and arranged to deliver fuel into the mixing space or manifold substantially at the point described with reference to Figs. 1 and 2; that is, axially toward the inlet of a rotary charge distributor, blower or supercharger, and fuel-controlling and metering means 177 of the character referred to early above, having as a principal characteristic and advantage the capacity to meter the fuel at low pressure (or at a low pressure-differential), while the necessary high pressure is maintained in the pipe line leading to the injecting valve 173; that is to say, while the fuel pressure actually existing in the neighborhood of the metering orifice and valve is high (of the order, in some cases, of 400 pounds per square inch, more or less), the difference in pressures at opposite ends of the metering orifice is comparatively small and actually may be very small, say of the order of about five pounds, (more or less) with the advantages sufficiently referred to previously.

The fuel controlling means comprises a casing 179 divided by a diaphragm 181 into a lower chamber 183 and an upper chamber 185. The pump 171, which may be of any known or suitable type, providing substantially continuous supply at a suitable pressure, has an intake passage 187 and a discharge passage or fitting 189 leading to the lower chamber 183. The upper chamber 185 is connected by a pipe 191 to the injection valve 173. The lower chamber 183 has a port 193 and connected thereat a return-flow or by-pass pipe 195 leading to the intake pipe 187 adjacent the pump. At the inner end of the port 193 is a valve seat 197 with which cooperates a valve 199 connected to the diaphragm 181. This valve is loaded by a spring 201 compressed between its upper end or the fitting connecting it to the diaphragm, and a spring retaining cap 203 screwed into the top casing wall.

The metering aperture is located in an operative sense between the upper and lower chambers. Specifically, as shown, this aperture 205 is in the end of a sleeve 207 inserted into the casing wall, and terminates in the lower chamber, while the sleeve is apertured to communicate with the passage formation 209 in the casing, affording communication from the metering aperture to the upper chamber 185. The metering valve 211 reciprocates in the sleeve 207, packing

such as 213 being provided as in analogous structures. This valve is positioned, to secure fuel regulation, in a manner described below.

The pump 171 supplies fuel to the lower chamber 183 at a rate greater than is required for engine consumption, the excess being returned to the supply pipe 187 through port 193 and bypass pipe 195 under control of valve 199. The control spring 201 of valve 199 is in practice, in one good example, set to open at about 400 pounds pressure and to maintain about the same pressure as the delivery of fuel increases. This puts approximately the same pressure on the fuel in pipe 191 and in the upper diaphragm chamber 185. The loading spring 201 is designed or adjusted to place a suitably determined pressure on the valve, say approximately five pounds, more or less. The result is that the system tends to maintain a pressure of approximately 400 pounds per square inch in the upper diaphragm chamber, pipe 191, and passages leading to the injection valve, together with substantially-continuous fuel-flow, when consumption-conditions so permit or demand; and a substantially though only moderately greater pressure, namely, approximately 405 pounds, in the lower diaphragm chamber 183.

There is thus applied at opposite ends of the metering orifice a pressure differential of only five pounds, so that the orifice and its valve operate as they would if the actual main line pressure of the system were of this low order; or, in brief, the orifice may be made large in relation to the amount of fuel delivered by the system at the stated high pressure; and when the orifice is of such substantial diameter the valve may also be of a corresponding substantial size, and these parts may be produced with necessary accuracy on a commercial basis.

This fuel supply system may of course be used in any of the forms of the invention, such as shown in Figs. 1 and 2, the various fuel control devices being in such case arranged to act on metering valve 211 instead of on the fuel-pump driving cam.

As suggested early above, this fuel supply means may be used for various other purposes, such for example as supplying fuel to injector valves of Diesel engines or those of analogous types, or in various other cases where the fuel is to be discharged against valve- or internal-pressure-resistance.

In the embodiment of Fig. 3, there is provided a mechanical fuel control and also a pressure-responsive control. The mechanical control, as shown, comprises a cam 213 on the shaft of throttle 11 acting upon a follower 215 carried by a lever 217 fulcrumed at a fixed point 219. The free end of this lever is connected by a link 221 or equivalent means to act upon the metering valve 211.

A pressure-responsive instrumentality 223, which may be a sealed or evacuated aneroid similar to those previously referred to, is enclosed in a fixed casing 225 and has a stem 227 passing through the casing, with a spring 229 arranged to act between the casing and the stem and tending to expand the aneroid. The stem is also connected to a lever 231 fulcrumed at 233 on a fixed support, and the lever is connected as through a link 235 to act upon the metering valve 211.

The lever mechanism for operating the metering valve 211, as here shown, comprises a lever 237 consisting of operatively-integral arms 237 and

239 fulcrumed at 241 on another lever 243 which is itself fulcrumed at 245 on a fixed point. Lever 243 has a short arm portion 247 extending beyond the point 241, and to the end of this arm portion link 235 is connected; while link 221 leading from the mechanically operated lever 217 is connected to the end of lever arm 239. A spring 249 is tensioned between a fixed point and the end of lever arm 239, tending generally to move the metering valve outward and also to retain cam follower 215 in engagement with its cam 213. The lever arm 237 is connected to the outward portion of the metering valve by a slidably acting fork structure 251, or the like, cooperating with an annular channel on the valve stem.

Apparatus having the essential elements of the invention as embodied in this general form (Fig. 3) may be arranged, adapted, or adjusted to operate in different ways. With the apparatus substantially as shown in this figure, in accordance with one preferred mode of operation, it may be assumed that operating conditions especially with regard to load characteristics are such that the throttle position is roughly proportional to the engine speed. In such case the cam 213 operates or permits movement of the follower 215 through link 221 and the lever mechanism just above described, so that the metering needle valve 211 is withdrawn from its seat as the throttle is opened.

As the engine altitude increases and external air pressure diminishes accordingly, the aneroid element 223 expands and causes link 235 to pull lever 243 upward; this motion imparted to lever arm 237, the upper end of which has a movement-component toward the casing, causes the metering valve to be moved inward, towards its seat, reducing the fuel flow. In the just-described mode of operation, the stated regulation by the aneroid element 223 is obtained when access to it of external air is permitted by providing an aperture at any convenient place in the casing.

If desired, in order partially to assist in fuel adjustment in accordance with throttle regulation, a connection as by a pipe 253 may be made from the otherwise closed casing to the manifold or air passage at a point 97 (substantially as in the previous example), and the amount of regulation obtained may be controlled, or balanced as to its effect, by an opening to external atmosphere, provided, as here specifically shown, by the pipe 255 leading from aperture 257 to which pipe 253 is connected, to the main or intake passage at 259; that is, at a point anterior to the throttle where the pressure is substantially that of atmosphere. Or, in case a main supercharger is used in the general manner explained in connection with Fig. 8, the pressure effect obtained at the point 259 will be an atmosphere-plus pressure. In some cases also the passages, such as pipe 253 through which communication is afforded from the manifold to the aneroid casing, may be partially obstructed as by a plug 261 having an aperture 263 of properly determined area.

In describing Fig. 1, reference was made to a yieldable connection 17 in the operating linkage for throttle 11.

Since the present apparatus depends to a large extent upon pneumatic action for positioning a fuel regulating element such as the shiftable pump cam 31, Fig. 1, or the needle valve 211, Fig. 3, and some small amount of time or slight delay is required for the pneumatic force to take effect and produce the change in power output intended by the act of throttle adjustment, it is sometimes desirable, substantially as shown in

Fig. 1, to provide means for slightly delaying throttle movement in response to the movement of the controlling element, such as rod 13.

Thus, as here shown, the throttle arm 265 has a forked or ball end 267, or the like, engaging between a collar 269 fixed on the rod 13 and a lug or collar 271 slidable on the rod and urged to engage the lever end by a spring 273 bearing against another collar 275 adjustably fixed on the rod. This provides for or permits a slight lag in the throttle movement under control of a retarder such as a dashpot, as will appear, when the rod is moved in a direction to produce throttle opening. When it is desired to provide the delayed throttle movement in either direction, an arrangement may be provided such as shown in Fig. 10 wherein the end of the throttle arm has a fork 277 with its ends at opposite sides of a collar or stop 279 secured to the controlling rod.

The fork ends are located between the flanges 281 of collars 283, which are slidable upon the rod and are normally held in engagement with the fixed stop or collar 279 by springs 285 compressed between the respective flanges, and other stops or collars 287 also in fixed position on the rod. This arrangement provides for a lag in throttle movement (under control of a dashpot 289 or the like) when the rod 13 is moved in a direction either to open or to close the throttle. Fig. 1 also shows a simplified dashpot arrangement representing broadly any suitable retarding device to produce the delayed movement of the throttle, in cooperation with the yieldable operating connection. This dashpot 289 has a plunger 291 with a rod 293 pivotally connected to a throttle arm 295 secured to the throttle shaft and will tend to retard the throttle movement in either direction, either by pneumatic action or, if desired, a liquid medium may be supplied to the dashpot, as especially indicated at 297. Evidently such throttle retarding means may be employed in any forms of the invention, as sufficiently indicated, for example, in Figs. 2 and 3.

In view of the early-preceding description (re. Fig. 1) of one practical structure embodying the invention principles as previously discussed with reference to the diagram, Fig. 4, the following somewhat different explanation of the application of that diagram may be understood. Assuming that the lateral diagram of pressures as there shown to represent the pressures which will be available, operating against the spring 75, Fig. 1, to vary the fuel feed, the slope of the line $a-a'$ shows the rate of pressure difference to the air charge when the throttle is operated; while the slope of the line $a-o$ shows the relation to air charge change caused by change of altitude. It is desired to bring these two lines to the same actual point, as regards their moment against the spring 75.

This can be done, first, by making the aneroid element 73 subject to external atmospheric pressure, and calibrating the moment of the diaphragm 93 in relation to the moment of the aneroid, either by changing its area or the lever length until the slope of its operating force versus air charge density change is the same as that of the aneroid alone.

Another arrangement, or modification of the invention structure calculated to obtain the same result, is shown in Fig. 7, in which the aneroid element 73 similar to that of Fig. 1 is enclosed in a sealed casing 299 and the diaphragm 93 is secured in a manner to seal an aperture 301 in the main casing and subjected at its inner face

to the same pressure that is applied to the aneroid element. The casing is connected by a pipe 303 to the intake manifold substantially as the distinct chamber 91 of Fig. 1 is connected to the manifold. The spring and lever arrangements may be substantially the same. By this means or arrangement, manifold pressure through pipe 303 is applied exteriorly to the aneroid element and at the same time is interiorly applied to the diaphragm; or, as otherwise stated in this case the action of the aneroid under manifold pressure is assisted by the action of the diaphragm under the same force. In such case the moment of the diaphragm will be less than in Fig. 1, since the diaphragm and aneroid together operate to reduce the fuel charge as the throttle is closed.

What is claimed is:

1. In combination with an engine having an air supply passage, a throttle therein, and means for supplying fuel into the passage between the throttle and the engine, a pneumatic pressure responsive instrumentality subjected to pneumatic pressure variations incident to variations in operating conditions of the engine and acting to control the ratio of the fuel and air mixture substantially in accordance with such condition variations, resilient means acting upon said instrumentality in opposition to the action thereon of pneumatic pressure, and means to vary the effect of the pressure responsive instrumentality in accordance with variations in operating conditions.

2. In combination with an engine having an air intake and a manually movable throttle therein, a fuel pump having a variable stroke for introducing fuel into the air intake posterior to the throttle, and pneumatic pressure operated means controlling the fuel pump stroke in accordance with the joint action of the air pressures on opposite sides of said throttle.

3. In combination with an engine having an air intake and a throttle therefor, means for supplying fuel to the engine, a supercharger for increasing air flow means responsive to the supercharger pressure for controlling the supply of fuel, and means for varying the effect of the responsive means in accordance with the air intake pressure at a point posterior of the throttle.

4. In combination with an engine having air and fuel supply means and a throttle controlling air supply, pneumatic pressure responsive means automatically tending to adjust the fuel supply in accordance with pressure variations in the air supply line posterior to the throttle, and other pressure actuated means for varying the effect of the first pressure means.

5. In combination with an engine having fuel supply means, an air passage to the engine having a throttle, a pneumatic pressure responsive instrumentality, means for applying thereto the pressure momentarily existing in the air passage to the engine posterior to the throttle, means actuated by said instrumentality tending to control the fuel supply in accordance with variation of such pressure, and atmospheric pressure actuated means for varying the effect of the pressure instrumentality.

6. In combination with an engine having pressure fuel supply means including a fuel pump having a variable stroke, an air passage to the engine having a manually movable throttle therein, pneumatic pressure responsive means affected by external atmospheric pressure and by pressure in the air passage posterior to the throttle and said pressure responsive means being opera-

tively connected with the fuel pump for controlling the fuel pump stroke in conjoint accordance with variations of said pressures.

7. In combination with an engine having fuel supply means, pneumatic pressure responsive means subjected to atmospheric pressure, other pneumatic pressure responsive means subjected to manifold pressure, and means affected by both said pressure responsive means to regulate the fuel supply.

8. In combination with an engine having fuel supply means, pneumatic pressure responsive means subjected to atmospheric pressure, other pneumatic pressure responsive means subjected to manifold pressure and also by atmospheric pressure, and means affected by both said pressure responsive means to regulate the fuel supply.

9. In combination with an engine having air and fuel supply means including a pressure pump and a throttle controlling air supply, a pneumatic pressure responsive instrumentality affected simultaneously by manifold pressure and by external atmospheric pressure and acting to automatically adjust the fuel supply of the pump.

10. In combination with an engine having air and fuel supply means including a pressure pump and a throttle controlling air supply, a pneumatic pressure responsive instrumentality affected simultaneously by manifold pressure and by external atmospheric pressure and acting to automatically adjust the fuel supply of the pump principally in accordance with manifold pressure and to a certain degree in accordance with atmospheric pressure.

11. In combination with an engine having air and fuel supply means and a throttle controlling air supply, pneumatic pressure responsive means automatically tending to adjust the fuel supply whereby to maintain an approximately uniform mixture proportion, and means automatically effecting a variation of mixture proportions in a part of the fuel adjustment range.

12. In combination with an engine having air and fuel supply means and a throttle controlling air supply, pneumatic pressure responsive means automatically tending to adjust the fuel supply whereby to maintain an approximately uniform mixture proportion, and means acting automatically to effect enrichment of the fuel mixture under conditions generally corresponding to high atmospheric pressure or density and full open throttle.

13. In combination with an engine having air and fuel supply means and a throttle controlling air supply, a pneumatic pressure responsive instrumentality tending to effect fuel supply adjustment in accordance with atmospheric pressure variations, and mechanical means responsive to throttle positioning and tending to affect the action of said instrumentality.

14. In combination with an engine having air and fuel supply means and a throttle controlling air supply, a pneumatic pressure responsive instrumentality tending to effect fuel supply adjustment in accordance with manifold pressure variations, and mechanical means responsive to throttle positioning and tending to affect the action of said instrumentality.

15. In combination with an engine having air and fuel supply means and a throttle controlling air supply, a pneumatic pressure responsive instrumentality tending to effect fuel supply adjustment in accordance with atmospheric pressure variations and also manifold pressure variations, and mechanical means responsive to throttle po-

sitioning and tending to affect the action of said instrumentality.

16. In combination with an engine having air and fuel supply means including a fuel pump and a throttle controlling air supply, means operated by throttle positioning to adjust the fuel supply, and pneumatic pressure responsive means coacting with the fuel pump to effect the fuel supply adjustment.

17. In combination with an engine having air and fuel supply means and a throttle controlling air supply, means operated by throttle positioning to adjust the fuel supply, and pneumatic pressure responsive means coacting with the means first named to effect said supply adjustment, said pneumatic pressure responsive means being subjected to both atmospheric pressure and air supply pressure.

18. In combination with an engine having air and fuel supply means and a throttle controlling air supply, means operated by throttle positioning to adjust the fuel supply, and pneumatic pressure responsive means coacting with the means first named to effect said supply adjustment, said pneumatic pressure responsive means being subjected to manifold pressure.

19. In combination with an engine having air and fuel supply means and a throttle controlling air supply, means operated by throttle positioning to adjust the fuel supply, and pneumatic pressure responsive means coacting with the means first named to effect said supply adjustment, said pneumatic pressure responsive means being subjected to manifold pressure and conjointly to atmospheric pressure.

20. Fuel supply apparatus comprising means for substantially continuously supplying fuel at a substantially high pressure to a delivery point, and means for varying the amount supplied, said means having two surfaces subjected to a relatively small pressure differential in fuel pressure.

21. Fuel supply apparatus comprising means for substantially continuously supplying fuel at a substantially high pressure to a delivery point, and means for varying the amount supplied, said means being subjected to fuel pressure and having an input pressure only moderately greater than the output pressure.

22. In combination with an engine having air and fuel supply means and a throttle controlling air supply, pneumatic pressure responsive means automatically tending to adjust the fuel supply, a spring tending to move said pressure responsive means in opposition to pneumatic pressure applied to it, and means to adjust the fuel supply at a different rate throughout a portion of the expansive range of the pressure responsive means.

23. For purposes described, in combination with an element movable to adjust fuel supply, controlling means therefor comprising two pneumatic pressure responsive devices, and mechanical means operated jointly by said devices and connected to move said element.

24. For purposes described, in combination with an element movable to adjust fuel supply, controlling means therefor comprising two pneumatic pressure responsive devices, and mechanical means operated jointly by said devices and connected to move said element, said mechanical means including means acting in a part of its range of movement to amplify the effective movement applied to said element.

25. For purposes described, in combination with

an element movable to adjust fuel supply, controlling means therefor comprising two pneumatic pressure responsive devices, and mechanical means operated jointly by said devices and connected to move said element, said mechanical means comprising a lever system including a three armed lever, one arm operatively connected to each of said pressure responsive devices and the other arm operatively connected to said element.

26. For purposes described, in combination with an element movable to adjust fuel supply, controlling means therefor comprising two pneumatic pressure responsive devices, and mechanical means operated jointly by said devices and connected to move said element, said mechanical means comprising a lever system including a three armed lever, one arm operatively connected to each of said pressure responsive devices, and a floating lever mounted on the third arm and itself connected to said element.

27. For purposes described, in combination with an element movable to adjust fuel supply, controlling means therefor comprising two pneumatic pressure responsive devices, and mechanical means operated jointly by said devices and connected to move said element, said mechanical means comprising a lever system including a three armed lever, one arm operatively connected to each of said pressure responsive devices, and a floating lever mounted on the third arm and itself connected to said element, and means normally retaining the floating lever in a fixed relation to the third arm.

28. For purposes described, in combination with an element movable to adjust fuel supply, controlling means therefor comprising two pneumatic pressure responsive devices, and mechanical means operated jointly by said devices and connected to move said element, said mechanical means comprising a lever system including a three armed lever, one arm operatively connected to each of said pressure responsive devices, and a floating lever mounted on the third arm and itself connected to said element, means normally retaining the floating lever in a fixed relation to the third arm, and means acting in an end range of movement of said arm to relatively move the floating lever.

29. A fuel supply system comprising an engine, an air supply passage, a throttle, means for forcing fuel under pressure into the passage between the throttle and the engine, and a pneumatic pressure responsive instrumentality subjected to pressure in the air passage anterior to the throttle and tending to affect the fuel supply substantially in accordance with air supply pressure variations at that point.

30. A fuel supply system comprising an engine, an air supply passage, a throttle, means for introducing fuel into the passage between the throttle and the engine, and a pneumatic pressure responsive instrumentality subjected to pressure in the air passage anterior to the throttle and tending to affect the fuel supply substantially in accordance with air supply pressure variations at that point and another pneumatic pressure responsive instrumentality subjected to manifold pressure and tending to affect fuel supply.

31. A fuel supply system comprising an engine, an air supply passage, a throttle, a pump for introducing fuel under pressure into the passage between the throttle and the engine, and pneumatic pressure responsive means arranged

to adjust the fuel supply delivered by the pump in relation to air charge weight in accordance with pressure variations in the air supply passage anterior to the throttle.

32. A fuel supply system comprising an engine, an air supply passage, a throttle, a pump for introducing fuel under pressure into the passage between the throttle and the engine, and pneumatic pressure responsive means arranged to adjust the fuel supply delivered by the pump in relation to air charge weight in accordance with pressure variations in the air supply passage anterior to the throttle, and also in accordance with pressure variations posterior to the throttle.

33. A fuel supply system comprising an engine, an air supply passage, a throttle, means for introducing fuel into the passage between the throttle and the engine, and pneumatic pressure responsive means arranged to adjust the fuel supply in relation to air charge weight in accordance with pressure variations in the air supply passage anterior to the throttle, and also in accordance with pressure variations posterior to the throttle, said means including a barometric device subjected to pressure in the air supply passage anterior to the throttle and another barometric device subjected to the same pressure and at the same time to pressure in the air passage posterior to the throttle.

34. A fuel supply system comprising an engine, an air supply passage, a throttle, a pump for introducing fuel under pressure into the passage between the throttle and the engine, a supercharger discharging into the passage anterior to the throttle, and a pneumatic pressure responsive instrumentality subjected to pressure in the air passage anterior to the throttle and tending to affect the fuel supply delivered by the pump substantially in accordance with air supply pressure variations at that point.

35. A fuel supply system comprising an engine, an air supply passage, a throttle, means for introducing fuel into the passage between the throttle and the engine, a supercharger discharging into the passage anterior to the throttle, and a pneumatic pressure responsive instrumentality subjected to pressure in the air passage between the supercharger and the throttle and tending to affect the fuel supply substantially in accordance with a variable pressure equal to that of atmosphere plus an increment due to action of the supercharger.

36. A fuel supply system comprising an engine, an air supply passage, a throttle, means for introducing fuel into the passage between the throttle and the engine, a supercharger discharging into the passage anterior to the throttle, and a pneumatic pressure responsive instrumentality subjected to pressure in the air passage anterior to the throttle and tending to affect the fuel supply substantially in accordance with air supply pressure variations at that point, and another pneumatic pressure responsive instrumentality subjected to manifold pressure and tending to affect fuel supply.

37. A fuel supply system comprising an engine, an air supply passage, a throttle, means for introducing fuel into the passage between the throttle and the engine, a supercharger discharging into the passage anterior to the throttle, and pneumatic pressure responsive means arranged to adjust the fuel supply in relation to air charge weight in accordance with pressure variations in

the air supply passage between the supercharger and the throttle.

38. A fuel supply system comprising an engine, an air supply passage, a throttle, means for introducing fuel into the passage between the throttle and the engine, a supercharger discharging into the passage anterior to the throttle, and pneumatic pressure responsive means arranged to adjust the fuel supply in relation to air charge weight in accordance with pressure variations in the air supply passage between the supercharger and the throttle, and also in accordance with pressure variations posterior to the throttle.

39. A fuel supply system comprising an engine, an air supply passage, a throttle, means for introducing fuel into the passage between the throttle and the engine, a supercharger discharging into the passage anterior to the throttle, and pneumatic pressure responsive means arranged to adjust the fuel supply in relation to air charge weight in accordance with pressure variations in the air supply passage anterior to the throttle, and also in accordance with pressure variations posterior to the throttle, said means including a barometric device subjected to pressure in the air supply passage between the supercharger and the throttle and another barometric device subjected to the same pressure and at the same time to pressure in the air passage posterior to the throttle.

40. In combination with an engine having air and fuel supply means including a pressure fuel pump and a conduit having a throttle controlling the air supply, pneumatic pressure responsive means affected simultaneously by the air conduit pressure and atmospheric pressure, and said pressure responsive means arranged to automatically adjust the fuel and air mixture supplied to the engine.

41. In combination with an engine having an air conduit, a throttle for the conduit, a pressure fuel pump having means for varying the supply of fuel supplied to the engine, means responsive both to conduit pressure posterior to the throttle and external atmospheric pressure, and means actuated by said pressure responsive means to automatically adjust the fuel and air mixture supplied to the engine in accordance with both atmospheric pressure and conduit pressure.

42. In combination with an engine having an air conduit, a throttle for the conduit, a pressure fuel pump having means for varying the supply of fuel supplied to the engine, means responsive both to conduit pressure posterior to the throttle and external atmospheric pressure, a linkage actuated by said pressure responsive means to automatically adjust the fuel and air mixture supplied to the engine in accordance with both atmospheric pressure and conduit pressure, and said linkage including a device to vary the controlling effect of the linkage throughout a portion of movement range thereof.

43. In combination with an engine having a

conduit for conducting air to the engine, mechanical means for forcing fuel to the engine, and means for controlling the fuel supplied by the mechanical means in accordance with the density of the air between the engine and the conduit entrance and in accordance with the density of the surrounding atmosphere.

44. In combination with an engine having a conduit for conducting air to the engine, a reciprocating pump for forcing fuel to the engine, and means for controlling the stroke of the fuel pump in accordance with the density of the air between the engine and the conduit entrance and in accordance with the density of the air anterior to the conduit entrance.

45. In combination with an engine having a conduit for conducting air to the engine, means for controlling the air charge to the engine, an engine driven pump for forcing fuel to the engine, and means for controlling the amount of fuel delivered by the pump in accordance with the joint action of the pressure between the engine and the conduit entrance and the pressure of the air anterior to the conduit entrance.

46. In combination with an engine having a conduit for conducting air to the engine, means for controlling the air charge to the engine, an engine driven pump for forcing fuel to the engine, means for controlling the amount of fuel delivered by the pump in accordance with the joint action of the pressure of the air between the engine and the conduit entrance and the pressure of the air anterior to the conduit entrance, said means including a sealed bellows the expansion and contraction of which is affected by the pressure of the air anterior to the entrance, and a device for controlling the expansion and contraction in accordance with the pressure of the air between the engine and the conduit entrance.

47. In combination with an engine, a fuel delivery pump, an air supply duct having a throttle, manually actuated means for controlling the quantity of the air and fuel mixture, pneumatic means controlled by the absolute pressure of the air anterior to the throttle arranged to control the relation between the fuel and air charges, and other pneumatic means associated with the first pneumatic means and responsive to the difference in pressures on opposite sides of the throttle for further controlling the relation of the air and fuel charges.

48. In combination with an engine, a fuel delivery pump, an air supply duct having a throttle, manually actuated means for controlling the quantity of the air and fuel mixture, pneumatic means responsive to the absolute pressure in the duct controlling the relation of the fuel and air charges, and other pneumatic means associated with the first pneumatic means and responsive to the difference in air pressure on opposite sides of the throttle for further controlling the relation of the fuel and air charges.

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