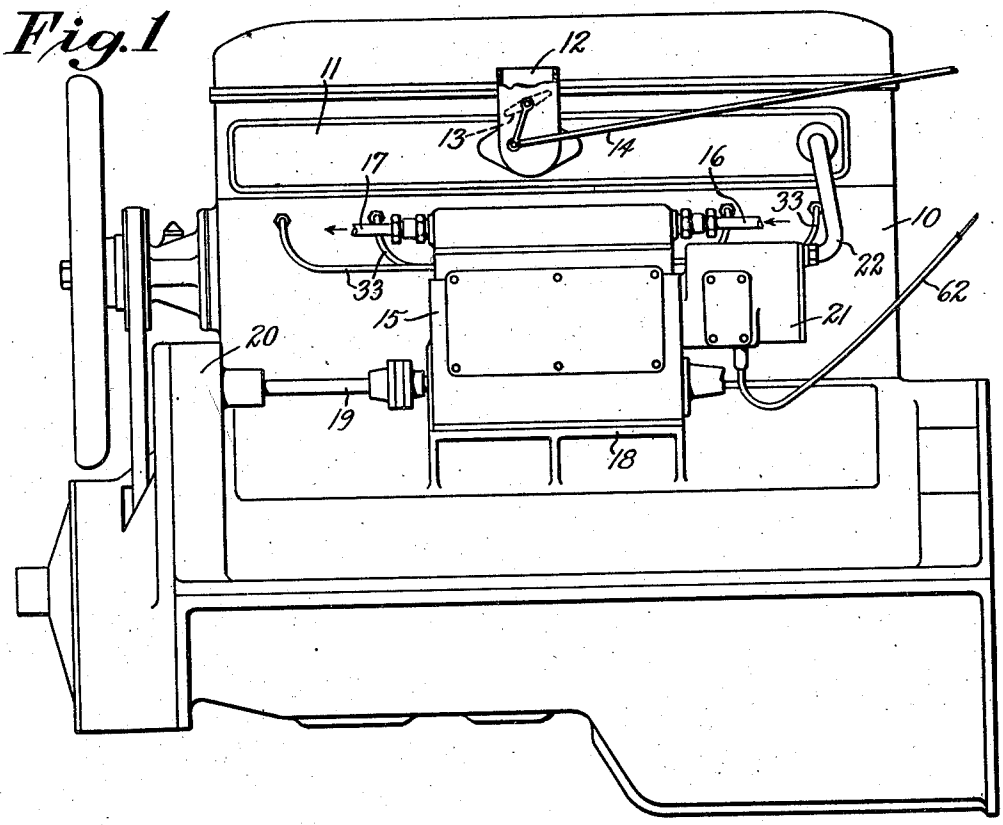
July 21, 1936. S. OLSEN 2,048,406

SUPPLYING FUEL TO INTERNAL COMBUSTION ENGINES

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Fig. 1



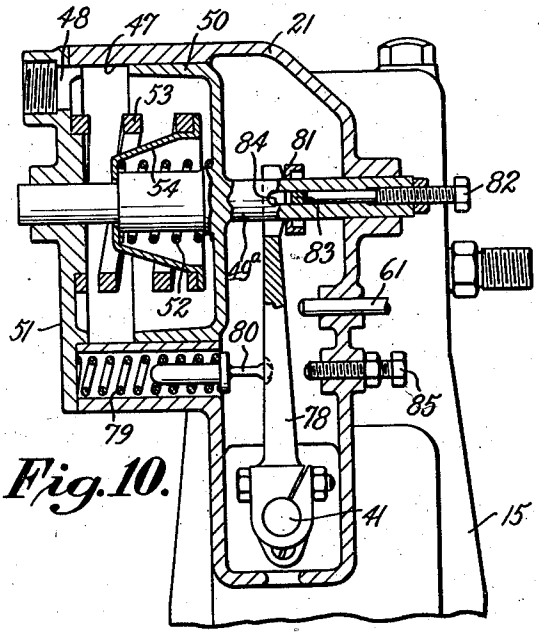


Fig. 10.

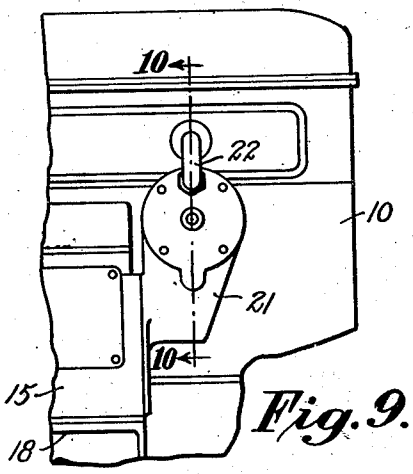


Fig. 9.

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Fig. 2.

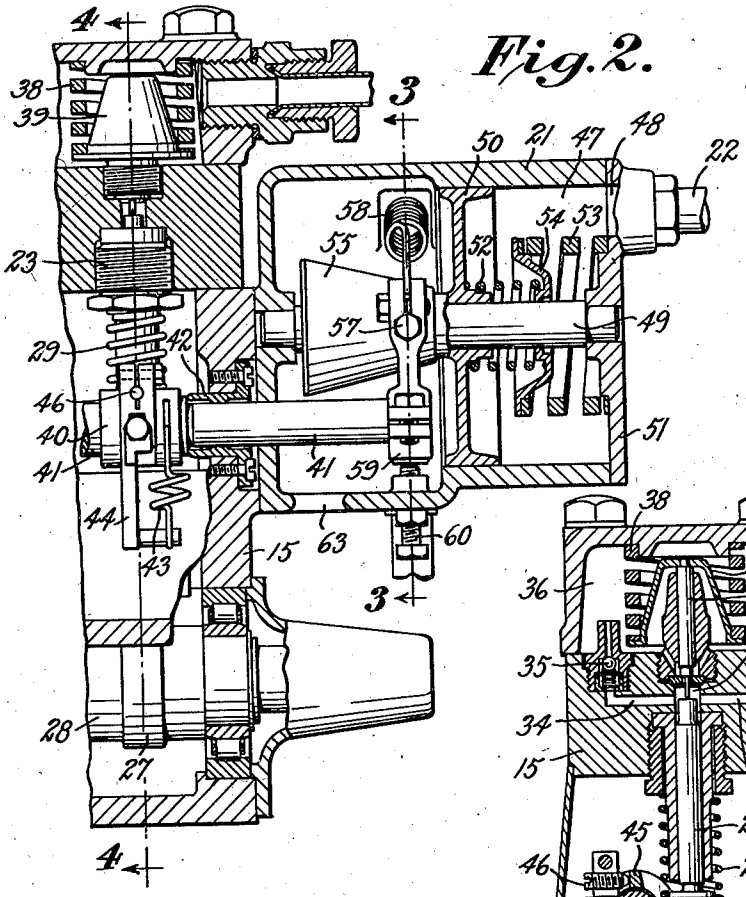


Fig. 4.

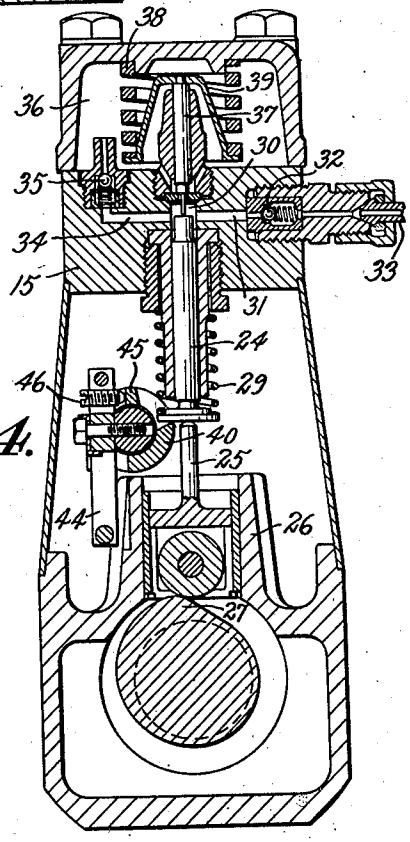
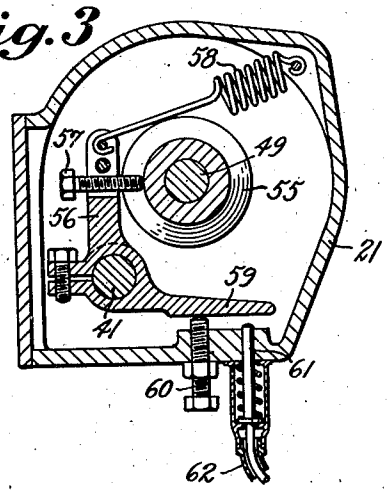


Fig. 3



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Fig. 5.

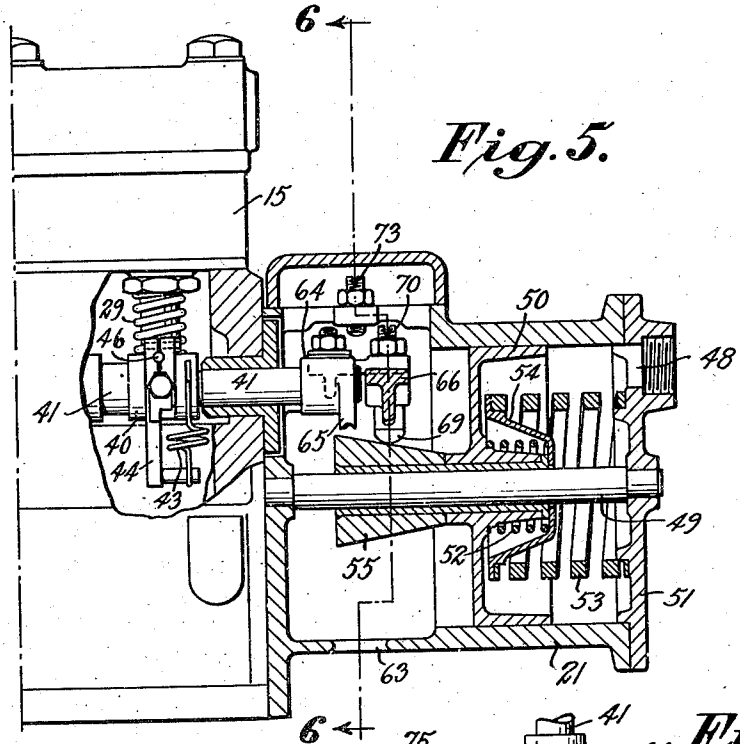


Fig. 7.

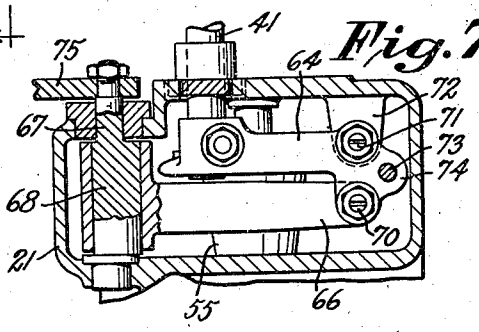
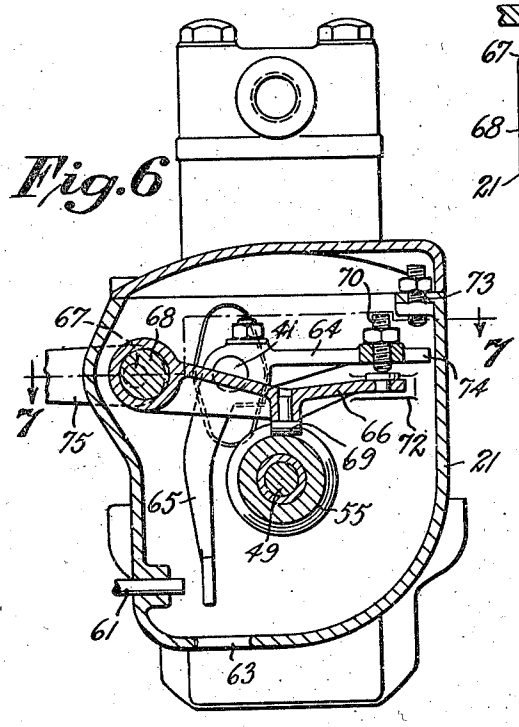


Fig. 6



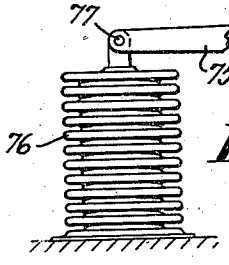


Fig. 8.

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SUPPLYING FUEL TO INTERNAL COMBUSTION ENGINES

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Fig. 11.

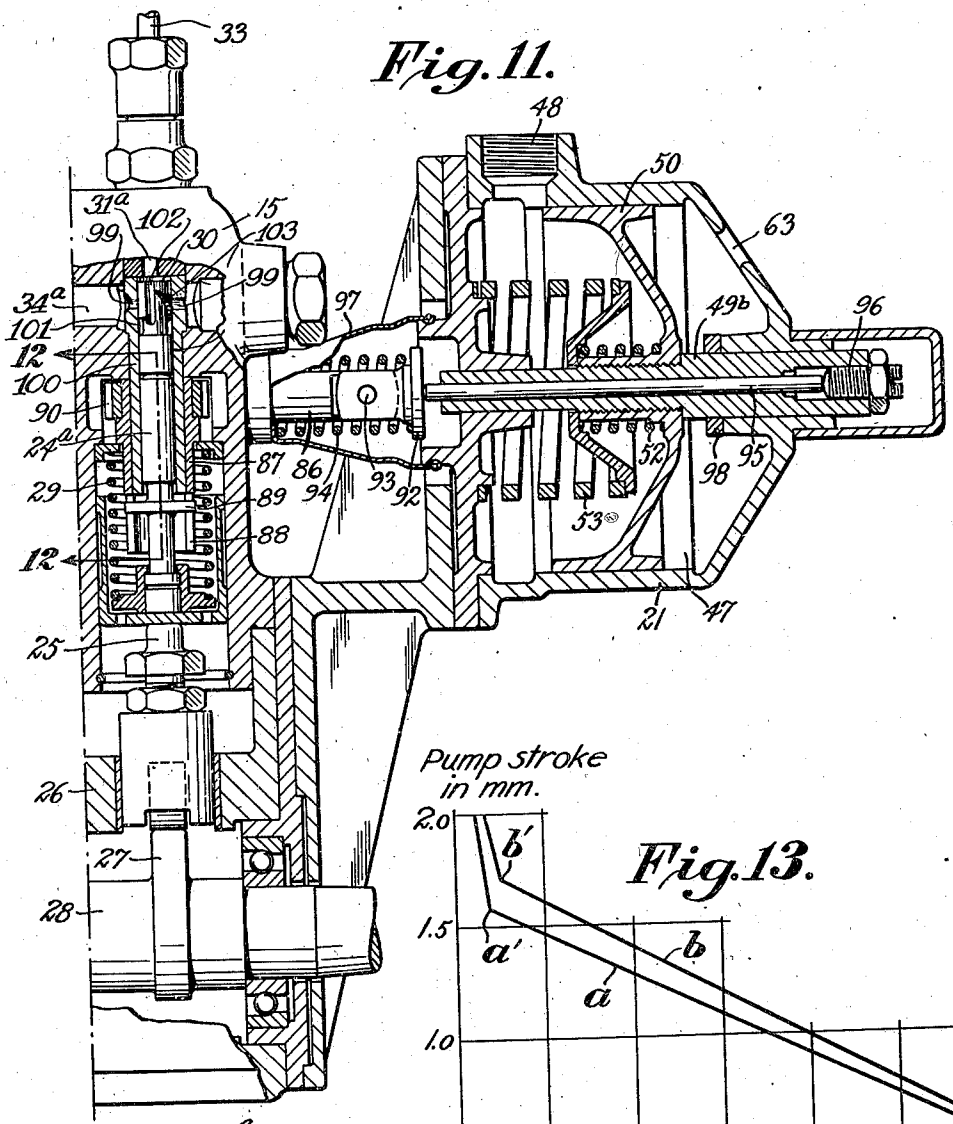
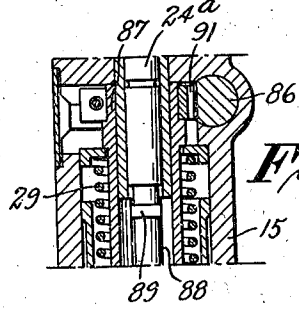


Fig. 13.

Fig. 12.



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Patented July 21, 1936 2,048,406

UNITED STATES PATENT OFFICE

2,048,406

SUPPLYING FUEL TO INTERNAL COMBUSTION ENGINES

Stig Olsen, Stockholm, Sweden, assignor to Hesselman Motor Corporation Ltd., London, England, a corporation of Great Britain

Application December 9, 1932, Serial No. 646,507
In Germany December 12, 1931

21 Claims. (Cl. 123—139)

The present invention relates to supplying fuel to internal combustion engines and has particular reference to supplying fuel to engines of the airless or solid injection type. More specifically, the invention relates to supplying fuel to an internal combustion engine automatically under the influence of variations in pressure within the induction pipe of the engine, so as to provide a controlled ratio of the quantities of fuel and air supplied to the engine. Still more particularly, the invention relates to fuel supplying apparatus for engines adapted to be used to propel automotive vehicles, aircraft and the like.

The general object of the invention is to provide improved fuel supplying apparatus of the character described which will fulfill satisfactorily and in an improved manner the numerous different requirements for apparatus of this kind.

The nature of the invention and the manner in which the above general object and other and more specific objects are attained may best be understood from a consideration of the ensuing specification descriptive of several forms of apparatus suitable for carrying the invention into effect and from the accompanying drawings in which:

Fig. 1 is a side elevation of an internal combustion engine provided with apparatus embodying the invention;

Fig. 2 is a view, partly in section, and on enlarged scale of part of the apparatus shown in Fig. 1;

Fig. 3 is a section taken on the line 3—3 of Fig. 2;

Fig. 4 is a section taken on the line 4—4 of Fig. 2;

Fig. 5 is a view similar to Fig. 2 showing a different form of apparatus;

Fig. 6 is a section taken on the line 6—6 of Fig. 5;

Fig. 7 is a section taken on the line 7—7 of Fig. 6;

Fig. 8 is a more or less diagrammatic view illustrating a device which may be used with the apparatus shown in Figs. 5 to 7;

Fig. 9 is a view similar to Fig. 1 showing part of an engine equipped with still another form of apparatus;

Fig. 10 is a section on enlarged scale taken on the line 10—10 of Fig. 9;

Fig. 11 is a section showing apparatus constructed in accordance with the invention applied to a different type of pump;

Fig. 12 is a section taken on the line 12—12 of Fig. 11; and,

Fig. 13 is a diagram illustrating the relation of the amount of fuel supplied to the induction pipe pressure when apparatus according to the invention is employed.

Referring now to the drawings, Fig. 1 shows in side elevation a multi-cylinder internal combustion engine equipped with fuel supplying apparatus according to the present invention. The motor is indicated generally at 10 and has the usual induction pipe 11 through which air for combustion is drawn from the inlet 12. Flow of air through pipe 11 is controlled by the usual butterfly throttle valve 13 actuated by rod 14 which is preferably connected to the usual throttle or accelerator pedal (not shown) when the engine is used in a vehicle.

The fuel supplying means comprises, in the present embodiment, a pump unit having a casing 15 and containing a plurality of pumps, one for each cylinder of the engine, the construction of which will be more fully described later. Fuel is admitted to the pumps through a fuel inlet pipe 16 and, if desired, the fuel supplying system may be of the circulating type in which excess fuel is returned to the supply tank from the pump unit through an outlet conduit 17. The pump casing is conveniently removably secured to a bracket 18 on the side of the engine and the drive for the pumps is effected through the medium of shaft 19 driven from the usual timing gears, or chain, the housing of which is indicated at 20.

At one end the pump casing 15 has an extension 21 which may or may not be integral with the casing 15 and which provides a cylinder having an opening adapted to be connected to the induction pipe 11 of the engine as by means of connection 22 which is preferably detachably secured to the extension 21 and which is also preferably flexible.

Considering now more particularly Figs. 2 to 4, I have shown in these figures the apparatus illustrated in elevation in Fig. 1. Within the pump casing 15 there is located a plurality of separate plunger pumps, indicated generally at 23. Each pump comprises a plunger 24 reciprocably mounted in a suitable guide and actuated on its discharge stroke by a tappet 25 guided in a suitable web 26 in the pump casing and reciprocated by a cam 27 on shaft 28 which is rotatably mounted in suitable bearings in the lower part of the casing 15 and connected to the pump driving shaft 19. Pump plunger 24 is moved on the suction stroke of the pump by spring 29 engaging a collar at the lower end of the pump plunger. The pump chamber is shown at 30

and from this chamber fuel is discharged through passage 31 and the spring loaded discharge valve 32 to conduit 33 leading to the injection nozzle of the cylinder which is supplied with fuel by the pump. Fuel is admitted to the pump chamber 30 through the inlet passage 34 in which is located the usual spring loaded check valve 35. Passage 34 is in communication with a chamber 36 in the head of the pump which provides a common supply chamber for all of the pumps and to which chamber fuel is supplied through the conduit 16. In the form of pump shown, the chamber 30 is provided with a relief valve 37 adapted to be contacted by the inner end of the plunger 24 before the plunger reaches the inner end of its stroke. This valve is held against its seat against pressure in the chamber 30 by means of the spring 38 engaging the spring retainer 39.

The present invention is not limited in its application to this specific form of pump, as will hereinafter more fully appear but is applicable to other specific pump designs as well.

Control of the amount of fuel delivered per stroke of the pump plunger 24 is effected by varying the length of the suction stroke of the pump plunger. The means for varying the suction stroke comprises an adjustable stop 40 in the form of a sleeve mounted around shaft 41 which is turnably mounted in the end walls of the casing in suitable bearings one of which is shown at 42. Sleeve 40 has limited turning movement with respect to shaft 41 and is biased so as to tend to turn counter-clockwise as viewed in Fig. 4 with respect to the shaft by means of a spring 43 connecting the sleeve to an arm 44 rigidly secured to the shaft. A stop 45 adapted to abut against a pin 46, serves to limit the turning movement of the sleeve with respect to the shaft under the influence of spring 43.

The specific form of pump construction just described forms per se no part of the present invention and the novel features thereof form the claimed subject matter of the application of Torbjorn Viktor Dillstrom, Serial No. 690,303, filed September 21, 1933.

The extension 21 carried by the pump casing provides a cylinder 47 connected with the induction pipe of the engine by way of opening 48 and pipe 22. Slidably mounted upon a guide 49 fixed within the extension axially of cylinder 47 is a piston 50 and between the end wall 51 of the extension and piston 50 are springs 52 and 53, between which is interposed a spring retainer 54 against which one end of each of the springs abuts. As indicated in the drawings, spring 52 is a relatively weak spring as compared with spring 53.

Attached to piston 50 and sliding therewith on the guide 49 is a cam member 55 which, in the illustrated embodiment is in the form of a truncated cone. One end of shaft 41 projects into the extension 21 and has fixed thereto the arm 56. Arm 56 has secured thereto a follower 57, preferably adjustable, and advantageously in the form of a set screw or the like, as indicated in Fig. 3. Follower 57 is adapted to contact the surface of the cam member 55 and is advantageously maintained in contact therewith by means of a spring 58.

A second arm 59 is also fixed to shaft 41 and movement of this arm and consequently shaft 41 in clockwise direction, as viewed in Fig. 3 is prevented by a stop 60 which is preferably adjustable. A movable pin 61 mounted in the extension 21 is adapted to contact arm 59 to turn it in counter-clockwise direction. Pin 61 provides a control to be later described and may be actuated in any convenient manner, as for example by a Bowden wire control 62 indicated in Fig. 1.

The operation of the apparatus is as follows: The pump plungers are actuated on their discharge strokes by rotation of cams 27 and are returned on their suction strokes by springs 29. The amount of fuel delivered per stroke will depend upon the length of the preceding suction stroke and this in turn will depend upon the position of rotation of the sleeves 40 on shaft 41, which sleeves for the moment may be considered as fixed to shaft 41.

The amount of air supplied to the engine is controlled by actuation of the throttle valve 13. As the valve 13 is moved toward closed position to throttle the air supply, the pressure in the induction pipe 11 (which is a negative pressure or vacuum) decreases and the decreased pressure is transmitted to cylinder 47 through connection 22. Decrease in pressure in cylinder 47 tends to move piston 50 to the right, as shown in Fig. 2, against the resistance of the springs in the cylinder, since the face of the piston opposite cylinder 47 is in free communication with the atmosphere by way of one or more ports 63 in the extension 21.

As piston 50 moves to the right, the cam member 55 slides with respect to the follower 57 and causes arm 56 and shaft 41 to be turned in counter-clockwise direction, as viewed in Fig. 3. This in turn causes the stops 40 to also turn in counter-clockwise direction to shorten the suction strokes of the pumps and consequently cause them to deliver less fuel per stroke. Thus, decrease in pressure in the induction pipe automatically effects decrease in the amount of fuel supplied. Conversely, when the throttle valve is opened and the induction pipe pressure increases piston 50 is moved to the left in Fig. 2 under the influence of the springs in cylinder 47 and shaft 41 together with stops 40 move under the influence of spring 58 in clockwise direction, as viewed in Fig. 3 to provide a longer pump stroke.

The stop 60 limits the movement of arm 59 and shaft 41 in clockwise direction, as viewed in Figs. 3 and 4, and serves to determine the maximum stroke of the pump plungers. By adjusting this stop the maximum pump stroke may be altered. The pin 61 provides a control for arbitrarily rendering the pumps inoperative irrespective of the position of the cam member 55. As will be evident from Fig. 3, if pin 61 is pushed inwardly of the casing it will operate to turn arm 59 and shaft 41 in counter-clockwise direction and thereby reduce the pump stroke to zero or to a value too small to cause an operative charge of fuel to be delivered by the pump. This movement can take place in any position of the cam member 55 since it involves merely moving the follower 57 away from the cam surface against the resistance of spring 58.

It will be evident from the foregoing description that the fuel supplying apparatus provides a simple and compact unit which may be readily detached from the engine without disturbing any of the adjustments and which comprises comparatively few and rugged parts not likely to be thrown out of adjustment by vibrations and shocks to which apparatus of this kind is necessarily subjected when applied to vehicle or air-

plane engines. By mounting the piston **50** on a central guide the amount of friction between the piston and the cylinder may be reduced to a minimum and possibility of the piston binding in the cylinder is also eliminated. This insures sensitive and rapid action of the mechanism in response to comparatively slight changes in pressure within cylinder **47** and the substantially direct connection between the piston **50** and the stops **40** reduces the likelihood of time lag in the apparatus which mechanism of more complicated nature might produce due to friction and the like. Also it is to be noted the arrangement eliminates possibility of inaccurate adjustment of the pumps due to lost motion in the mechanism.

Initial adjustment of the piston **50** with respect to the position of the adjustable stops **40** is readily effected by means of the adjustable follower **57**.

The resilient connection provided by springs **43** between shaft **41** and the stop sleeves **40** forms per se no part of the present invention but provides a desirable means for preventing adjustment of the stroke of the pump plungers to take place at an undesired point in the working cycle. These springs have insufficient strength to move the plungers on their discharge strokes against the pressure in the pump chambers and if the pressure responsive piston **50** is moved to decrease the stroke of the pumps the several stop sleeves **40** will not effect the desired adjustment until the pump plunger with which they are individually associated is positively lifted by its tappet **25**. This resilient connection to the stop sleeves permits the pressure responsive piston to move immediately upon change in pressure in the cylinder, without having to force any of the pump plungers against pump discharge pressure thus making the device more sensitive and it also prevents adjusting movement of the pump plungers in a manner which might cause a slight injection of fuel from the pump at the wrong time in the engine cycle, as for example during the exhaust stroke of the piston in the engine cylinder.

In order to provide for the maximum of fuel economy while at the same time insuring reliability of combustion and consequent evenness of engine operation throughout the entire working range of the engine from idling load to full load, the amount of fuel and air supplied to the engine for each working stroke must be supplied at a controlled ratio, and this ratio may be most conveniently considered in terms of the amount of fuel supplied for each working stroke of the engine and the pressure existing in the induction pipe as determined by the position of the throttle valve, which pressure is indicative of the quantity of air drawn into each engine cylinder per working stroke. This ratio should be different for different loads on the engine and should provide a mixture relatively rich in fuel at idling and full loads as compared with the richness of the fuel mixture supplied at intermediate loads. The relatively rich mixture at idling load is necessary in order to insure reliable and even idling of the engine, and at full load the mixture should be sufficiently rich in fuel to use up all of the air supplied to the engine in order that the maximum power may be derived from an engine of given dimensions. The obtaining of maximum power from the engine at full load and the obtaining of steady idling, by the use of a relatively rich mixture, is secured at the expense of maximum fuel economy, but the considerations of obtaining maximum power and steady idling outweigh the necessity for maximum fuel economy in most internal combustion engine applications.

At intermediate engine loads satisfactory engine operation is obtainable and improved fuel economy is also obtainable by the use of fuel mixtures having a higher ratio of air to fuel than the ratio or ratios most suitable for use at full load and idling load.

In accordance with the present invention, I provide for the supply to the engine of a fuel mixture having a ratio of fuel to air which varies with variations in engine load and is proportioned so as to provide a relatively rich mixture at idling load, which mixture decreases progressively in richness as the load increases from idling load to a load within the upper range of engine loads, and which then progressively increases in richness as the load further increases, to a degree again providing a relatively rich mixture at full engine load, so that at this latter load all of the air supplied to the engine may be utilized and the maximum amount of power developed.

A preferred means for providing this controlled ratio of the amount of fuel and air supplied to the engine consists in the provision of different resistances to movement of the pressure responsive piston **50**, which resistances cause different amounts of movement of the piston in different load ranges of the engine in response to a given variation in the pressure within the induction pipe of the engine. In the embodiment of the invention just described the different resistances are provided by the springs **52** and **53** of different strength. In the position of the apparatus as shown in Fig. 2, the pressure in the cylinder **47** is substantially atmospheric (corresponding to open throttle) and movement of the piston **50** to the right as the throttle is moved from open position is first resisted by the comparatively weak spring **52** and this resistance continues to increase at a definite proportional rate until the piston moves to the right to a point bringing the hub of the piston into contact with the spring retainer **54**. Further movement of the piston to the right is then resisted by the stronger spring **53** which provides resistance increasing at a definite proportional rate, which rate is, however, different from the rate of increase of resistance provided by the weak spring **52**. It will be evident that the same effect may be obtained by employing a plurality of relatively weak springs in place of the single stiff spring **53**.

With the springs arranged in series as shown in Fig. 2, the strong spring **53** acts as an abutment for the spring retainer **54**, and as spring **52** is compressed by initial movement of piston **50** to the right from the position shown in the figure, spring **53** will yield by a certain amount as spring **52** is compressed due to the force transmitted to it by the latter spring. The relative strength of the two springs is however such that for all practical purposes spring **53** acts as a fixed abutment until force from the piston is transmitted directly to it either by contact of the piston with the retainer or because of the fact that the resiliency of spring **52** is fully taken up. It may thus be said that the weaker spring essentially determines the resistance to movement of the piston in the range of piston movement where this spring is active and that there-

after the stronger spring essentially determines the resistance to movement.

Fig. 13 shows diagrammatically the character of the variation in fuel-air ratio obtained by apparatus of the character just described. In this diagram, ordinates represent length of pump stroke and consequently quantity of fuel supplied and abscissa represent the degree of vacuum in the induction pipe (measured in centimeters of mercury). From the diagram it will be evident that in the range of high engine loads a comparatively slight change in induction pipe pressure effects a relatively large change in the amount of fuel supplied. Expressed in another way, it may be said that in the range of high engine loads there is relatively little variation in the amount of air admitted as compared with the variation in the amount of fuel supplied. The part of the curve representing the fuel-air ratio in the range of high load is given the above described character due to the comparatively weak spring resistance, which permits relatively great movement of the pressure responsive piston under the influence of comparatively slight changes in induction pipe pressure.

In the lower load range a given variation in induction pipe pressure produces a relatively smaller variation in the amount of fuel supplied. This is due to the increased resistance provided by the strong spring **53** or its equivalent. In other words, it may be said that for comparatively low engine loads a given variation in the amount of air supplied is accompanied by a smaller variation in the amount of fuel supplied than is the case in the range of high engine loads.

If we again refer to the diagram of Fig. 13, it will be evident that apparatus productive of curves of the character of curves *a* and *b* of this diagram will provide for variations of the character above described in the richness of the fuel-air mixture. If we take curve *a*, for example, and substitute for this curve a curve that would be produced if a single spring adapted to give the same fuel-air ratio at idling and full loads as curve *a* were substituted in the construction shown for the springs **52** and **53**, the substituted curve would be in the form of a straight line connecting the two ends of curve *a*. If, now, we compare curve *a* with this suppositious straight line curve, it will be evident that as the degree of vacuum decreases from that obtained at idling load, the increase in the amount of fuel corresponding to a given decrease in the amount of vacuum and consequent increase in the amount of air supplied to the engine when curve *a* is followed, is less than it would be if the straight line curve were followed, until the point *a'* of curve *a* is reached. Consequently, during this range of operation, as the load increases from idling load, the mixture supplied to the engine decreases in richness, and consequently fuel economy is increased due to the fact that complete combustion of all of the fuel is insured because of the presence of an ample supply of excess air. From the point *a'* to the full load end of the curve *a*, the amount of fuel supplied for a given decrease in vacuum increases much more than the increase in the amount of fuel for a corresponding given decrease in vacuum on the straight line curve. Consequently, in this range of operation, the fuel mixture increases in richness as the load increases, thus enabling a fuel mixture to be supplied at full load in which there is enough fuel present to consume all of the air that can be drawn into the cylinder.

In this connection, it may be well to point out the known fact that in internal combustion engines of the injection type the maximum power of a given engine is not determined by the amount of fuel that can be injected, since it is relatively easy to inject any desired quantity of fuel into the engine cylinders, but is determined by the amount of fresh air that can be inducted into the cylinder under full load operating conditions. Consequently, the maximum power obtainable at full load in an engine of this type is determined by the amount of air that can be burned in the cylinder, and for this reason comparative richness of mixture, with the minimum or no excess air, is most desirable.

Other factors, such as variations in atmospheric pressure which are encountered in the normal operation of an airplane engine should be compensated for and in Figs. 5 to 7, I have shown an arrangement which provides an additional control whereby the position of the stop sleeves may be varied with respect to the pressure responsive piston in any given position of the piston. In this arrangement the pump construction is the same as that previously described in connection with Figs. 1 to 4 as is also the construction of the mechanism comprising the pressure responsive piston and cam member. In the present arrangement the shaft **41** has fixed thereto a bell crank comprising an arm **64** and an arm **65**. A lever **66** is rotatably mounted at one end on a pin **67** journaled in the casing extension **21** and having an eccentric part **68** around which one end of lever **66** is pivoted. Intermediate its ends lever **66** carries a roller **69** adapted to contact the surface of the cam member **55**. The free end of lever **66** is adapted to abut against an adjustable set screw **70** on arm **64**. An adjustable stop for determining maximum pump stroke is provided by the set screw **71** on arm **64**, which is adapted to abut against the bracket **72** beneath the end of this arm. The pin **61** for arbitrarily turning shaft **41** to shut off the fuel supply acts on the end of arm **65** and an adjustable set screw **73** is provided in the casing for limiting movement of shaft **41** under the influence of pin **61** by providing a stop adapted to engage the projecting outer end **74** of arm **64**. Pin **67** has fixed thereto any suitable means, such as lever **75**, for turning the eccentric part **68** to shift the position of lever **66**.

The operation of this form of apparatus is similar to that previously described with respect to the manner in which the pump stroke is varied by movement of piston **50**. It will be evident, however, from Fig. 6 that with the cam member **55** in any given position, turning movement of lever **75** will raise or lower the left hand end of lever **66**, depending upon the direction in which the lever **75** is turned and will consequently lower or raise the right hand end of lever **66**. This in turn will cause arm **64** to be moved to shift the position of the stop sleeves governing the stroke of the pump plungers. If for example, lever **75** is turned clockwise, as viewed in Fig. 6, it will result in turning shaft **41** in counterclockwise direction, thus reducing the amount of fuel supplied by the pumps. This arrangement may advantageously be used in connection with aviation engines where, due to changes in the density of the air at different altitudes, the differential pressure acting on piston **50** will be different for a given value of induction pipe pressure.

In Fig. 8, I have shown more or less diagrammatically a suitable bellows arrangement for con-

trolling the position of lever 75 in accordance with variations in atmospheric pressure. This arrangement comprises a closed bellows 76 fixed to any suitable support and pivotally connected at 77 to the end of lever 75. In order to further illustrate the manner in which this mechanism functions, let it be assumed that the apparatus shown in Figs. 5 to 8 is installed on an airplane engine. When the engine is on the ground a given value of pressure in the induction pipe will produce, let us say, a differential pressure of five pounds per square inch acting on the piston. This will move the piston a certain distance against the action of the springs and will provide a certain definite length of pump stroke. If, now, the craft in which the engine is mounted rises to a high altitude with the throttle control maintaining the same induction pipe pressure, the decrease in atmospheric pressure will cause a decrease in the differential pressure acting on the piston to a value less than that assumed and the piston will move to the left. This will cause an increase in the amount of fuel supplied, although, as assumed, the induction pipe pressure remains constant. This undesirable variation in the rate of fuel supply with constant induction pipe pressure is avoided by apparatus such as is shown in Fig. 8, since upon decrease in atmospheric pressure the bellows 76 expands and turns lever 75 in clockwise direction, thus, as previously explained, moving lever 66 and arm 64 so as to reduce the fuel supply. Thus, the movement of arm 75, tending to cause a decrease in fuel supply compensates for the tendency of the fuel supply to be increased due to reduction in atmospheric pressure.

It will be evident that the control afforded by the lever 75 may be employed to compensate for other factors of operation occurring in connection with different engine uses. Thus, for example, in the case of a vehicle engine adapted to be operated at ground level, this control may be employed to provide a richer or leaner mixture in order to take care of special operating conditions such as cold weather starting and the like.

In connection with this control, it is to be noted that it does not serve to alter the characteristic form of the curves illustrated in Fig. 13 but serves to raise or lower any given curve substantially parallel to itself in the diagram.

If it is desired to alter the characteristics of the curves, this is done by altering the strength of the springs resisting the movement of piston 50 and it will be evident that the strength of these springs can readily be altered by making adjustable the abutments against which they act or by the substitution of springs of different strengths. It is further to be noted that more than two springs of different strengths can be arranged in series between the cylinder casing and the pump piston in order to provide resistance varying at more than two different rates.

In the forms of apparatus described, the cam member is in the form of a truncated cone, but it will be apparent that other cam forms may be employed and it will further be evident that the same effect obtained by the eccentric part 68 may readily be obtained by employing an eccentrically mounted cam member which can be turned to present different axial contours for engagement with the cam follower or by adjusting by hand or automatically the distance of the follower from the cam, for example, by means of the set screw 57 shown in Fig. 3.

Turning now to Figs. 9 and 10, I have shown a different form of construction in which the extension 21 provides a cylinder 47 the axis of which is transverse to the axis of the pump shaft 41. In this arrangement the piston 50 is fixed to the guide stem 49a which is slidably mounted in the casing extension 21. Lever 78 is fixed to the end of shaft 41 and at its upper end is forked to embrace the guide 49. Spring 79 and pin 80 act to hold lever 78 in engagement with a collar 81 slidably mounted on guide 49 and adjustably fixed axially of the guide by means of the set screw 82 abutting against pin 83 passing through a collar 81 and a slot 84 in the guide stem 49a. The adjusting screw 82 serves to fix the initial position of adjustment of the lever 78 and shaft 41 with respect to piston 50. The set screw 85 serves to limit the maximum pump stroke and the supply of fuel may be arbitrarily shut off by actuation of pin 61 adapted to contact the lever 78.

In the form of apparatus illustrated in Figs. 11 and 12, a somewhat different pump construction is employed in which the variation of the effective stroke of the pump plungers is effected through the medium of a reciprocably mounted shaft 86 which operates to rotate the pump plungers to alter their effective stroke instead of shortening the suction stroke of the plungers. Turning now more particularly to the figures, the pump casing 15 carries a plurality of plunger pumps, one of which is shown at 23. Pump 23 comprises plunger 24a actuated on its discharge stroke by cam 27 acting through tappet 25 and actuated on its suction stroke by spring 29. Plunger 24a is reciprocably in a turnably mounted sleeve 87 which is slotted at its lower end at 88 and the plunger is provided with a transverse arm or pin 89 engaging slot 88 so that the plunger is prevented from moving rotationally with respect to sleeve 87 but is free to reciprocate with respect thereto. Mounted on sleeve 87 so as to rotate therewith is a pinion 90 engaging a rack 91 on shaft 86 so that upon reciprocation of shaft 86 the plunger 24a is rotated about its axis.

In the embodiment of pump shown in Fig. 11 the pump chamber 30 is in communication with the fuel inlet passage 34a by way of ports 99 in the pump sleeve 100, and the upper portion of the pump plunger 24a is provided with an annular recess 101 which is in communication with the pump chamber 30 by way of the vertical slot 102 in the plunger. Slot 102 is out of registry with the ports 99 and the upper edge of the recess 101 is formed by a spiral edge indicated at 103. When the pump plunger is at the lower end of the stroke, the upper edge of the plunger is below the level of ports 99 and the chamber 30 is filled with fuel. Injection commences when the upper edge of the plunger closes ports 99 and during the effective discharge stroke the recess 101 is filled with fuel under pressure because of the communication between this recess and the pump chamber through slot 102. Injection ceases when one of the inlet ports 99 is uncovered by the spiral edge 103, such uncovering placing the inlet passage 34a in communication with the pump chamber 30 by way of slot 102 and recess 101. It will be evident that by varying the position of rotation of the pump plunger the edge 103 will uncover the inlet port in different positions of stroke of the plunger, thereby varying the effective discharge stroke of the pump.

The above described pump plunger construction is known per se and insofar as the present invention is concerned, other forms of pump con-

struction whereby the quantity of fuel discharged per stroke is varied by rotation of the pump plunger may be employed in lieu of the above described pump construction, which has been shown merely by way of example.

In accordance with the present invention, the end of shaft 86 is provided with an abutment collar 92 pinned to the shaft at 93 and between this collar and the casing a spring 94 tends to move the shaft to the right, as viewed in Fig. 11. Movement of the shaft in this direction tends to increase the fuel supply.

In the cylinder 47 the pressure responsive piston 50 is carried by the guide 49. Between piston 50 and the end wall of the extension are the loading springs 52 and 53. Opening 48 provides a connection to the induction pipe of the engine and ports 63 permit atmospheric pressure to reach the outer face of piston 50. The slidably mounted guide stem 49*b* is provided with a central axially slidable pin 95 abutting at one end against the abutment collar 92 and at its other end abutting against the adjusting screw 96. Pin 95 and set screw 96 provide for initial adjustment of the relative positions of piston 50 and shaft 86. A protecting boot 97 is advantageously placed around the end of shaft 86 and spring 94.

The operation of this embodiment is in general similar to that previously described but due to the fact that both the piston 50 and the shaft 86 move reciprocably, the movement of piston 50 may be transmitted directly to the shaft by placing the axis of the piston in alignment with the axis of the shaft.

Shaft 86 extends through the casing and in order to arbitrarily shut off the fuel supply independently of the position of piston 50, a suitable Bowden wire control, such as is indicated in connection with the pins 61 in the previously described embodiments, may be attached to the end of shaft 86 opposite the end shown in Fig. 11, so that the shaft may be drawn to the left away from the pin 95.

For purposes of the present invention the pinion 90 and sleeve 87 may be considered as an adjustable stop for varying the effective stroke of the pump plunger since these parts in effect provide a stop determining the position of rotation of the pump plunger which in turn determines the effective discharge stroke of the pump.

While in the present embodiment I have shown no structure corresponding to the springs 43 providing a resilient connection between the shaft 41 and the stop sleeves 40 in the embodiments previously described, it will be apparent that equivalent resilient means may readily be employed in the present embodiment between the shaft 86 and the stops determining the position of rotation of the pump plungers.

The movement of the guide stem 49*b* in the right hand direction and thereby the maximum delivery stroke of the pump pistons may be adjusted by means of a distance disc 98 or the like.

From the foregoing description it will be evident that apparatus constructed in accordance with the invention may be employed to give various different curves of ratio of fuel and air supplied but I have found arrangements of the type shown to be very satisfactory in operation, these arrangements producing curves of ratio of the character indicated in Fig. 13. In this figure it will be noted that the curves *a* and *b* which represent ratios of different richness of the fuel mixture, both have the same general characteristics with respect to the variation of the amount of fuel in relation to the degree of vacuum. These curves denote a straight line relationship in the variation between the amount of fuel supplied and the induction pipe pressure but the relationship is different in two different ranges of load on the engine. I have found from experience that most satisfactory results are obtained with airless injection engines if the change in the relationship between the amount of fuel supplied and the value of the induction pipe pressure occurs at approximately half engine load. In the curves shown in Fig. 13 the point of change in the relationship is indicated at *a'* and *b'*, respectively, and these points on the curves occur at the time when the resistance to movement of piston 50 in the apparatus is transferred from the weak spring 52 to the strong spring 53.

It is to be noted that in the several embodiments of apparatus shown, the adjustment is for maximum supply of fuel when atmospheric pressure exists in the cylinder which communicates with the induction pipe. Thus, when the motor is at rest and induction pipe pressure is equal to that of the atmosphere, the device is adjusted for maximum fuel delivery. If, however, the engine is started with the throttle valve adjusted for a restricted air supply, the fuel supplying device will be substantially immediately adjusted for a reduced supply of fuel, since in starting with a partially closed throttle the induction pipe pressure falls rapidly as soon as engine operation commences.

It may further be noted that according to my invention the vacuum controlled piston apparatus and the regulating means on the fuel pump determining the delivery stroke are connected in such a manner that they can be separated at any time arbitrarily or by means actuated by the engine speed. Moreover the said connection is always adjustable as pointed out in the foregoing by suitable means such as set screws so that a movement of the vacuum controlled piston produces a quite definite delivery stroke of the fuel pump.

With regard to Fig. 13 and the curves shown thereby it will be seen that any other character can be given to these curves when for each acting range of the spring or springs the stiffness is predetermined in accordance with the actual operating conditions. Thus it will always be possible to obtain a desired ratio of air to fuel.

While I have shown, for purposes of illustration and explanation, forms of apparatus which I consider to be most suitable for carrying the invention into effect, it will be apparent to those skilled in the art that many changes and variations may be made in the specific design of the apparatus without departing from the scope of the invention and that for numerous of the specific elements herein illustrated, other equivalent elements may be substituted.

What I claim is:

1. In fuel supplying means for internal combustion engines having an induction pipe, the combination with a fuel pump, means for varying the effective stroke of the pump, pressure responsive means adapted to move under the influence of variations in pressure in said induction pipe, and means for transmitting movement from said pressure responsive means to the first mentioned means, of means providing a plurality of resistances for opposing movement of the pressure responsive means in response to decrease in said pressure, the last mentioned means comprising a plurality of springs of different strength arranged

so that movement of the pressure responsive member due to decrease in said pressure is resisted first by a relatively weak spring and then by a relatively strong spring.

2. Fuel supplying means for internal combustion engines having an induction pipe comprising, in combination, a pump casing, a plurality of plunger pumps having plungers mounted in line within said casing, a shaft movably mounted in said casing to one side of the line of plungers, means associated with said shaft for causing movement of the shaft to vary the effective delivery strokes of said plungers, pressure responsive means adapted to move under the influence of variations in pressure in said induction pipe, means for transmitting movement from said pressure responsive means to said shaft, and a plurality of springs for opposing movement of the pressure responsive means in response to decrease in said pressure, said springs being of different strength and acting to oppose said movement first by a relatively weak spring and then by a relatively stronger spring.

3. Apparatus of the character described comprising, in combination, a fuel pump, means for varying the effective discharge stroke of the pump comprising a turnably mounted shaft, means providing a cylinder having an opening adapted to be connected to the induction pipe of an engine, a piston reciprocably mounted in said cylinder, spring means for resisting movement of said piston in response to decrease in pressure in said cylinder, a cam member operatively connected to and reciprocable with said piston, said cam member having a surface inclined with respect to the axis of reciprocation of the cam and means comprising an arm in engagement with the surface of said cam member for causing turning movement of said shaft upon movement of said cam member, said spring means and said cam being constructed and arranged to cause less decrease in the effective discharge stroke of the pump for a given decrease in pressure in said pipe in the low load range of operation of the engine than for the same decrease in pressure in said pipe in the high load range of operation of the engine.

4. Apparatus of the character described comprising, in combination, a fuel pump, means for varying the effective discharge stroke of the pump comprising a turnably mounted shaft, means providing a cylinder having an opening adapted to be connected to the induction pipe of an engine, a piston reciprocably mounted in said cylinder, spring means for resisting movement of said piston in response to decrease in pressure in said cylinder, a cam member connected to and reciprocable with said piston and mechanism comprising a part in engagement with the surface of said cam member for causing turning movement of said shaft upon movement of said cam member, said spring means and said cam being constructed and arranged to cause less decrease in the effective discharge stroke of the pump for a given decrease in pressure in said pipe in the low load range of operation of the engine than for the same decrease in pressure in said pipe in the high load range of operation of the engine and said mechanism including a part movable to alter the position of said shaft relative to said cam member in a given position of the cam member.

5. Apparatus of the character described comprising, in combination, a fuel pump, means for varying the effective discharge stroke of the pump, means providing a cylinder having an opening adapted to be connected to the induction pipe of an engine, a piston reciprocably mounted in said cylinder, spring means comprising portions of different strength for resisting movement of said piston with different rates of resistance in different ranges of position of the piston in response to decrease in pressure in said cylinder, mechanism providing an operative connection for transmitting movement from said piston to said first mentioned means and means for arbitrarily moving said first mentioned mechanism independently of said piston to render said pump inoperative.

6. Apparatus of the character described comprising, in combination, a fuel pump, means for varying the effective discharge stroke of the pump comprising a turnably mounted shaft, means providing a cylinder having an opening adapted to be connected to the induction pipe of an engine, a piston reciprocably mounted in said cylinder, spring means for resisting movement of said piston in response to decrease of pressure in said cylinder, a cam member operatively connected to and reciprocable with said piston, mechanism having a follower engaging the surface of said cam member and comprising an arm secured to said shaft for causing turning movement of the shaft upon movement of the cam member, said spring means and the surface of said cam member being constructed and arranged to cause less movement of said arm for a given decrease in pressure in said pipe in the low load range of operation of the engine than for the same decrease in pressure in said pipe in the high load range of operation of the engine and means for arbitrarily moving said follower out of contact with the cam surface and turning said shaft to a position rendering said pump ineffective independent of the position of said cam member.

7. Fuel supplying apparatus for a multi-cylinder internal combustion engine having an induction pipe comprising a plurality of plunger pumps, one for each cylinder of the engine, a movably mounted member having a plurality of stops associated therewith for varying the effective stroke of the pumps, means providing a cylinder having an opening adapted to be connected to said induction pipe, a piston reciprocably mounted in said cylinder, spring means for resisting movement of said piston in response to decrease of pressure in said cylinder, said spring means comprising portions of different strength arranged with the portion of greater strength resisting movement of said piston in the range of movement thereof corresponding to low air pressure in said cylinder and mechanism including a part operatively connected to and reciprocable with said piston for moving said movably mounted member to vary the position of said stops.

8. Fuel supplying apparatus for a multi-cylinder internal combustion engine having an induction pipe comprising a casing, a plurality of plunger pumps, one for each cylinder of the engine, mounted in said casing, a turnably mounted shaft having a plurality of stops associated therewith for varying the stroke of said pumps upon turning movement of the shaft, means providing a cylinder at one end of the casing, said cylinder having an opening adapted to be connected to said induction pipe and the axis of the cylinder being parallel to said shaft, a guide mounted axially of said cylinder, a piston slidably mounted on said guide and reciprocable in said cylinder, spring means for resisting movement of said piston upon decrease in pressure in the cylinder, a cam member connected to said piston and slidable on said guide, an arm fixed to said

shaft, a lever having a part adapted to engage said cam member and a part adapted to engage said arm for transmitting motion from said cam member to said shaft, and an adjustable pivot for said lever for altering the position of rotation of said arm with the cam member in a given position.

9. Fuel supplying apparatus for a multi-cylinder internal combustion engine having an induction pipe comprising a casing, a plurality of plunger pumps, one for each cylinder of the engine, mounted in said casing, a reciprocably mounted shaft having a plurality of stops associated therewith for varying the effective stroke of said pumps upon movement of the shaft, means providing a cylinder at one end of the casing, said cylinder having an opening adapted to be connected to said induction pipe and the axis of the cylinder being in alignment with said shaft, a piston reciprocable in said cylinder, spring means for resisting movement of said piston upon decrease in pressure in the cylinder, and means for transmitting movement of said piston directly to said shaft, said spring means comprising portions of different strength and the portion of greater strength being arranged to resist movement of said piston in the range of movement thereof corresponding to low air pressure in said cylinder.

10. Fuel supplying apparatus for a multi-cylinder internal combustion engine having an induction pipe comprising a casing, a plurality of plunger pumps, one for each cylinder of the engine, mounted in said casing, a reciprocably mounted shaft having a plurality of racks thereon, rotatably mounted stops engaging said racks for varying the effective stroke of said pumps upon movement of the shaft, means providing a cylinder at one end of the casing, said cylinder having an opening adapted to be connected to said induction pipe and the axis of the cylinder being in alignment with said shaft, a piston reciprocable in said cylinder, spring means for resisting movement of said piston upon decrease in pressure in the cylinder and means for transmitting movement of said piston directly to said shaft, said spring means comprising portions of different strength and the portion of greater strength being arranged to resist movement of said piston in the range of movement thereof corresponding to low air pressure in said cylinder.

11. In charge forming apparatus for injection engines having a throttle controlled air admission conduit, the combination with fuel injecting means for separately injecting fuel to the engine and pressure responsive means responsive to variations in the pressure of the controlled air in said conduit of mechanism including a device for delivering measured quantities of fuel to said fuel injecting means, said mechanism being adjustable in response to movement of said pressure responsive means and including parts arranged to move in response to a movement of the pressure responsive means corresponding to an increase in pressure in said conduit of given value when the load on the engine is in the range between idling load and an intermediate load at least as great as half load so as to increase the amount of fuel injected by an amount proportionately less than the increase in the amount of air supplied, whereby to decrease the proportion of fuel in the fuel-air mixture as the load on the engine increases in said range, and to move in response to a movement of the pressure responsive means corresponding to the same given value of pressure increase in said conduit when the load on the engine is in the range between said intermediate load and full load so as to increase the amount of fuel injected by an amount proportionately greater than the increase in the amount of air supplied, whereby to increase the proportion of fuel in the fuel-air mixture supplied to the engine as the load increases in the second mentioned range.

12. In charge forming apparatus for injection engines to which air and fuel are separately supplied and in which air is admitted to the engine through a throttle controlled air admission conduit, a fuel pump means for varying the proportion of fuel to air supplied to the engine comprising pressure responsive means movable under the influence of variations in pressure in said admission conduit, means for causing the movement of said pressure responsive means corresponding to a given pressure change in said conduit in the range of engine loads from idling load to an intermediate engine load to vary the effective discharge stroke of the pump by a relatively small amount, whereby to cause a fuel-air mixture having a progressively smaller proportion of fuel to be supplied to the engine as the load increases within said range, and means for causing the movement of said pressure responsive mechanism corresponding to the same given pressure change in said conduit in the range of engine loads from said intermediate load to full load to vary the effective discharge stroke of the pump by a relatively large amount, whereby to cause a fuel-air mixture having a progressively larger proportion of fuel to be supplied to the engine as the load increases in the second mentioned range.

13. In charge forming apparatus for injection engines to which air and fuel are separately supplied and in which air is admitted to the engine through a throttle controlled air admission conduit, a fuel pump means for varying the proportion of fuel to air supplied to the engine comprising pressure responsive means movable in response to variations in pressure in said conduit, means for causing the movement of said pressure responsive means corresponding to a given pressure change in said conduit in the range of engine loads from idling load to an intermediate load at least as great as half load to vary the effective discharge stroke of the pump by a relatively small amount, whereby to cause a fuel-air mixture having a progressively smaller proportion of fuel to be supplied to the engine as the load increases within said range, and means for causing the movement of said pressure responsive means corresponding to the same given pressure change in said conduit in the load range of engine loads from said intermediate load to full load to vary the effective discharge stroke of the pump by a relatively large amount, whereby to cause a fuel-air mixture having a progressively larger proportion of fuel to be supplied to the engine as the load increases in the second mentioned range.

14. In charge forming apparatus for injection engines to which air and fuel are separately supplied and in which air is admitted to the engine through a throttle controlled air admission conduit, a fuel pump means for varying the proportion of fuel to air supplied to the engine comprising pressure responsive means movable in response to pressure variations in said conduit, means for causing the movement of said pressure responsive means corresponding to a given pressure change in said conduit in the lower load range of the engine to vary the effective discharge stroke of the pump by an amount sufficiently

small to provide a fuel-air mixture having a smaller proportion of fuel as the load increases from idling load, and means operative only in the high load range of the engine for causing the amount of variation in the effective discharge stroke of the pump corresponding to said given pressure change to be increased sufficiently to provide a fuel-air mixture having a larger proportion of fuel as the load increases in said high load range.

15. In the operation of an internal combustion engine of the injection type to which air is admitted through an induction pipe and in which the amount of fuel injected is controlled by the pressure in said induction pipe, that improvement which consists in causing a pressure change of given value in said pipe when the engine is operating in the range of loads between idling load and an intermediate load to change the amount of fuel injected by an amount such that the proportion of fuel in the fuel-air mixture admitted to the engine decreases as the load increases in said range and causing the same given value of pressure change in said pipe when the engine is operating in the range of loads from said intermediate load to full load to change the amount of fuel injected by an amount such that the proportion of fuel to air in the fuel-air mixture supplied to the engine increases as the load increases in the second mentioned range.

16. In the operation of an internal combustion engine of the injection type to which air is admitted through an induction pipe and in which the amount of fuel injected is controlled by the pressure in said induction pipe, that improvement which consists in causing a pressure change of given value in said pipe when the engine is operating in the range of loads from idling load to an intermediate load at least as great as half load to change the amount of fuel injected by an amount such that the proportion of fuel in the fuel-air mixture admitted to the engine decreases as the load increases in said range and causing the same given value of pressure change in said pipe when the engine is operating in the range of loads from said intermediate load to full load to change the amount of fuel injected by an amount such that the proportion of fuel to air in the fuel-air mixture supplied to the engine increases as the load increases in the second mentioned range.

17. In the operation of an internal combustion engine of the injection type to which air is admitted through a throttle controlled induction pipe through which a throttled supply of air is admitted at partial load on the engine and in which the amount of fuel injected is controlled by the pressure in said pipe, that improvement which consists in causing the amount of fuel injected to be increased in response to an increase in pressure of given value in said pipe by an amount proportionally less than the increase in the amount of air supplied due to said increase in pressure when the amount of throttling is reduced to compensate for increase in engine load in the range of loads from idling load to an intermediate load at least as great as half load, whereby to effect a reduction in the proportion of fuel in the fuel-air mixture supplied to the engine as the load increases in said range, and causing the amount of fuel injected to be increased in response to an increase in pressure in said pipe of the same given value by an amount proportionally greater than the increase in the amount of air supplied due to said increase in pressure when the amount of air throttling is further reduced to compensate for increase in engine load in the range of loads from such intermediate load to full load, whereby to effect an increase in the proportion of fuel in the fuel-air mixture supplied to the engine as the load increases in the second mentioned range.

18. In charge forming apparatus for injection engines to which fuel and air are separately supplied, the combination with a throttle controlled air admission conduit, a fuel pump, means for varying the effective discharge stroke of the pump, pressure responsive means movable under the influence of the variations in pressure of the controlled air in said admission conduit, and means for transmitting movement from said pressure responsive means to the means for varying the effective stroke of the pump, of means providing resistance opposing the movement of the pressure responsive means occasioned by decrease in said pressure, the means providing such resistance being yieldable and comprising portions of different strength arranged to provide proportionately less resistance per unit decrease in said pressure in the range of pressures from normal maximum pressure to an intermediate pressure than in the range of pressures below said intermediate pressure.

19. In charge forming apparatus for injection engines to which fuel and air are separately supplied, the combination with a throttle controlled air admission conduit, a fuel pump, means for varying the effective discharge stroke of the pump pressure responsive means movable under the influence of the variations in pressure of the controlled air in said admission conduit, and means for transmitting movement from said pressure responsive means to the means for varying the effective stroke of the pump, of spring means providing resistance opposing movement of the pressure responsive means occasioned by decrease in said pressure, said spring means comprising portions having different strengths arranged for a portion of lesser strength to essentially determine the resistance opposing movement of the pressure responsive means occasioned by decrease in said pressure from the normal maximum value to an intermediate value and for a portion of greater strength to essentially determine the resistance to movement of the pressure responsive means occasioned by decrease in said pressure to a value less than said intermediate value.

20. In charge forming apparatus for injection engines to which fuel and air are separately supplied, the combination with a throttle controlled air admission conduit, a fuel pump, means for varying the effective discharge stroke of the pump, pressure responsive means movable under the influence of the variations in pressure of the controlled air in said admission conduit, and means for transmitting movement from said pressure responsive means to the means for varying the effective stroke of the pump, of spring means providing resistance opposing the movement of the pressure responsive means occasioned by decrease in said pressure, said spring means comprising portions having different strengths including one portion having a strength several times as great as other portions, said portions being arranged for a portion of lesser strength to essentially determine the resistance opposing movement of the pressure responsive means occasioned by decrease in said pressure from the normal maximum value to an inter-

mediate value and for said one portion to essentially determine the resistance to movement of the pressure responsive means occasioned by decrease in said pressure to a value less than said intermediate value.

21. Charge forming apparatus of the character described comprising, in combination, a fuel pump, means for varying the effective discharge stroke of the pump comprising a turnably mounted part, a pressure responsive member axially movable under the influence of the variations in pressure in the air admission conduit of an engine, means for translating axial movement of said pressure responsive member into turning movement of said part whereby to effect control of the effective stroke of the pump, and spring means providing resistance opposing the movement of the pressure responsive means occasioned by decrease in said pressure, said spring means comprising portions having different strengths arranged for a portion of lesser strength to essentially determine the resistance opposing movement of the pressure responsive means occasioned by decrease in said pressure from the normal maximum value to an intermediate value and for a portion of greater strength to essentially determine the resistance to movement of the pressure responsive means occasioned by decrease in said pressure to a value less than said intermediate value.

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