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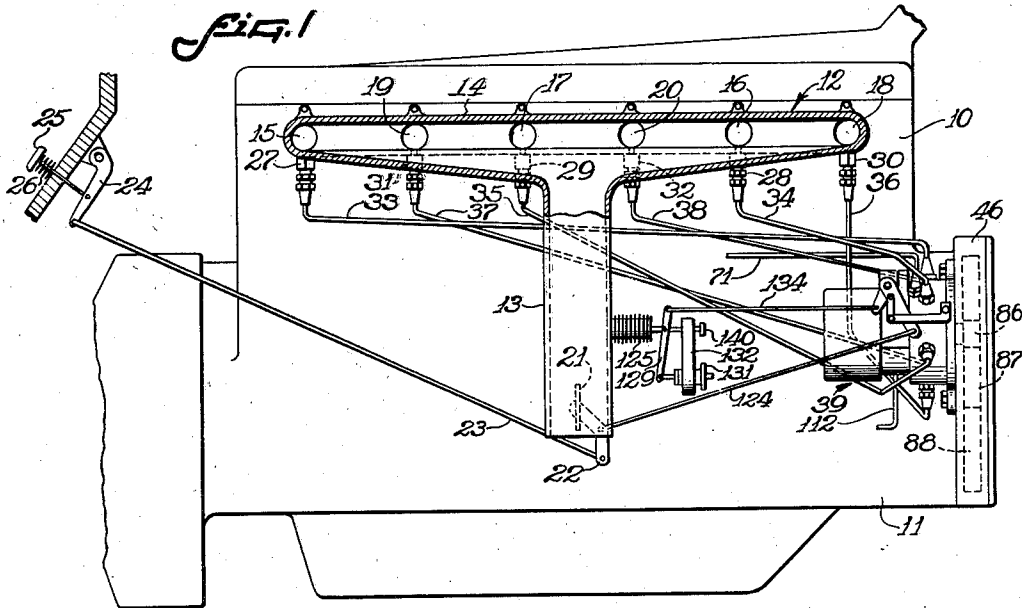
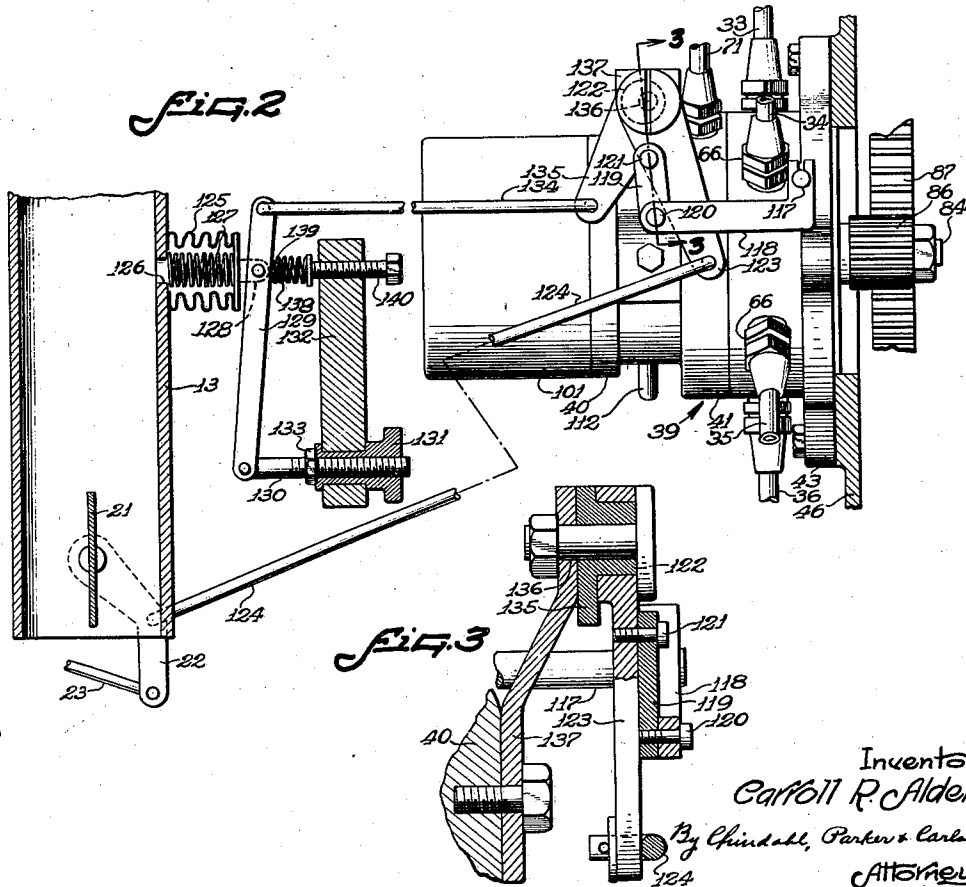
C. R. ALDEN

2,087,233

FUEL INJECTION SYSTEM

Filed Oct. 8, 1932

2 Sheets-Sheet 1



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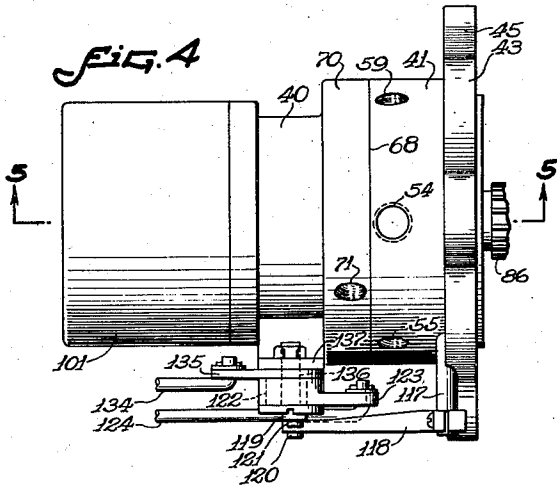
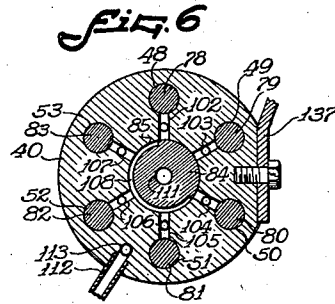
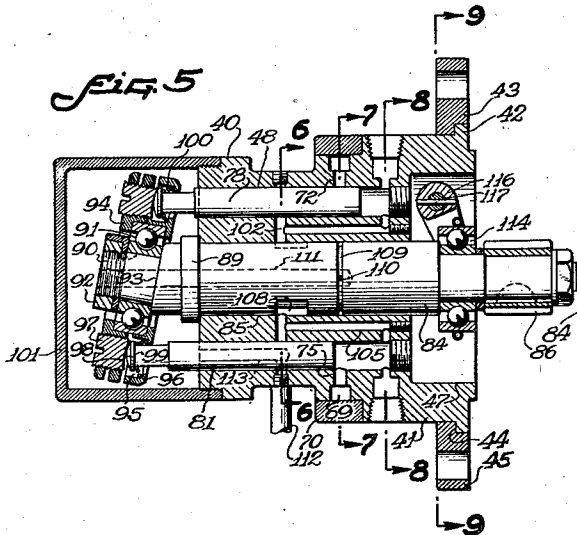
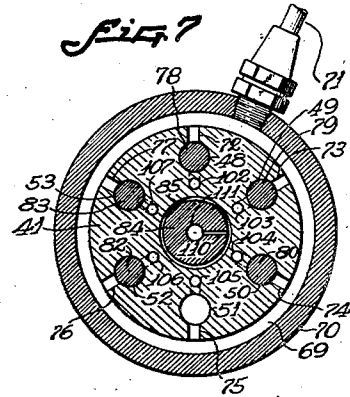
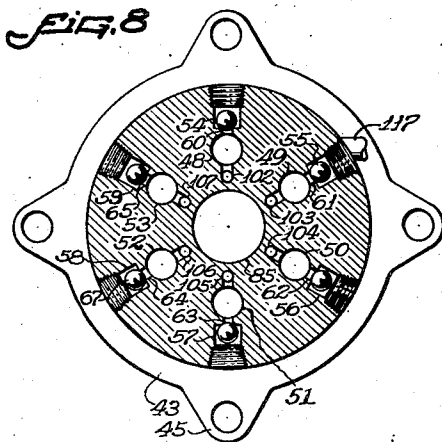
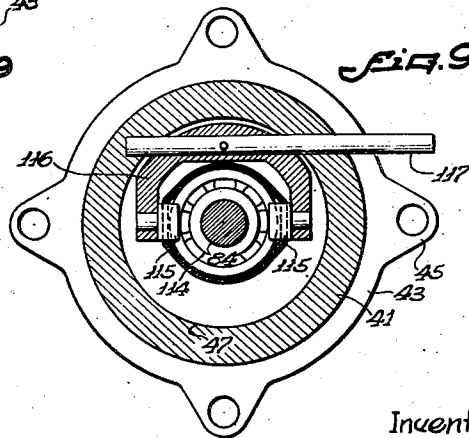
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2 Sheets-Sheet 2



Inventor
Carl R. Alden
By *Chindahl, Parker & Carlson*
Attorneys

UNITED STATES PATENT OFFICE

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FUEL INJECTION SYSTEM

Carroll R. Alden, Detroit, Mich., assignor to Ex-Cell-O Corporation, a corporation of Michigan

Application October 8, 1932, Serial No. 636,791

6 Claims. (Cl. 123—139)

The present invention relates generally to improvements in fuel injection systems, and has particular reference to such systems that are well adapted to inject fuel into the air intake manifolds of internal combustion engines.

One of the primary objects of the present invention is to provide a new and improved fuel injection system in which a predetermined fuel-air ratio is substantially maintained regardless of changes in atmospheric conditions, fluctuations in engine speeds, and/or variations in the amount of fuel-air mixture supplied.

Another object of the invention is to provide a novel fuel injection system in which the fuel is supplied in metered quantities, and in which pressure responsive means located externally of the intake manifold is automatically operable upon adjusting the supply of air to vary the quantity of fuel in each charge in accordance with changes in the static pressure in the intake manifold.

A more specific object resides in the provision of a new and improved fuel injection system comprising an air throttle, a fuel throttle, means for operating the throttles jointly over a substantial range in accordance with a predetermined fuel-air ratio, and means for automatically adjusting the fuel throttle independently of the air throttle to compensate for changes in operating conditions tending to affect the fuel-air ratio.

Another object of the invention is to provide a novel fuel throttle actuator, subject to manual or automatic operation, which is not appreciably affected by the pumping reaction, and which therefore is capable of easy, sensitive and accurate adjustment.

Further objects and advantages will become apparent as the description proceeds.

In the accompanying drawings, Figure 1 is a side view of an internal combustion engine to which a fuel injection system embodying the features of my invention has been applied.

Fig. 2 is a fragmentary view on an enlarged scale and partially in section of the fuel-air ratio control and the fuel pump.

Fig. 3 is a fragmentary detail sectional view of the fuel throttle actuator taken along line 3—3 of Fig. 2.

Fig. 4 is a plan view of the fuel pump.

Fig. 5 is a vertical axial sectional view taken along line 5—5 of Fig. 4.

Figs. 6, 7, 8 and 9 are transverse vertical sectional views taken respectively along lines 6—6 to 9—9 inclusive of Fig. 5.

While the invention is susceptible of various

modifications and alternative constructions, I have shown in the drawings and will herein describe in detail the preferred embodiment, but it is to be understood that I do not thereby intend to limit the invention to the specific form disclosed, but intend to cover all modifications and alternative constructions falling within the spirit and scope of the invention as expressed in the appended claims.

Referring more particularly to the drawings, the fuel injection system generally is adapted for use in connection with various kinds of internal combustion engines, and for purposes of illustration is herein disclosed as applied to an engine having six cylinders in line and operating on a mixture of vaporized hydrocarbon fuel and air.

The engine (see Fig. 1) comprises a cylinder block 10, a crank case 11 and an intake manifold 12. In the present instance, the manifold 12 is of the usual T-shaped form, having a vertical inlet arm 13 and a horizontal distributing arm 14 with connections 15 to 20 opening to the respective cylinders.

It will be understood that the arm 13 of the manifold 12 serves to supply the air for the combustible fuel mixture from the atmosphere. The amount of air supplied is under the control of a suitable air throttle which is herein shown as a butterfly valve 21 pivotally mounted in the inlet end of the arm 13, and operatively connected through a crank arm 22, a link 23 and a lever 24 to a manual actuator 25. A spring 26 engaging the actuator 25 acts in a direction tending to close the valve 21.

The fuel, such as naphtha or gasoline, is introduced into the manifold 12 in proportion to the volume of air supplied so as to obtain the desired fuel-air ratio. Preferably, the fuel is injected into the manifold 12 in successive charges in timed relation to the sequential operation of the engine cylinders, and comprising a charge for each cycle of each cylinder. In the present instance, a series of injection nozzles 27 to 32 are mounted to discharge the fuel respectively into the connections 15 to 20 opening into the engine cylinders. The metered charges of fuel are supplied under pressure to the nozzles 27 and 32 respectively through fuel conduits 33 to 38 leading from a suitable fuel charging device 39, preferably in the form of a variable-flow metering pump (see Figs. 4 to 9). The pump 39 per se constitutes the subject matter of, and is claimed in, my copending divisional application Serial No. 135,846, filed April 9, 1937.

In its preferred form, the pump 39 comprises

a casing 40 which is generally cylindrical in shape, and peripherally enlarged at one end as indicated at 41. The enlarged portion 41 is formed adjacent its free end with a peripheral flange 42. To mount the casing 40 in position, a ring 43 notched in its inner periphery as indicated at 44 to interfit with the flange 42 is disposed on the enlarged portion 41, and is formed with peripherally spaced ears 45 secured to a gear housing 46 on the engine block 10.

The casing 40 is formed in the enlarged end with an axial cylindrical recess 47. Formed in the other end of the casing 10 and extending at their inner ends almost through to the recess 47 are a plurality of parallel longitudinal bores or pump cylinders, six cylinders 48 to 53 in the present instance (see Figs. 5 to 7), uniformly spaced concentrically about the axial center of the casing. A plurality of radial bores 54 to 59 (see Fig. 8) tapped in their outer ends, are formed in the enlarged portion of the casing 40, and open at their inner ends respectively through ports 60 to 65 to the closed inner ends of the cylinders 48 to 53. The bores 54 to 59 are connected by means of fittings 66 threaded therein respectively to the inlet ends of the fuel conduits 33 to 38. Spring-pressed ball check valves 67 in the bores 54 to 59 seated against the ports 60 to 65 prevent any back flow of fuel into the cylinders 48 to 53.

The inner end of the enlarged portion 41 of the casing 40 is formed externally with a peripheral notch 68, and in the cylindrical surface of the latter is formed a peripheral groove 69. A seal ring 70 fitted in the notch 68 serves to close the groove 69. Opening through the ring 70 is an inlet conduit 71 leading from a suitable fuel supply under a relatively low pressure (not shown). A plurality of inlet ports 72 to 77 (see Fig. 7) formed in the casing 40 open from the groove 69 respectively into the cylinders 48 to 53.

Slidably disposed respectively in the cylinders 48 to 53 are a plurality of pump pistons or plungers 78 to 83. Each pump piston (78 to 83) in its outward or suction stroke is adapted to uncover the associated inlet port (72 to 77), and on its return or pressure stroke to cut off the inlet port and force the fuel under pressure in a metered quantity through the associated outlet port (60 to 65) past the valve 67 into the fuel conduit (33 to 38). It will be evident that the extent of movement of each piston on its pressure stroke past its inlet port determines the volume of fuel metered in each charge.

Any suitable drive may be provided for reciprocating the pistons 78 to 83 in timed sequence and in timed relation to the engine. In the present instance, this means comprises a drive shaft 84 extending through and journaled in an axial bore 85 formed in the casing 40. The end of the shaft 84 outside of the recess 47 has fixed thereon a pinion 86 connected through gears 87 and 88 (see Fig. 1) to the engine crankshaft (not shown).

The other or inner end of the shaft 84 is formed with a peripheral collar 89 adapted to abut rotatably against the adjacent end of the casing 40, and beyond the collar is reduced in size and bent at an angle to its axis to provide an eccentric hub 90.

The inner raceway of a ball bearing 91 is secured by means of a nut 92 on the hub 90 against a peripheral transverse shoulder 93. The outer raceway of the bearing 91 is seated in the inner

periphery of an annular concentric wobble plate 94.

Formed in the wobble plate 94 in uniformly spaced relation about the bearing 91 are a plurality of recesses 95, each of which has an internal peripheral flange 96 at its outer end. A plurality of bearing plugs 97 are threaded into the wobble plate 74 at the other ends of the recesses 95, and each plug is formed in its inner end with a concave or semi-spherical bearing seat 98. The outer ends of the pistons 78 to 83 extend respectively into the recesses 95 and are formed with rounded heads 99 in bearing engagement with the seats 98. Coiled compression springs 100 seated against the flanges 95 and impinging against the heads 99 serve to hold the latter continuously against the seats 98. A cap 101 secured to the end of the casing 40 encloses the wobble plate 94 and associated parts. It will be evident that each of the pistons 78 to 83 has a universal connection with the wobble plate 94, and that upon rotation of the latter the pistons will be reciprocated in timed sequence.

The volume of fuel to be charged may be adjusted by shifting the shaft 84 axially to vary the point of cut-off of the inlet ports 72 to 77 by the pistons 78 to 83. Thus, upon adjusting the shaft 84 into its outermost position, as shown in Fig. 5, the pump will meter the maximum charge, and upon adjusting the shaft inwardly the volume of the charge will be progressively reduced.

A pump of the character thus far described is subject to the objection, particularly where a highly volatile fuel such as gasoline is handled, that on the suction stroke of each of the pistons 78 to 83, a substantial vacuum is induced in the associated cylinder, with the result that the fuel in the cylinder tends to vaporize, and that upon uncovering the inlet port the fresh fuel enters with a decided rush. These conditions are not conducive to efficient operation of either the pump or the engine. To prevent same, provision is made to flood each of the cylinders 48 to 53 with fuel during the suction stroke of the associated piston regardless of whether or not the associated inlet port has been uncovered. More particularly, all cylinders whose pistons are on their suction stroke and preferably also those whose pistons are on their pressure stroke but have not cut-off the associated inlet ports are interconnected for the by-pass of fuel. Since some one or more of these cylinders are always in communication with their inlet ports, all of the connected cylinders will be flooded with fuel.

The by-pass means comprises a plurality of passages 102 to 107 (see Figs. 6 and 8) formed in the body of the casing 40 and communicating respectively with the closed inner ends of the cylinders 47 to 53. The passages 102 to 107 open in uniformly spaced relation in a common transverse plane to the periphery of the bore 85, each passage preferably being located in a common radial plane with its associated pump cylinder.

Formed in the periphery of the drive shaft 84 is a circumferential groove 108 extending through approximately 240°. The lead end of the groove 108 is movable into successive communication with the passages 102 to 107 upon rotation of the shaft 84 in a counterclockwise direction as viewed from the right in Fig. 5. The width of the groove 108 is substantially greater than that of the communicating ends of the passages 102 to 107 so that the rotary valve constituted there-

by is unaffected by axial adjustment of the shaft 84. The groove 108 has a phase relation to the pistons 78 to 83 such that all of the cylinders except those in which the pistons at any particular time are in the effective portions of their pressure strokes are intercommunicating. Thus, as a given piston reaches a predetermined point in its inward movement, namely cut-off at full throttle, the associated cylinder is cut out of communication with others of the cylinders.

To prevent fuel from leaking along the shaft 84 out of the casing 40 to the atmosphere, a labyrinth groove 109 is formed in the periphery of the shaft externally of and in spaced relation to the by-pass groove 108. The groove 109 opens through a radial duct 110 and an axial bore 111 in the shaft 84 to the interior of the end cap 101. Fuel leaking along the pistons 78 to 83 also enters the end cap 101. A drain conduit 112 connected to the casing 40 and opening through a passage 113 in the latter to the interior of the cap 101 serves to remove any fuel collecting therein.

The shaft 84 as a rotatable element constitutes the drive for the pump 39, and as a shiftable element constitutes the fuel throttle. Thus, axial adjustment of the shaft 84 is effective to shift the region of reciprocation of the pistons 78 to 83 collectively relative to the inlet ports 72 to 77, and thereby to vary the amount of the discharge, and incidentally the length of the discharge period and the phase relation of the start of each period to the engine cycle.

To provide means for adjusting the shaft 84 axially, the inner raceway of a ball bearing 114 is rigidly secured thereon within the recess 47. Two shifter shoes 115 pivotally mounted in the arms of a rocking yoke 116 engage the outer raceway of the bearing 114 at diametrically opposed points. The yoke 116 is fixed on a rock shaft 117 journaled in the casing 40 and extending therefrom for external actuation.

Since the shaft 84 and the pump pistons 78 to 83 are axially shiftable as a unit, the reaction set up in the pump tends to shift them in a direction to decrease the pumping action. The resulting force is transmitted to the shaft 117 and obviously increases as the metered charge is increased. An actuator (see Figs. 2 and 3) for the shaft 117 is therefore provided which will prevent the pump reaction from causing any objectionable displacement of the fuel throttle, and from setting up any substantial resistance to easy adjustment of the throttle at will.

In its preferred form, the fuel throttle actuator comprises a right angle arm 118 having one end secured to the outer end of the rock shaft 117. A toggle link 119 has a pivotal connection 120 at one end with the free end of the arm 118, and a similar connection 121 at the other end with an intermediate portion of an arm 123 anchored at one end for pivotal movement on a cylindrical bearing 122. The arm 123 may be adapted either for manual operation or for connection to a governing device (not shown). In the present instance, the arm 123 is shown connected at its free end by a link 124 to the crank arm 22 for synchronous adjustment with the air throttle 21 so that the supply of air and fuel may be simultaneously adjusted to vary the quantity of fuel mixture in accordance with the operating requirements of the engine while maintaining the fuel-air ratio constant.

Upon adjustment of the arm 123 to effect full throttle operation, the toggle pivots 120, 121, and

122 will be in direct alinement as shown in Fig. 2. Although the pumping reaction is at a maximum during full throttle operation, it can in no way affect the throttle adjustment since the arm 118 can impart no movement through the link 119 to the arm 123. Upon adjustment of the arm 123 in a direction to close the fuel throttle, the intermediate pivot 121 will be moved out of alinement, thus gradually building up a small lateral component of force, representing a slight departure from the ideal condition, but the pumping reaction also decreases accordingly. At closed throttle, there is no pumping reaction. Hence, the pumping reaction has no appreciable effect on the arm 123 at any time, and none when the reaction is the strongest.

While the fuel and air throttles are synchronously adjustable, it is difficult to maintain the desired fuel-air ratio constant under varying operating conditions. Thus, a change in the speed of the engine due to a fluctuating load, or a change in the position of the air throttle 21, will result in a corresponding change in the pressure drop across the throttle. As a result, a different air pressure will prevail in the intake manifold 12, and consequently the weight of the air will be different than in the theoretically correct ratio.

Means is provided for automatically compensating for fluctuating conditions tending to affect the fuel-air ratio. In the present instance, this means (see Fig. 2) is operable to adjust the fuel throttle independently of the air throttle in accordance with pressure changes of the air within the intake manifold 12, and comprises a pressure responsive element, preferably in the form of a sealed corrugated cylindrical diaphragm 125 known in the trade as a syphon. One end of the diaphragm 125 is mounted in fixed relation externally of the intake manifold 12, and the interior thereof is in communication through a passage 126 with the interior of the manifold at the low pressure side of the air throttle 21. The other end of the diaphragm 125 is relatively movable, and hence responsive to the suction in the intake manifold 12. Preferably, the diaphragm 125 is resilient so that it is normally under compression and tends to elongate. A coil compression spring 127 may be disposed in the diaphragm 125 to supplement the resilient action of the latter.

A lug 128 on the free end of the diaphragm 125 is pivotally connected to a lever 129 at an intermediate point. One end of the lever 129 is fulcrumed in a stud 130 adjustably threaded through a nut 131 rotatable in a support 132. A lock nut 133 on the stud 130 serves to secure the nut 131 against rotation on the stud 130. Thus, the nut 130 when released serves as means for adjusting the fulcrum of the lever 129.

The other end of the lever 129 is connected through a link 134 to the free end of an arm 135. The other end of the arm 135 is pivotally mounted on a pin 136 in a bracket 137 secured to the casing 40. The pivot 122 for the arm 123 is formed on the arm 135 eccentrically of the pin 136, which extends therethrough, and is so located to one side of the line between the pivots 120 and 122 that elongation of the diaphragm 125 will increase the fuel constituent of the fuel-air mixture, while contraction of the diaphragm will have the opposite effect.

Opposing the resilient action of the diaphragm 125 and the spring 127 is a coil spring 138. Of the spring 138, one end impinges against a lug 75

139 on the lever 129, and the other end abuts against one end of an adjusting bolt 140 threaded through the support 132. It will be evident that the characteristics of the pressure-responsive element 125 are the resultant of the various opposing actions set up by the springs 127 and 138 and the inherent resiliency of the diaphragm itself, and are adjustable by varying the compression of the spring 138.

10 The operation will be understood from the foregoing description. In general, the amount of fuel mixture supplied to the engine is controlled by simultaneously adjusting the air throttle 21 and the fuel throttle 84 which are
15 mechanically interconnected to effect a proportional variation of the air and fuel in accordance with a predetermined ratio. The ratio is subject to selective adjustment by adjusting the shaft 117 relative to the arm 118. To adapt
20 the ratio control to the particular characteristics of each engine, the compression of the spring 138 may be adjusted to vary the pressure characteristics of the diaphragm 125, and/or the fulcrum 130 for the lever 129 may be adjusted to vary the
25 effective throw of the eccentric pivot 122.

In the event of a variation in the pressure of the air on which the fuel-air ratio is based, the diaphragm 125 will automatically adjust the fuel throttle independently of the air throttle to
30 compensate for the change, and thereby maintain the desired fuel-air ratio. The control device need not overcome any substantial mechanical resistance or pumping reaction, and hence is sensitive and accurate in operation. Since, the
35 main component of pull of the arm 118 is directed through the pivot 122, the pumping reaction is incapable of causing undesirable self-adjustment of the air and fuel throttles, or of setting up resistance to easy and expeditious adjustment thereof when desired. Due to the flooding of the
40 pump cylinders 48 to 53, no fuel vapor is formed and a solid body of fuel is always maintained in the conduits 33 to 38.

Multiple cylinder pumps having metering and
45 distributing functions, and hence of the same general type as the pump disclosed herein, are disclosed and claimed in my co-pending applications Serial No. 648,606, filed December 23, 1932, and Serial No. 688,815, filed September 9, 1933.

50 I claim as my invention:

1. In a fuel injection system for an internal combustion engine, in combination, means including an air throttle for supplying air to said engine, a fuel metering pump driven in timed
55 relation to said engine, said pump having an adjustable throttle for varying the output of fuel and tending to be adjusted in response to the pressure of the fuel, a rock shaft for adjusting said fuel throttle, an arm fixed on said rock shaft, a pivotal controlling arm, an actuating arm having an eccentric pivot on said controlling
60 arm, a toggle link pivotally connecting the free end of said first mentioned arm to said actuating arm, said actuating arm and link being disposed substantially at right angles to said first mentioned arm to resist the thrust of the fuel on said throttle, means for operating said air throttle and said actuating arm in timed relation, and means responsive to the pressure in said
65 manifold for adjusting said control arm to shift said pivot generally transversely of said first mentioned arm.

2. In a fuel injection system for an internal combustion engine, in combination, means including a fuel throttle for supplying fuel to said

engine, means including an air throttle for supplying air to said engine, an oscillatory member for adjusting said fuel throttle, an actuating arm mounted on an adjustably anchored pivot, a toggle link connecting said member to said arm, means
5 for swinging said arm and simultaneously adjusting said air throttle, and means for adjusting said pivot in accordance with pressure changes in the air supplied to said engine to shift said arm and thereby actuate said fuel throttle independently of said air throttle.

3. In a fuel injection system for an internal combustion engine having an air intake passage and an air throttle controlling said passage, in combination, a fuel metering device driven in
15 timed relation to the engine and connected to supply fuel thereto, said device having an adjustable control for varying the output of fuel and tending to be adjusted in response to the pressure of the fuel, a rock shaft for adjusting said control, an arm fixed to said rock shaft, a toggle mechanism for actuating said arm and a mechanical connection between and for actuating
20 said air throttle and said toggle mechanism synchronously, said toggle mechanism tending to straighten and to approach a line substantially perpendicular to said arm upon adjustment of said arm in a direction to open said control, and acting to hold said control in position of adjustment against the pressure of the fuel.

4. In a fuel injection system for an internal combustion engine having an air intake manifold and an adjustable air throttle for controlling the admission of air to said manifold, in combination, power operated means for supplying
35 metered charges of liquid fuel under pressure to said engine and having a fuel throttle adjustable to effect a variation in the volume of said charges, a mechanical connection between said throttles for effecting synchronous movement thereof throughout the operating range in accordance with a predetermined air-fuel ratio, a device included in said connection and being substantially self-locking against movement of said fuel throttle in response to the back thrust of
45 the fuel, a control device having an element movable automatically in response to variations in the manifold pressure, and means operable by said element for adjusting said first-mentioned device to effect adjustment of said fuel throttle
50 in either direction relatively to said air throttle so as to modify said air-fuel ratio in accordance with said pressure variations.

5. In a fuel injection system for an internal combustion engine having an air intake manifold and an adjustable air throttle for controlling the admission of air to said manifold, in combination, means for supplying fuel to said engine and having a throttle adjustable to effect variations in the amount of fuel supplied, a mechanical interconnection between said throttles and operable to adjust said throttles positively in synchronism in accordance with a predetermined air-fuel ratio, a device included in said connection and being substantially self-locking against
65 movement by said fuel throttle in response to back thrust of the fuel, a pressure responsive control device having an element movable in response to variations in the pressure of the air charge, and means operable by said element for adjusting said first mentioned device to adjust said throttles relatively and thereby modify said ratio automatically in accordance with said pressure variations.

6. In a fuel injection system for an internal

combustion engine having an air intake manifold and an air throttle for controlling the supply of air therethrough, in combination, means including a fuel throttle for supplying fuel to said engine, a mechanical connection between said throttles for effecting synchronous adjustment thereof and including a toggle having an adjustable anchor at one end and connected to said fuel throttle at the other end, said toggle being substantially self-locking against movement by

said fuel throttle in response to back thrust of the fuel, said connection being operable to impart a transverse force to the center pivot of said toggle so as to actuate said fuel throttle, and means automatically operable in response to variations in the condition of the air charge for shifting said anchor longitudinally of said toggle whereby to adjust said fuel throttle relatively to said air throttle.

CARROLL R. ALDEN. 10