

Feb. 9, 1937.

C. R. ALDEN

2,069,744

FLUID DISTRIBUTION SYSTEM

Filed Jan. 16, 1932

4 Sheets-Sheet 1

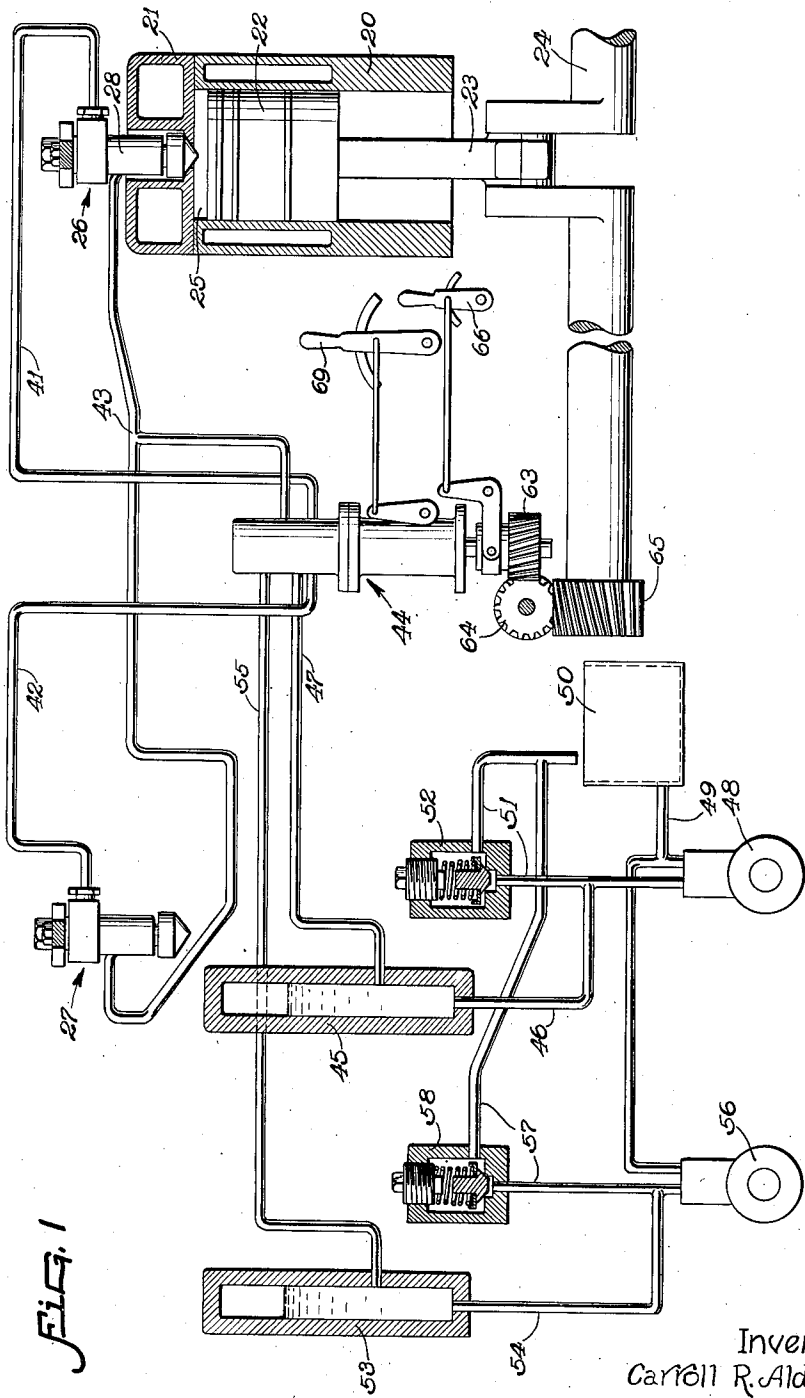


Fig. 1

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Fig. 2

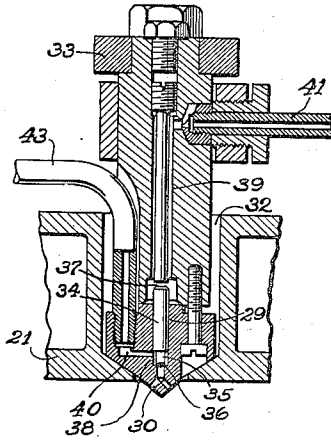


Fig. 3

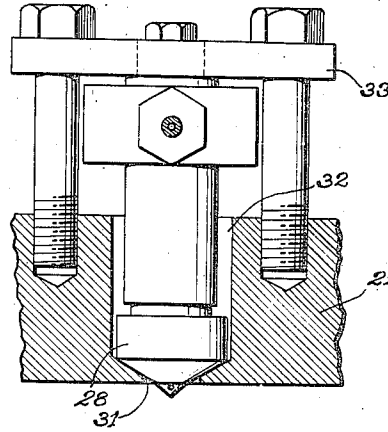


Fig. 4

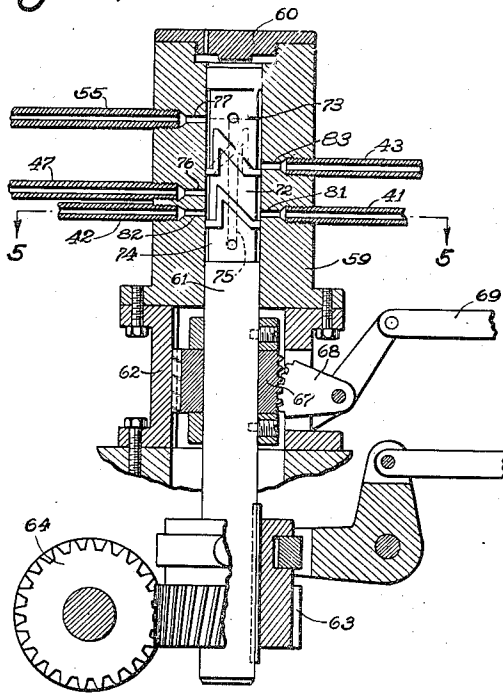
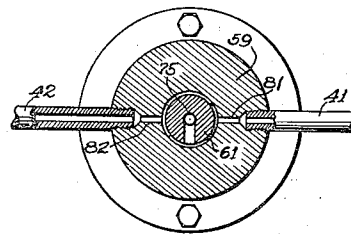


Fig. 5



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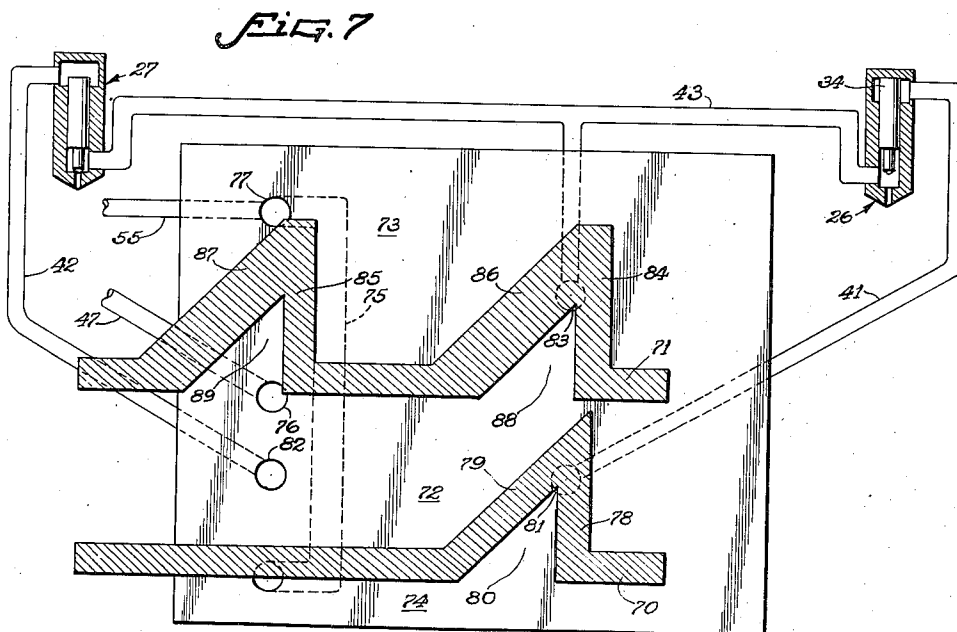
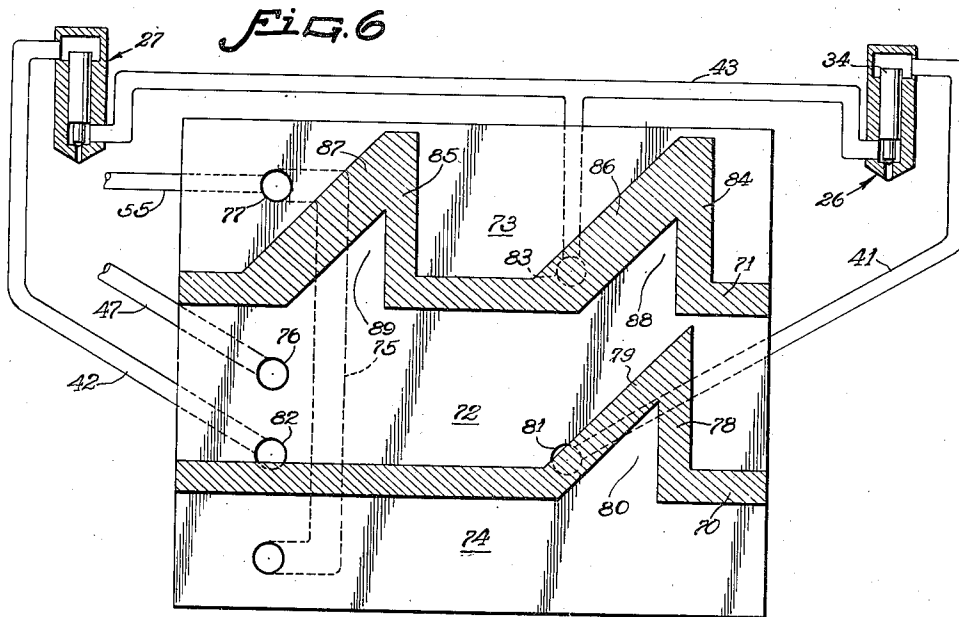
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FLUID DISTRIBUTION SYSTEM

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4 Sheets-Sheet 3



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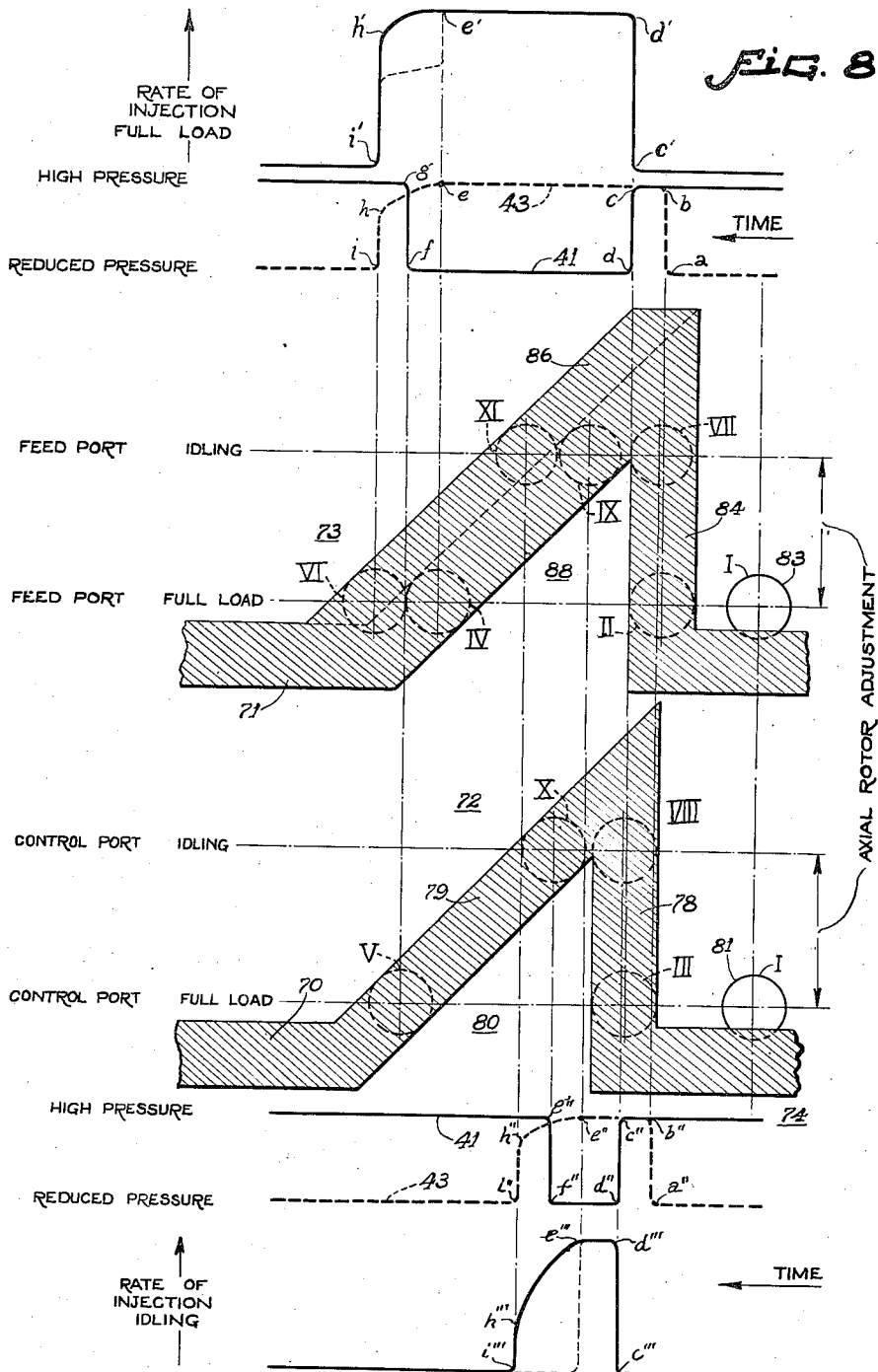
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FLUID DISTRIBUTION SYSTEM

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UNITED STATES PATENT OFFICE

2,069,744

FLUID DISTRIBUTION SYSTEM

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Application January 16, 1932, Serial No. 587,003

24 Claims. (Cl. 123—138)

The present invention relates generally to im-
provements in fluid distribution systems, and
more particularly to systems adapted for the dis-
tribution and/or injection of fuel in internal
combustion engines.

The present system is of the general type in
which fluid is distributed to one or a plurality
of discharge valves, and in which each valve
comprises a casing having a discharge orifice and
two pressure chambers, and a fluid-pressure-re-
sponsive valve member in the casing having op-
posed pressure areas exposed respectively in the
pressure chambers, and being adapted to be
acted on by a pressure differential that is re-
versible in direction so as to effect alternate
opening and closing of the orifice.

One of the primary objects of the present in-
vention resides in the provision of a novel sys-
tem of the foregoing type having a plurality of
discharge valves with one set of pressure cham-
bers in uninterrupted communication and adapt-
ed to be served by a common fluid line, and with
the other set of pressure chambers served re-
spectively by independent fluid lines.

Other objects relate to a new and improved
system in which the pressure chambers with the
common fluid line open respectively to the dis-
charge orifices of the corresponding valves, and
in which the common line and the independent
lines are controlled by a common distributor for
effecting the desired pressure fluctuations.

In its more limited aspects, the invention con-
templates the provision of a source of pressure
fluid under a relatively high pressure and an-
other source of pressure fluid under a relatively
low pressure, and means for connecting these
sources respectively and reversibly to the op-
posed pressure chambers of each valve so as to
effect the opening and closing movements of the
valve member.

In internal combustion engines, and particu-
larly Diesel engines, dribbling of fuel from the
valve into the cylinder, at the start and also at
the cut-off of the fuel injection period is highly
objectionable in that it results in inefficient and
inaccurate control of the volume of fuel injected,
particularly at idling speeds, and in poor atomi-
zation of the fuel. Any fuel dribbling from the
valve into the cylinder enters the latter in rela-
tively large globules which penetrate the com-
pressed charge of air very poorly and which burn
slowly, thus causing a lag in ignition and incom-
plete combustion. Dribbling is caused by slug-
gish opening and closing of the injection valve
which in turn results from throttling of fuel in

the fuel lines. Where two pressures acting on
the opposed areas of the valve member are re-
versibly transposed to effect movement of the
valve member from one position to the other,
such throttling will occur when the transposi-
tions are effected simultaneously.

An object of the present invention therefore
resides in the provision of a novel fluid injection
system comprising a fluid actuated valve in which
the valve is quickly opened and quickly seated,
thus preventing dribbling and all attendant dis-
advantages, and resulting in an injection period
with sharply defined limits permitting of a fine
and accurate control of the amount of fuel sup-
plied. I accomplish the foregoing object by pre-
venting throttling of the fuel to the discharge
end of the valve at the time the injection starts,
and by preventing throttling of the fuel to the
opposite end of the valve when the injection is
being cut-off.

Another object is to provide a new and im-
proved fuel injection system of the foregoing
character for internal combustion engines which
is adjustable to vary the duration of injection
while maintaining constant the time in the crank
shaft rotation when injection commences.

Other objects and advantages will become ap-
parent as the description proceeds.

In the accompanying drawings, Figure 1 is a
diagrammatic representation of a fluid injection
system embodying the features of my invention.

Fig. 2 is an enlarged axial sectional view of
one of the injection valves.

Fig. 3 is a side elevational view of the valve.

Fig. 4 is an enlarged axial sectional view of
the distributor.

Fig. 5 is a transverse sectional view of the dis-
tributor taken along broken line 5—5 of Fig. 4
which through the rotor is in an elevated plane.

Fig. 6 is a fragmentary diagrammatic view of
the system showing a development of the dis-
tributor casing in full outline, the tube connec-
tions thereto including the injection valves, and
a fragmentary development of the rotor in sec-
tion superimposed on the development of the cas-
ing, with the rotor adjusted axially for full open
throttle operation.

Fig. 7 is a view similar to Fig. 6, but with the
rotor adjusted axially for idling throttle opera-
tion.

Fig. 8 is a time chart illustrating the timed
relation of the valve opening and pressure fluc-
tuations in the feed and control tubes to the
degree of distributor and crank shaft rotation.

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.

The present system is adapted in its broadest aspects to effect the injection or distribution of fluids for various purposes. However, for purposes of illustration, it is herein disclosed as a fuel injection system for Diesel engines for which it is especially suited.

Referring more particularly to the drawings, the system constituting the exemplary embodiment of the invention is applied to an engine having a plurality of cylinders, two in the present instance, of which only one is shown. Each cylinder comprises a cylinder body 20 provided with a removable cylinder head 21, and with suitable air inlet and exhaust valves (not shown). A piston 22 is slidably disposed in the cylinder 20 and is connected through a rod 23 to a crank shaft 24. The piston 22 is so related to the cylinder 20 that at the end of the compression stroke, a high degree of compression will be obtained in the initially small combustion space 25 underlying the cylinder head 21.

Any desired number of fuel injection valves may be provided, and in the present instance two valves 26 and 27, one for each cylinder, are shown. Each valve is mounted in any suitable position, as for example in the cylinder head 21 to discharge a jet of fuel into the combustion space 25. Preferably, the valves are alike in construction, and hence a detailed description of the valve 26 will suffice for both.

The valve 26 in its preferred form (see Figs. 2 and 3) comprises a casing 28 which is formed with a bore 29 opening at one end through one or more discharge orifices 30. Formed in the cylinder head 21 and communicating through an opening 31 with the interior of the engine cylinder 20 is a well or recess 32 in which the discharge end of the casing 28 is securely held in seated relation as by means of a clamp 33 with the orifices 30 opening to the combustion space 25.

A valve plunger or piston 34 is slidably disposed in the casing 28, and is formed on its inner end with a valve member 35 adapted to coact with a valve seat 36 of a somewhat smaller diameter than the bore 29 and communicating with the discharge orifices 30. It will be evident that the plunger 34 defines a pressure chamber 37 in the outer end of the bore 29, and a fuel chamber 38 in the inner end of the bore adapted to be brought into communication with the discharge orifices 30 when the valve member 35 is raised off its seat 36, and that the inner end of the plunger 34 when the valve member 35 is raised from its seat 36 represents a total effective area exposed to the pressure in the fuel chamber 38 equal to that of the opposite end, and when the valve member is seated represents an area reduced in effectiveness by the area of the seat 36, thus constituting the valve 26 one of the differential type.

The casing 28 is formed with two passages 39 and 40 leading respectively to the opposed chambers 37 and 38. A plurality of independent conduits or tubes 41 and 42 defining flow passages are connected respectively to one set of the passages 39 and 40, and a single common conduit or tube 43 defining a flow passage is connected

through branches respectively to the other set of passages, of the valves 26 and 27. In the present instance, the tubes 41 and 42 are connected to the passages 39 and constitute control tubes, and the tube 43 is connected to the passages 40 and constitutes a fuel feed tube. Hence, the fuel chambers 38 of all of the valves (26 and 27) are in uninterrupted communication.

Means is provided for producing suitable timed pressure fluctuations in the tubes 41, 42 and 43 so as to effect successive operation of the valves 26 and 27. While the nature and sequence of the cyclic pressure fluctuations may be varied in some respects without departing from the broad scope of the invention, in the present instance, the valves are seated by a relatively high pressure in the pressure chambers 37 while the feed tube 43 and the feed chambers 38 are at a relatively lower pressure. To effect opening of the valves, the feed tube 43 is periodically brought up to the high pressure, and during such successive pressure rises, the pressures in the control tubes 41 and 42 are alternately reduced.

In the preferred embodiment of the invention, two independent sources respectively of relatively high and low constant pressures are adapted to be reversibly connected by means of a distributor 44 to the control and feed tubes of each valve. In the present instance, the high pressure source comprises a closed container 45 having an inlet tube 46 and an outlet tube 47. The inlet tube 46 is connected to the discharge of a suitable pump 48 taking fuel through a tube 49 from a supply reservoir 50, and has a branch tube 51, in which an adjustable pressure relief valve 52 is interposed, for returning excess fuel delivered by the pump to the reservoir so as to maintain a substantially constant high pressure in the container 45. Likewise, the low pressure source comprises a closed container 53 having an inlet tube 54 and an outlet tube 55. The inlet tube 54 is connected to the discharge side of a suitable pump 56 also taking fuel from the supply tube 49, and has a branch tube 57, including a low pressure adjustable relief valve 58, overflowing to the reservoir 50 for maintaining a substantially constant pressure in the container 53.

Referring to valve 26, it will be evident that when the control tube 41 is connected to the high pressure tube 47, and the feed tube 43 is connected to the low pressure tube 55, the valve member 35 will be seated, and when these connections are transposed, the valve member will be raised, and fuel will be injected.

The preferred form of distributor 44 (see Figs. 4 and 5) is of the rotary type, and comprises a tubular casing 59 closed at one end by a cap 60, and a rotor 61 extending into the other end of the casing for rotary operation and for axial adjustment. An axially aligned tubular housing 62 adapted to be mounted on the engine is provided to support the casing 59. The outer end of the rotor 61 is in the form of a shaft projection which extends through the housing 62 and is connected through meshing spiral gears 63, 64 and 65 to the crank shaft 24. To afford means for adjusting the angular phase relation of the rotor 61 to the crank shaft 24, the gear 63 is splined on the rotor shaft for axial adjustment through the medium of a hand actuator 66. The rotor 61 is adapted to be adjusted axially, as desired, by means of a rack 67 and sector 68 operatively connected to a hand actuator 69.

The operative end of the rotor 61 is reduced

in diameter, and is formed with two longitudinally spaced peripheral vanes 70 and 71 closely contacting with the interior of the casing 59 and defining an intermediate peripheral space 72. Preferably, end peripheral spaces 73 and 74, interconnected by a duct 75, are also formed at opposite sides of the space 72.

The high pressure tube 47 is connected to the casing 59, and communicates through a port 76 with the intermediate space 72, thus constituting the latter an area of high pressure. Similarly, the low pressure tube 55 is connected to the casing 59 in a different transverse plane, and communicates through a port 77 with the end space 73, thus constituting both end spaces 73 and 74 areas of low pressure.

The rotor vane 70 is formed with a longitudinal triangular offset portion consisting of a leading land 78 and a trailing land 79. These lands define a triangular projection 80 of the low pressure space 74 into the high pressure range. Opening to the interior of the casing 59 in a single transverse plane intersecting the lands 78 and 79 for all positions of axial adjustment of the rotor 61 are two uniformly peripherally spaced ports which are connected respectively to the control tubes 41 and 42 for the valves 26 and 27. It will be evident that upon rotation of the rotor 61, the set-off portion of the vane 70 will coast in uniformly timed sequence with the ports 81 and 82 to connect each port for a short time to the low pressure projection 80 and for a comparatively long time to the high pressure space 72. The period of pressure reduction is subject to variation through axial adjustment of the rotor 61.

The rotor vane 71 is likewise formed to cause the high pressure space to project in part into the range of the low pressure space 73. Since a single feed tube 43 is provided for the valves 26 and 27, the vane 71 is formed with two uniformly peripherally spaced triangular offset portions which are adapted to coast alternately in uniformly timed sequence with a feed port 83 connected to the tube 43, and which comprise respectively leading lands 84 and 85, trailing lands 86 and 87, and high pressure area projections 88 and 89. Thus, the feed tube 43 is periodically connected for a short time to the high pressure, and during alternate periods of a comparatively long time is connected to the low pressure. The period of pressure rise is subject to variation through axial adjustment of the rotor 61.

The pressure projection 80 and ports 81 and 82 are so related in angular phase to the projections 88 and 89 and the port 83 that the pressure impulses in the tubes 41 to 43 will effect the necessary reversals in pressure differential to actuate the valves 26 and 27. In the present instance, all of the ports 81 to 83 are located in one axial plane, and two of the pressure projections, namely 80 and 88, are substantially longitudinally aligned.

One of the features of the invention resides in avoiding simultaneous transposition of pressures in the control and feed tubes so as to prevent dribbling and insure quick opening and closing, and positive seating of the valves. This is accomplished in the present instance by locating the pressure projections 87 and 88 somewhat in advance of the projection 80. As a result, the high pressure will be established in the feed tube 43, as a preparatory step, before the pressure in the control tube is reduced to open the valve so

that there will be no appreciable throttling of fuel across the port 83 while the valve is opening and the valve will be opened quickly. Preferably, the trailing lands 86 and 87 are greater in width than the land 79 by an amount sufficient to ensure opening of the control port to the high pressure before opening of the feed port 83 to the low pressure so as to prevent appreciable throttling across the control port while the valve is closing and to effect a quick and positive seating of the valve. This construction prevents pressure surging or momentum since each end of the valve is charged with high pressure before movement of the valve member is instituted.

Preferably, the leading lands 78, 84 and 85 are parallel to the rotor axis while the trailing lands 79, 86 and 87 are inclined so that, subject to adjustment of the gear 63 to vary the phase relation to the crank shaft 24, the start of each period of injection will always be the same regardless of the duration.

The operation, which is illustrated diagrammatically in Figs. 6 and 8, is as follows: With the rotor adjusted for full load operation and the ports 81 and 83 in position I (see Fig. 8), the control tube 41 is connected to the high pressure space 72 and the feed tube 43 is connected to the low pressure space 73, and hence the valve 26 is closed.

In position II, the port 83 is opening to the high pressure space 72, thus effecting a pressure increase along line *a-b* in the feed tube 43, but the valve 26 remains closed since the high pressure is still impressed in the tube 41 and since the effective valve pressure area at the feed end is reduced by the size of the orifice 30. This prepares the feed tube 43 for injection so as to prevent the building up of pressure and hence throttling across the port 83 while the valve is opening.

In position III, the port 81 is opening to the low pressure space 74, thus causing a pressure drop along line *c-d* in the control tube 41. Since the feed tube 43 is already under high pressure, the valve 26 opens sharply, and institutes the injection of fuel, as indicated at *c'-d'*.

The injection of fuel continues at the full rate along line *d'-e'* until in position IV the feed port 83 is cut off at *e* from the high pressure space 72 by the land 86.

In position V, the control port 81 is opening to the high pressure space 72, thus effecting a pressure increase along line *f-g* in the control tube 41, but since the feed tube 83 has not as yet been connected to the low pressure space 73, the valve 26 remains open, and injection continues at a slightly diminishing rate along line *e'-h'*.

In position VI, the feed port 83 is opening to the low pressure space 73, thus causing a pressure drop along line *h-i*. Since the control tube 41, because of the preparatory transposition of connections, is under the high pressure, the valve 26 now closes and is firmly seated, and injection is cut off along line *h'-i'*. Where in a modification the trailing lands 86 and 87 are of the same width as the land 79 so that the rear edge is advanced to the dotted position indicated in Fig. 8, the feed tube 43 will be connected to the low pressure before the control tube 41 or 42 is connected to the high pressure, thereby resulting in a slight drop in the rate of injection just before the valve is closed.

Subsequently, the foregoing operation, but involving the pressure area projections 80 and 89, will be repeated for the valve 27. It will be un-

derstood that the control tubes 41 and 42 are alternately subjected to cyclic pressure fluctuations, but that the feed tube 43 is subjected to cyclic pressure fluctuations with each control tube.

The duration of injection is subject to control by adjusting the axial position of the rotor 61. For idling injection (see Fig. 8) the port 83 opens to the space 88 in position VII, is cut off in position IX and opens to the low pressure space 73 in position XI to stop injection; and the port 81 opens to the low pressure space 80 in position VIII to start injection and opens to the high pressure space 72 in position X. The pressure fluctuations in the tubes 41 and 43 are indicated respectively by the line a'' , b'' , e'' , h'' and i'' and the line c'' , d'' , f'' and g'' , and the rate of injection is indicated by the line c''' , d''' , e''' , h''' and i''' .

The height of rise of the valve plungers 34 may be relatively adjusted to cause all the valves to inject at the same rate.

I claim as my invention:

1. In a fuel injection system, in combination, a plurality of injection valves, each valve having a discharge orifice, and a pressure responsive valve member with an inner pressure face acting in a direction to open said orifice and an outer pressure face acting in the opposed direction to close said orifice, a single line defining a flow passage for a fluid under pressure and being in constant communication with said inner faces, independent lines defining flow passages for fluid under pressure and being in communication respectively with said outer faces, and means for effecting relative pressure fluctuations in said lines to cause successive actuation of said valves.

2. In a fuel injection system, in combination, a plurality of injection valves, each valve comprising a casing having a feed chamber opening to a discharge orifice and having a pressure chamber, and a valve plunger reciprocable in said casing for controlling said orifice, said plunger having opposed pressure faces exposed respectively in said chambers, a common feed conduit defining a flow passage for a fluid under pressure and being connected continuously to said feed chambers, a plurality of independent control conduits defining flow passages for fluid under pressure and being connected respectively to said pressure chambers, and means for effecting relative pressure fluctuations in said conduits to cause opening and closing of said valves.

3. In a fuel injection system, in combination, a plurality of injection valves, each valve comprising a casing having a feed chamber opening to a discharge orifice and having a pressure chamber, and a valve plunger reciprocable in said casing for controlling said orifice, said plunger having equal opposite inner and outer ends exposed respectively in said chambers, the effective pressure area of said inner end in said feed chamber when said plunger is seated being reduced by the area of said orifice, a common feed conduit adapted to contain a fluid under pressure and connected to said feed chambers, a plurality of independent control conduits defining flow passages for fluid under pressure and being connected respectively to said pressure chambers, and means for effecting pressure fluctuations successively in said control conduits.

4. In a fuel injection system, in combination, a plurality of injection valves, each valve com-

prising a casing having a feed chamber opening to a discharge orifice and having a pressure chamber, and a valve plunger reciprocable in said casing for controlling said orifice, said plunger having equal opposite inner and outer ends exposed respectively in said chambers, the effective pressure area of said inner end in said feed chamber when said plunger is seated being reduced by the area of said orifice, a common feed conduit adapted to contain a fluid under pressure and being connected to said feed chambers, a plurality of independent control conduits defining flow passages for fluid under pressure and being connected respectively to said pressure chambers, and distributor means for periodically effecting a pressure fluctuation in said feed conduit and successively pressure fluctuations in said control conduits in timed relation to the fluctuations in said feed conduit to cause successive actuation of said valves.

5. In a fuel injection system for a multi-cylinder engine, in combination, a plurality of fuel injection valves one for each engine cylinder, each valve having a discharge orifice and a pressure responsive member with inner and outer pressure faces, said inner pressure face controlling said orifice and being reduced in effective area thereby when seated, means establishing intercommunication between the inner valve faces and adapted to contain a fluid under pressure, a plurality of conduits defining flow passages for fluid under pressure and being in communication respectively with the outer valve faces, and distributor means for directing fluid under pressure into said conduits in predetermined sequence and for sequentially reducing the pressure on the fluid in said conduits to effect successive operation of said valves.

6. Means for operating a fuel injection valve of an internal combustion engine, comprising, in combination, a casing, a pressure responsive member movable in said casing and controlling the valve, two fuel passages opening into said casing respectively at opposite sides of said member, a source of fuel under a high pressure, a source of fuel under a relatively low pressure, and means operable to connect said sources respectively with said passages to locate said member in one position and on occasion to simultaneously subject the fuel in both of said passages to the pressure of the same source and to subsequently transpose the respective initial connections of said sources with said passages to locate said member in the other position with a rapid positive movement thereof.

7. Means for operating a fuel injection valve of an internal combustion engine comprising, in combination, a valve cylinder communicating at one end with the injection valve passage, a piston reciprocable in said cylinder and carrying the valve for opening and closing said passage, a feed conduit communicating with said cylinder at one side of said piston and adapted to supply liquid fuel to said cylinder for discharge through said passage when said valve is opened by the fuel pressure, a control conduit communicating with said cylinder at the other side of said piston, a source of fuel under a substantially constant high pressure, a source of fuel under a substantially constant relatively low pressure, and means driven by the engine for connecting said high and low pressure sources on occasion respectively to said control and feed conduits to close said valve passage, and for transposing the connections with said sources first of said

feed conduit, and then of said control conduit to effect opening of said passage.

8. Means for operating a fuel injection valve of an internal combustion engine comprising, in combination, a valve cylinder communicating at one end with the injection valve passage, a piston reciprocable in said cylinder and carrying the valve for opening and closing said passage, a feed conduit communicating with said cylinder at one side of said piston and adapted to supply liquid fuel to said cylinder for discharge through said passage when said valve is opened by the fuel pressure, a control conduit communicating with said cylinder at the other side of said piston, a source of fuel under a substantially constant high pressure, a source of fuel under a substantially constant relatively low pressure, and means driven by the engine for connecting said high and low pressure sources on occasion respectively to said control and feed conduits to close said valve passage, and for transposing the connections with said sources first of said feed conduit, and then of said control conduit to effect a pressure reversal on said piston so as to open said passage, and then again transposing the connections with said sources first of said control conduit and then of said feed conduit to reclose said passage.

9. Means for operating a fuel injection valve of an internal combustion engine comprising, in combination, a valve cylinder communicating at one end with the injection valve passage, a piston reciprocable in said cylinder and carrying the valve for opening and closing said passage, a feed conduit communicating with said cylinder at one side of said piston and adapted to supply liquid fuel to said cylinder for discharge through said passage when said valve is opened by the fuel pressure, a control conduit communicating with said cylinder at the other side of said piston, a source of fuel under a substantially constant high pressure, a source of fuel under a substantially constant relatively low pressure, and means driven by the engine for connecting said high and low pressure sources on occasion respectively to said control and feed conduits to close said valve passage, and for transposing the connections with said sources first of said feed conduit, and then of said control conduit to effect a pressure reversal on said piston so as to open said passage, and then again transposing the connections with said sources first of said control conduit and then of said feed conduit to reclose said passage, and means for varying the time interval between opening and closing of said passage while maintaining fixed the point in the engine operation at which the valve is opened.

10. In a fuel injection system, a fluid distributor having, in combination, a cylindrical casing, an axially shiftable rotor in said casing, said rotor having in one transverse plane in its periphery a plurality of high pressure spaces and a plurality of alternate low pressure spaces, and having in another transverse plane a single low pressure space and a high pressure space, a single conduit opening into said casing in the path of said first mentioned high pressure spaces, and a plurality of conduits equal in number to said high pressure spaces and opening in a single transverse plane into said casing in the path of said last mentioned low pressure space.

11. In a fuel injection system, a fluid distributor having, in combination, a cylindrical casing,

an axially shiftable rotor in said casing, said rotor having two axially spaced peripheral vanes defining an intermediate pressure space and a second pressure space open at opposite sides of said intermediate space, one of said vanes being formed with an offset angular portion defining a projection of said intermediate space into said second space, and the other of said vanes being formed with an offset angular portion defining a projection of said second space into said intermediate space, each projection having one land parallel to the rotor axis and the other land inclined to said axis, a low pressure fluid conduit opening to one of said spaces, a high pressure fluid conduit opening to the other of said spaces, and two conduits opening into said casing respectively in the paths of said space projections.

12. In a fuel injection system having a discharge valve with a fluid pressure responsive valve member with oppositely acting pressure faces, and conduits communicating respectively with said faces, in combination, a cylindrical casing, an axially shiftable rotor in said casing, said rotor having two axially spaced peripheral vanes defining an intermediate pressure space and a second pressure space open at opposite sides of said intermediate space, one of said vanes being formed with an offset angular portion defining a projection of said intermediate space into said second space, and the other of said vanes being formed with an offset angular portion defining a projection of said second space into said intermediate space, each projection having a leading land parallel to the rotor axis and a trailing land inclined to said axis, a low pressure fluid conduit opening to one of said spaces, a high pressure fluid conduit opening to the other of said spaces, and two ports adapted for connection with said conduits and opening into said casing respectively in the paths of said space projections, the relation of said projections respectively to said two last mentioned ports differing in angular phase.

13. In a fuel injection system, a fluid distributor having, in combination, a cylindrical casing, an axially shiftable rotor in said casing, said rotor having two axially spaced peripheral vanes defining an intermediate high pressure space and opposite end low pressure spaces, said low pressure spaces being in intercommunication, one of said vanes being formed with two uniformly peripherally spaced offset angular high pressure projections into the adjacent low pressure space, and the other of said vanes being formed with a single offset angular low pressure projection into said intermediate space, each projection having a leading land parallel to the rotor axis and a trailing land inclined to said axis, the trailing lands of said high pressure projections being substantially wider than said leading lands, a low pressure fluid conduit opening to one of said low pressure spaces, a high pressure fluid conduit opening to said high pressure space, a single feed conduit opening into said casing in the path of said high pressure projections, and two uniformly spaced control conduits opening in a single transverse plane into said casing in the path of said low pressure projection, all of said conduits opening to said casing in the same axial plane, said low pressure projection lagging said high pressure projections in angular phase.

14. In a fuel injection system, a fluid distributor having, in combination, a cylindrical casing, an

axially shiftable rotor in said casing, said rotor having two axially spaced peripheral vanes defining an intermediate high pressure space and opposite end low pressure spaces, said end pressure spaces being in intercommunication, one of said vanes being formed with a plurality of uniformly peripherally spaced offset angular high pressure projections into the adjacent low pressure space, and the other of said vanes being formed with a single offset angular low pressure projection into said intermediate space, each projection having a leading land parallel to the rotor axis and a trailing land inclined to said axis, a low pressure fluid conduit opening to one of said low pressure spaces, a high pressure fluid conduit opening to said high pressure space, a single feed conduit opening into said casing in the path of said high pressure projections, and a plurality of uniformly spaced control conduits equal in number to said high pressure projections and opening in a single transverse plane into said casing in the path of said low pressure projection, the relation of said low pressure projection to said control conduits lagging in angular phase the relation of said high pressure projections to said feed conduit.

15. In a fuel injection system for an internal combustion engine, in combination, a plurality of injection valves, each valve comprising a feed chamber having a discharge orifice, and a pressure chamber, a reversibly movable pressure responsive member having oppositely acting lifting and seating pressure faces exposed respectively in said feed and pressure chambers, and a valve member movable with said pressure responsive member for opening and closing said orifice, the effective area of said lifting face when said orifice is closed being less than that of said seating face, a common feed conduit connected continuously to said feed chambers and establishing constant intercommunication therebetween, a plurality of independent control conduits connected respectively to said pressure chambers, means for supplying fluid under pressure to said common feed conduit, and means normally supplying fluid to said control conduits under sufficient pressure to overbalance the lifting pressure in said feed chambers and being operable periodically to reduce and then reestablish the pressure sequentially in said control conduits to effect successive operation of said valves.

16. In a fuel injection system for an internal combustion engine, in combination, a plurality of injection valves, each valve comprising a feed chamber having a discharge orifice, and a pressure chamber, a reversibly movable pressure responsive member having oppositely acting lifting and seating pressure faces exposed respectively in said feed and pressure chambers, and a valve member movable with said pressure responsive member for opening and closing said orifice, the effective area of said lifting face when said orifice is closed being less than that of said seating face, a common feed conduit connected to said feed chambers and establishing constant intercommunication therebetween, a plurality of independent control conduits connected respectively to said pressure chambers, a source of fluid under a relatively high pressure, a source of fluid under a relatively low pressure, means driven by the engine for connecting said sources alternately to said feed conduit, and means driven by the engine for normally connecting said high pressure source to said control conduits and for connect-

ing said control conduits in sequence to said low pressure source during predetermined periods respectively overlapping the successive periods during which said feed conduit is connected to said high pressure source to effect sequential operation of said valves, the changes in the connections of said sources to the respective feed and control conduits for each valve occurring at different times.

17. In a fuel injection system, in combination, a fluid distributor comprising a cylindrical casing, an axially shiftable rotor in said casing and having two axially spaced peripheral vanes defining an intermediate pressure space and an end pressure space, one of said vanes being formed to define a projection of said intermediate space axially of said rotor, and the other of said vanes being formed to define a projection of said end space axially of said rotor into the peripheral range of said intermediate space, a low pressure fluid conduit opening to said end space, a high pressure fluid conduit opening to said intermediate space, said projections having controlling edges spaced peripherally of said rotor, an injection valve having a casing, a pressure responsive member reversibly movable in said valve casing, a discharge orifice and a valve member movable with said pressure responsive member for controlling said orifice, and two conduits connected to said valve casing respectively at opposite sides of said pressure responsive member and opening into said cylindrical casing respectively in the paths of said projections.

18. In a fuel injection system, a fluid distributor having, in combination, a cylindrical casing, an axially shiftable rotor in said casing, said rotor having two axially spaced peripheral vanes defining an intermediate high pressure space and opposite end low pressure spaces, one of said vanes being formed with a plurality of uniformly peripherally spaced offset high pressure projections extending into the peripheral zone of the adjacent low pressure space, the other of said vanes being formed with a single offset low pressure projection extending into the peripheral zone of said intermediate space, a source of fluid under a relatively low pressure opening to said end spaces, a source of fluid under a relatively high pressure opening to said intermediate space, a single feed conduit opening to said casing in the path of said high pressure projections, and a plurality of control conduits equal in number to said high pressure projections and opening in a single transverse plane into said casing in the path of said low pressure projection, the relation of said low pressure projection to said control conduits being different in angular phase than the relation of said high pressure projections to said feed conduit.

19. In a fuel injection system, a fluid distributor having, in combination, a casing having a bore, an axially shiftable rotor in said bore, said rotor having in one general transverse plane in its periphery a high pressure space and a low pressure space and in another transverse plane a low pressure space and a high pressure space, a conduit opening into said casing in the path of said first mentioned high pressure space, and a conduit opening into said casing in the path of said last mentioned low pressure space, said last two mentioned spaces being generally in alignment axially of said rotor and peripherally offset respectively a sufficient distance with respect to said first two mentioned spaces that both of said conduits are simultaneously connected pe-

riodically to spaces of substantially equal pressure for short intervals of time.

20. In a fluid distribution system, in combination, a plurality of discharge valves, each valve having a fluid pressure responsive valve member provided with at least two oppositely positioned pressure faces, each of said valve members being movable to its closed position upon the application of an unbalanced pressure to one of said pressure faces thereof, said one pressure faces constituting a set of pressure faces and each of said valve members being movable to its open position upon the application of an unbalanced pressure to a second of said pressure faces thereof oppositely positioned with respect to said one pressure faces, said second faces constituting a second set of pressure faces, means including a fluid conduit establishing a constant fluid intercommunication between each of said pressure faces of one of said sets for directing a fluid under pressure thereto, means including flow passages connected respectively to said valves for successively directing a fluid under pressure to each of said pressure faces of the other of said sets and for sequentially and successively reducing the pressure of the fluid directed to the last mentioned pressure faces to effect pressure fluctuation thereon in timed sequence so as to cause successive actuation of said valves.

21. In a fluid distribution system, in combination, a plurality of discharge valves, each valve having a fluid pressure responsive valve member provided with at least two oppositely positioned pressure faces, each of said valve members being movable to its closed position upon the application of an unbalanced pressure to one of said pressure faces thereof, said one pressure faces constituting a set of pressure faces, and movable to its open position upon the application of an unbalanced pressure to a second of said pressure faces thereof oppositely positioned with respect to said one pressure faces and constituting a second set of pressure faces, means including a fluid conduit establishing a constant fluid intercommunication between each of said pressure faces of one of said sets for directing a fluid under pressure thereto, a plurality of lines defining flow passages for fluid under pressure and in communication respectively with said pressure faces of the other of said sets, and means for effecting sequential pressure fluctuations in the fluid in said lines to cause successive actuation of said valves.

22. In a fluid distribution system, in combination, a plurality of discharge valves, each valve having a fluid pressure responsive valve member provided with at least two oppositely positioned pressure faces, each of said valve members being movable to its closed position upon the application of an unbalanced pressure to one of said pressure faces thereof, said one pressure faces constituting a set of pressure faces, and movable to its open position upon the application of an unbalanced pressure to a second of said pressure faces thereof oppositely positioned with respect to said one pressure faces and constituting a second set of pressure faces, means including a fluid conduit establishing a constant fluid intercommunication between each of said pressure faces

of one of said sets for directing a fluid under pressure thereto, means for periodically increasing the pressure of the fluid in said conduit, means including flow passages connected respectively to said valves for successively directing a fluid under pressure to each of the second pressure faces of the other of said sets and for sequentially and successively reducing the pressure of the fluid directed to the last mentioned pressure faces in timed relation to the variations in pressure of the fluid directed to said pressure faces of said first set to effect pressure fluctuation thereon in timed sequence so as to cause successive actuation of said valves.

23. In a fluid distribution system, in combination, a plurality of discharge valves, each valve having a fluid pressure responsive valve member provided with at least two oppositely positioned pressure faces, each of said valve members being movable to its closed position upon the application of an unbalanced pressure to one of said pressure faces thereof, said one pressure faces constituting a set of pressure faces, and movable to its open position upon the application of an unbalanced pressure to a second of said pressure faces thereof oppositely positioned with respect to said one pressure faces and constituting a second set of pressure faces, means including a fluid conduit establishing a constant fluid intercommunication between each of said pressure faces of one of said sets for directing a fluid under pressure thereto, means including flow passages connected respectively to said valves for successively directing a fluid under pressure to each of said pressure faces of the other of said sets, and means for periodically increasing the pressure of the fluid directed to said one set of pressure faces slightly before each of said successive reductions in the pressure of the fluid directed to said pressure faces of the other of said sets to increase the rapidity of movement of said valve elements.

24. In a fuel feeding system for a multiple cylinder internal combustion engine, in combination, a plurality of fluid pressure operable fuel injection valves, one for each engine cylinder each injection valve having a reciprocable valve member with lifting and seating areas at opposite ends thereof, a plurality of control lines, one for each injection valve, having control ports at one end and opening to said seating areas of the respective injection valves at the other end, a common feed line in constant open communication with the lifting areas of each of said injection valves and having a single control port, a source of fluid under relatively high pressure, a source of fluid under relatively low pressure and means for periodically connecting said single control port with said source of high pressure for predetermined period to charge said common feed line and then alternately connect a control port of a selected control line in a predetermined order to said source of relatively low pressure to vent the pressure from the seating area of the associated injection valve, whereby said valves are opened and closed for a predetermined time and in a predetermined order.

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