Nov. 17, 1953 G. M. HOLLEY, JR 2,659,309

FUEL INJECTION FOR INTERNAL-COMBUSTION ENGINES

Filed Sept. 18, 1948 3 Sheets-Sheet 1

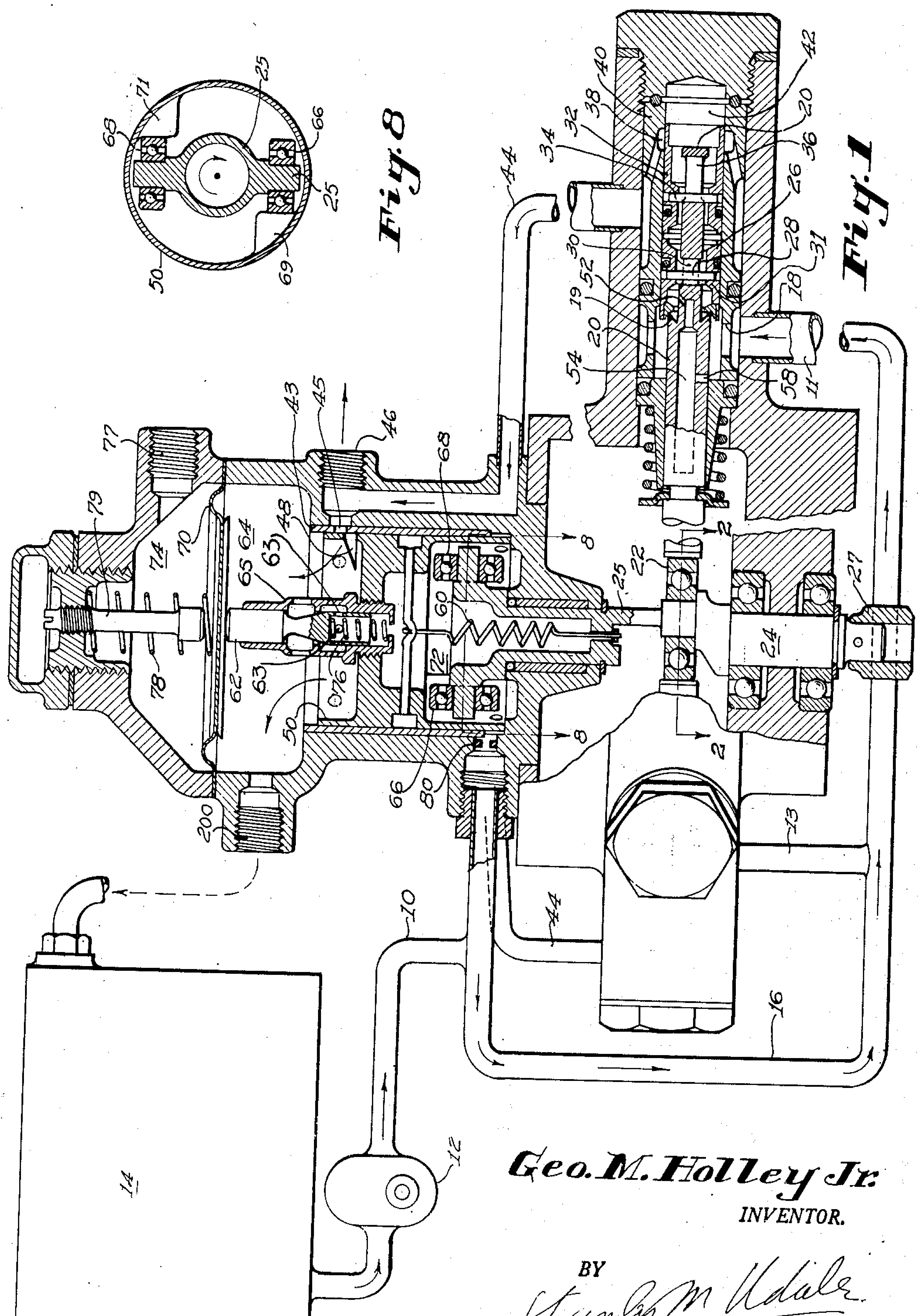

Fig. 8

Fig. 1

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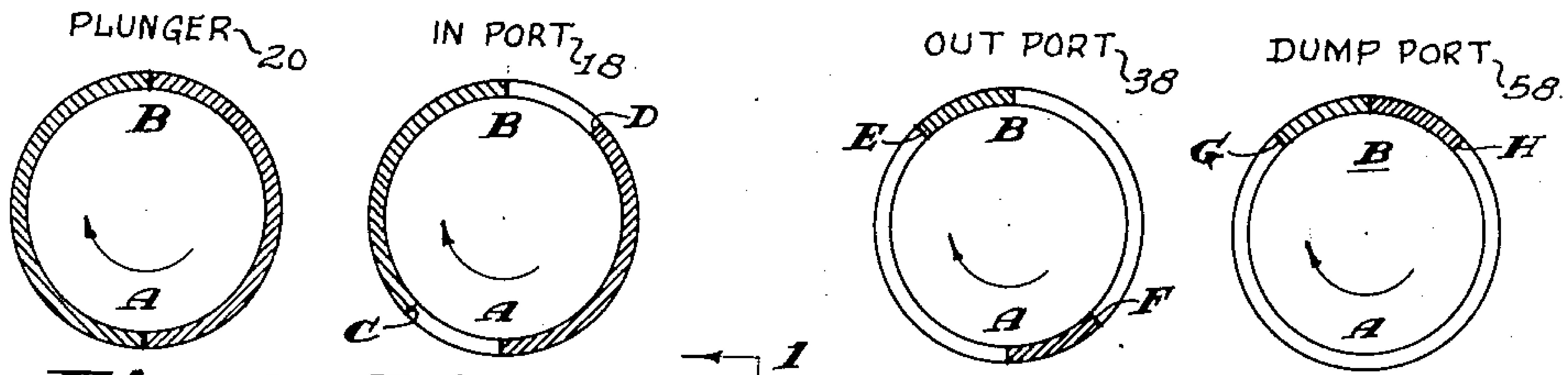

Fig. 3 Fig. 4 Fig. 5 Fig. 6

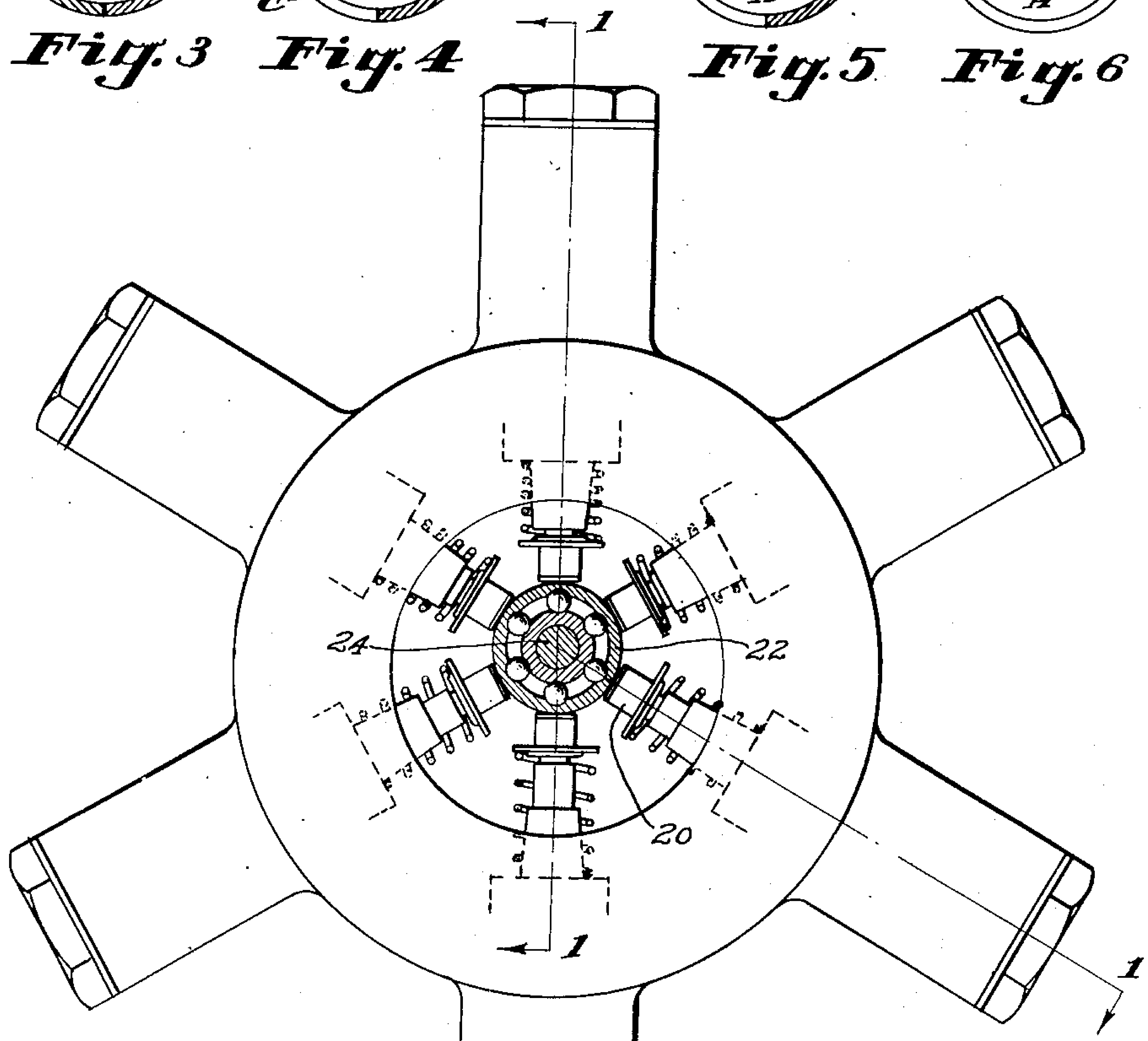

Fig. 2

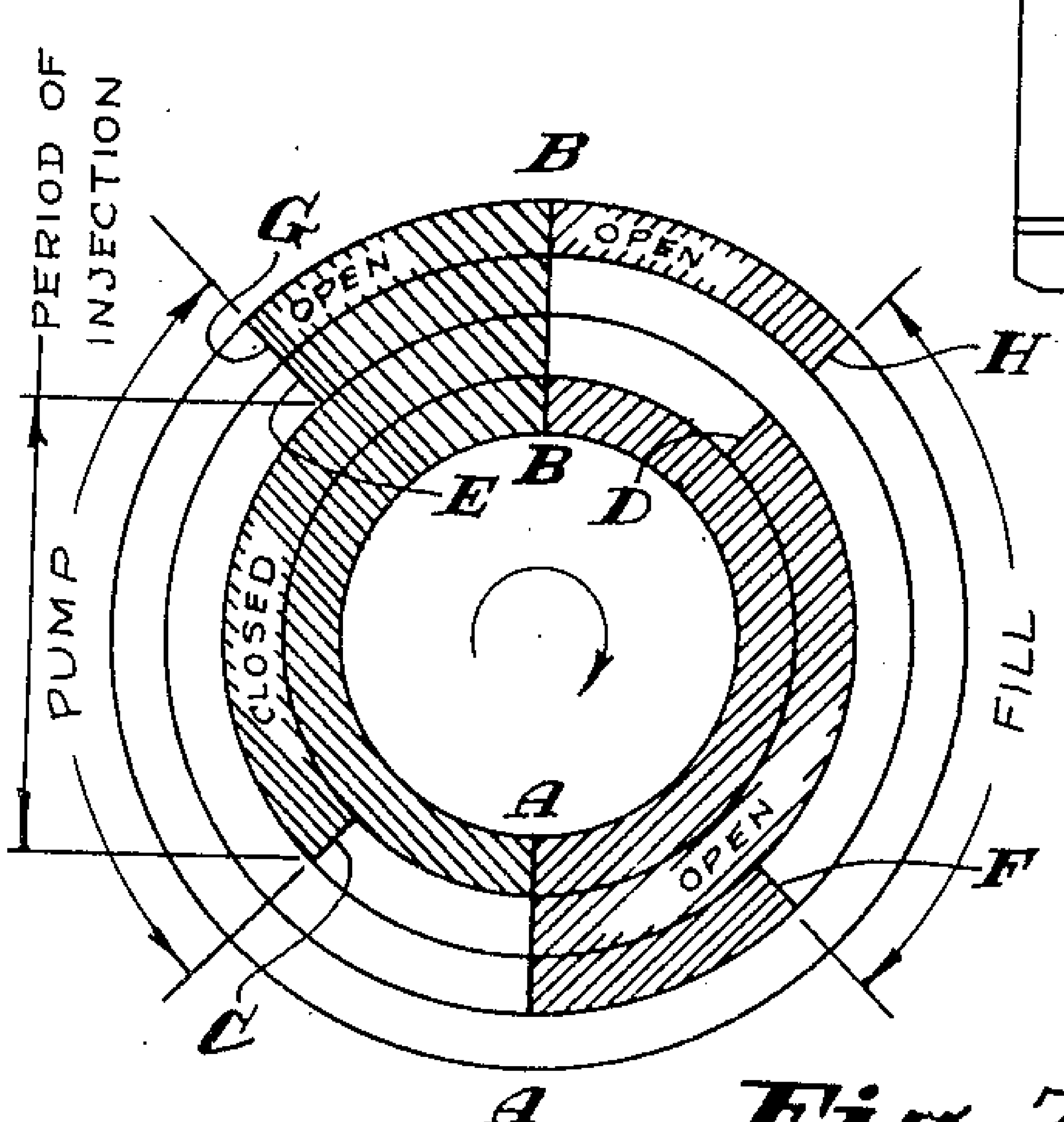

Fig. 7

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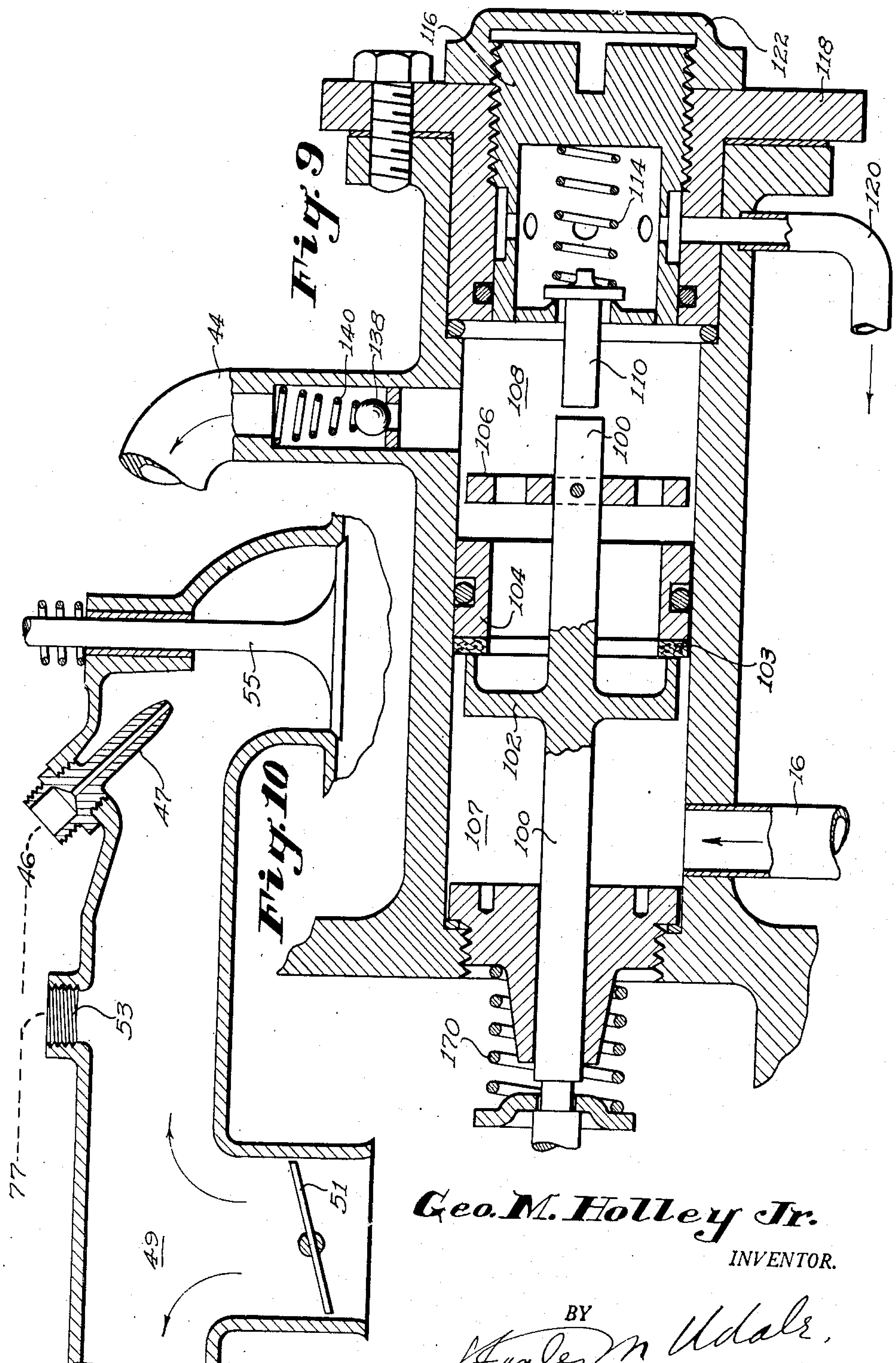

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FUEL INJECTION FOR INTERNAL-COMBUSTION ENGINES

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6 Claims. (Cl. 103—41)

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The object of this invention is to improve the control of the fuel injection on an internal combustion engine of the spark ignition type.

Fig. 1 shows a partial cross section taken on plane 1—1 of Fig. 2.

Fig. 2 shows a partial plan view taken on plane 2—2 of Fig. 1.

Fig. 3 represents diagrammatically the motion of plunger 20.

Fig. 4 represents diagrammatically the opening and closing of inlet port 18.

Fig. 5 represents diagrammatically the opening and closing of outlet port 38.

Fig. 6 represents diagrammatically the opening and closing of dump port 58.

Fig. 7 represents diagrammatically the composite motion of the motions illustrated in Figs. 3, 4, 5, and 6.

Fig. 8 shows a partial cross section taken on plane 8—8 of Fig. 1.

Fig. 9 shows an alternative simplified construction.

Fig. 10 shows diagrammatically the preferred method of injecting the fuel into the inlet manifold of the engine.

In Figs. 1, 2 and 8, 10 is the fuel entrance leading out of the transfer pump 12, which derives its fuel from the fuel reservoir 14.

16 is the pipe delivering fuel from entrance 10 to the individual pump inlets 11 and 13 and from inlet 11 and so through 11 to port 18, shown closed at the right of Fig. 1.

20 is the shaft, plunger or piston reciprocated by the eccentric roller 22 mounted on the crank shaft 24 which carries an extension 25. The shaft 24 is driven by a coupling 27 which is driven by the engine.

The valve seat of the port 18 is formed between a shoulder 19 on the plunger, shaft or piston 20 and the left hand end of the floating piston 26, which piston carries a pin 28.

A slot 30, in the shaft 20, extends on both sides of the pin 28 and allows a limited amount of relative motion between pin 28 and the slot 30. By this means the plunger 20 and the piston 26 are loosely coupled together. The port 18 is closed on the shoulder 19 before the pin 28 is even engaged by the left of the slot 30.

A similar floating piston 32, a similar pin 34 and a similar, although somewhat larger, slot 36 in the right hand end of plunger 20 extends to the right of the pin 34 which is similar to the pin 28.

The extreme right hand end of floating piston 32 is shown covering the outlet port 38 in the stationary sleeve 40. Fuel trapped in the end of the cylinder 42, before the left hand end of sleeve 32 closes port 38, is discharged through the pipe 44 and out of one of the ports 46 to one of the injection nozzles, not shown. Triangular port 48, in movable sleeve 50, regulates the time and amount of fuel injected into the engine by regulating the time and amount of fuel rejected through outlet passage 200. A port 45 in the stationary sleeve 43 is provided for each one of the outlet passages 46. Each of these ports 48 is timed to release the pressure in the outlet 46 for a longer and longer period of time as the throttle 51 is closed and the suction in chamber 74 increases. The position of this slot 48 as it rotates and is reciprocated determines what percentage of the fuel pumped is burnt in the engine and how much is returned to the tank 14.

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Opening 52, in plunger 20, allows fuel trapped in cylinder 42, after port 38 is closed, to escape along the passage 54 in the center of plunger 20, through the escape port 58, back into inlet pipe 16.

The sleeve 50 reciprocates and rotates. It is rotated by shaft 24 and its extension 25. The sleeve 50 is moved up by pressure from transfer pump 12 and is pulled down by tension spring 60 inside the forked rotating extension 25. A tapered perforated valve 62 provided with perforations 63 allows fuel to escape from chamber 72 inside sleeve 50 to chamber 64. The projections 69—71, from the sleeve 50, slide on the two ball bearings 66 and 68 carried by the forked extension 25. (See Fig. 8.) This is a clockwise driving means, the abutments 69 and 71 having vertical faces which drive the rollers 66 and 68 which are free to rise or fall without disturbing the timing of the V slots 48. The pressure in chamber 64 is maintained at atmospheric pressure. The fact that there is only a small resistance in the pipe connecting the outlet 200 with the top of the tank 14 and the fact that this tank 14 is open to the atmosphere cause this to be true. Valve 62 is moved down by diaphragm 70. Compressing spring 78 tends to open valve 62 and to compress the spring 76, supporting the valve 62. The spring 60 pulls the sleeve 50 down. A valve cage 65 (in which the valve 62 slides) is carried down by the downward motion of the sleeve 50. The compression springs 76 and 78 hold the valve 62 and cause it to remain stationary and thus valve 62 tends to close the opening between space 64 and space 51 when the valve cage 65 is drawn down. Manifold air suction is applied to chamber 74, located above the diaphragm 70, through the passage 77. This suction acts against the spring 78. 76 is the spring holding the valve 62 up against the diaphragm 70. Fuel pressure in chamber 72 tends to open the valve 62. Spring 60 tends to close the valve 62. The upward movement of the diaphragm 70 is checked by the adjustable stop 79.

The action of the valve 62 is that of a servomotor valve and whenever valve 62 rises the sleeve valve 50 follows so as to make the effective pressure in the chamber 72, inside the sleeve 50, equal the tension spring 60. When the valve 62 falls the pressure in chamber 72 falls and the spring 60 pulls valve 50 down to restore equilibrium. A restricted jet 80 is provided to make this servomotor mechanism work in the manner characteristic of all servovalves now in general use. That is to say, the restriction 80 increases as increase in flow through this restriction 80 increases. An increase in flow through this restriction 80 follows the opening of valve ports 63. Valve 62 and ports 63 constitute the servovalve. The pressure in the chamber 51 is balanced at all times against the pressure above the bridge in chamber 64 (which is a low pressure) and by the tension of the spring 60. When the valve 62 is pushed down by the upper compression spring 78, the pressure in chamber 51 falls (as valve 62 opens) so that the sleeve 50 descends to restore equilibrium; hence, there is a true servo-motor action and the sleeve 50 moves in response to variations of pressure in chamber 74.

In Fig. 3 AB represents the travel of one of the plungers 20. The complete circle represents one complete rotation of crank shaft 24 (360°), A to B to A. The piston, to the right of Fig. 1, is shown at B.

In Fig. 4 the inlet port 18 is open from angular position (of 24) C to B and again from D to A. The gap B to D in Fig. 4 represents the travel from the piston 20, to the left, until it engages the pin 28, that is, the distance between the right hand face of the pin 28 and the right hand face of the slot 30. The piston 20 then picks up the piston 26 and D A represents the stroke of the piston 28 when the cylinder 42 is being filled with fuel. The gap A C, which equals the gap B D, represents the travel of the piston 20 before it picks up the piston 26 and closes the port 18 when injection begins.

In Fig. 5 the outlet port 38 is closed from angular position (of 24) E to B and from F to A. The travel from B F corresponds to the gap 36 during which travel the port 38 remains closed. During the stroke from F to A pressure in the pipe 44 is made equal to the pressure in the chamber 42. During the travel from A to C (Fig. 4) port 18 gradually closes. During the travel from C to E fuel is ejected from chamber 42.

In Fig. 6 the dump port 58 is opened at the instant the out port 38 is closed. The angular position (of 24) G indicates the opening of port 58. The angular position (of 24) H indicates the closure of port 58.

In Fig. 7 the Figs. 3, 4, 5, and 6 have been combined so that the fuel is injected along pipe 44 between angular positions (of 24) C and G and fuel is drawn in from pipe 16 between positions H and F.

In Fig. 9, 100 is a shaft corresponding to shaft 20 of Fig. 1.

Flange 102 corresponds to pin 28 of Fig. 1.

Annular piston 104 corresponds to piston 26 of Fig. 1.

Perforated disc 106, mounted on shaft 100, engages with the right hand of the annular piston 104. A soft metal sealing ring 103 is shown forming the left hand face of the loose piston 104.

When the shaft 100 has completed its stroke (operative pressure stroke) to the right, the right hand end of 100 engages with the left hand end of valve 110 and compresses the compression spring 114. Fuel caught in chamber 108 then escapes through the pipe 120, which is connected to the entrance 16 or to the tank 14.

Prior to the unseating of valve 110 fuel escapes past the non-return valve 138 (sealed by the spring 140), through the passage 44 as before.

In Fig. 10 the pipe connected to the opening 46 of Fig. 1 is connected to a fuel nozzle 47, mounted in the inlet manifold 49. Throttle 51 controls the flow of air into the manifold 49. The pipe, connected to the opening 77 of Fig. 1, is connected to the inlet manifold 49 at the opening 53. Air inlet valve 55 is shown adjacent to the fuel inlet nozzle 47.

Operation

In Figs. 1, 2 and 8 assume the eccentric roller 22 is 180° from the position in which it is shown, then the port 18—19 is open and the port 38 is closed and fuel fills the chamber 42 and pipe 44. After the eccentric roller 22 has been rotated about 45° the port 18—19 is closed and fuel is pushed along the pipe 44 to the injectors.

As the sleeve 50 rotates the port 48 allows fuel to escape into the chamber 64. The location of the sleeve 50 determines for how many degrees rotation the port 48 is effective. The greater the suction in chamber 74 the more the valve 62 rises, the more the sleeve 50 rises carrying with it the port 48 and the more fuel escapes through the port 45 in the stationary sleeve 43 and so through the outlet passage 209 thus reducing the fuel available for injection into the engine. The port 48 is shaped to close later and later as the suction in 74 increases as the shaft 24, Fig. 2, continues to turn so that eventually the plunger 20 reaches dead center and the motion of the pump is reversed. On the return stroke, the port 58 is closed immediately and port 38 remains closed because of the width of the slot 36 in the plunger 20. This prevents any suction forming in the pipe 44. The moment the motion reverses then the port 18—19 is opened and remains open. When the pin 28, by remaining stationary, engages with the right hand end of slot 30, valve 26 travels to the left creating a suction in chamber 42 which draws in fuel. When plunger 20 almost reaches the end of its motion to the left, the pin 34 is engaged by the right hand end of slot 36 in the plunger 20. This results in the port 38 being opened and the cycle is repeated as the shaft 20 reverses and moves to the right.

Operation of Fig. 9

The shaft 100 is shown moving to the right pushing fuel out of chamber 108, through the passage 44, to the engine and drawing fuel into the chamber 107, to the left of flange 102, through the inlet passage 16. At the end of the stroke, valve 110 is unseated and the correct time when valve 110 is unseated is determined by the adjustable valve housing 116, contained in the flanged valve housing 118.

A cap 122 prevents leakage around the threads inside the valve housing 116.

When the shaft travels to the left under the influence of the spring 170 the perforated disc 106 picks up the free piston 104 and fuel flows into chamber 108 from chamber 107 through the perforated disc 106, and the cycle is repeated.

It will be noted that the fuel is never under a vacuum as the moment the plunger 100 reverses and moves to the left no appreciable drop in pressure can ever exist in chamber 108. The moment this happens fuel flows from chamber 107, to the left of loose piston 104, into chamber 108. The result is that no vapor is released and no vapor problem is created. The intent is to be able to pump ordinary gasoline without any vapor separator.

It will also be noticed that if the fuel in the pipe 44 ever does contain vapor or air bubbles these bubbles will escape through the ports in the rotary valve 48—50 as fuel is discharged first through valve 48 and immediately thereafter through nozzle 47.

The fuel returned through passage 200, to the tank 14, conveys the heat generated by the power required to pump, hence, the fuel is not overheated and for this additional reason there is no need of a vapor separator. The tank 14 is usually at atmospheric pressure.

Obviously without departing from the teaching of my invention the element 50 may be held from rotation and merely reciprocated by the effect of manifold suction acting on the diaphragm 70. In that event the port 48 will open the port 45 at all times and there will be a port similar to 48 for each of the pump units. Each such port 48 and each such port 45 and their relation to each other must be held to close limits to get uniform distribution of fuel between the various cylinders. The uniformity of this distribution is the measure of success achieved by fuel injection devices as compared with ordinary carburetors.

What I claim is:

1. A fuel injection pump and control therefor comprising a reciprocating rod, a cylinder, an annular free piston slidably mounted in said cylinder and surrounding said rod and spaced apart therefrom, a disc extending from and carried by said rod and engaging with the inner end of said piston so as to close the central opening in the piston during its pumping stroke and to open the said central opening during the suction operation of said pump, a passage to deliver fuel under pressure from said cylinder, pressure release means engaged by the outer end of said rod towards the end of its pumping stroke to check the discharge of fuel, a second one way connection from said rod to said piston adapted to engage with the other end of said annular free piston so as to leave the middle of the piston free to permit fuel to freely flow therein during its suction stroke, a rotating release valve said rotating release valve consisting of a rotating cylindrical drum, a formed port in the wall of said drum an outlet from said fuel pump, a sationary escape port located in the outlet from said fuel pump and aligned with said formed port, the rotation of said drum being to timed that fuel is not delivered until said formed port has moved out of alignment with said escape port.

2. A fuel injection system, an air inlet manifold, a throttle in the inlet to said manifold, a source of fuel under pressure, a metering pump comprising a cylindrical pump chamber, a fuel entrance thereto, a flanged plunger reciprocating therein, a loose piston spaced apart from said plunger and slidably mounted in and closely fitting said cylinder and engaged by said flange on the pumping stroke of said plunger, an element projecting laterally from said plunger and located on the other side of said piston so as to engage therewith on the suction stroke of said plunger after a certain travel of said plunger, a discharge outlet delivering fuel to the air inlet manifold, a relief port in said cylinder, a valve to close said port and means associated with said plunger to open said port when the plunger approaches the end of its pumping stroke, and in which there is an escape port located in the outlet from said fuel pump, an escape valve located adjacent said escape port and in which there is also an air chamber, a moving wall forming one wall of said air chamber, a passage from said air chamber to the suction side of the throttle controlled air entrance, yieldable means acting on said moving wall to oppose the movement in response to said suction in the air entrance and mechanism connecting said escape valve with said moving wall.

3. A fuel injection pump and control therefor comprising a reciprocating rod, a cylinder, an annular free piston slidably mounted in said cylinder and surrounding said rod and spaced apart therefrom, a disc extending from and carried by said rod and engaging with the inner end of said piston so as to close the central opening in the piston during its pumping stroke and to open the said central opening during the suction operation of said pump, a passage to deliver fuel under pressure from said cylinder, pressure release means engaged by the outer end of said rod towards the end of its pumping stroke to check the discharge of fuel, a second one way connection from said rod to said piston adapted to engage with the other end of said annular free piston so as to leave the middle of the piston free to permit fuel to freely flow therein during its suction stroke, in which there is an air inlet manifold, a throttle in the inlet thereto, an escape port located in the outlet from said fuel pump, a release valve located adjacent said escape port and in which there is also an air chamber, a moving wall forming one wall of said air chamber, a passage from said air chamber to the suction side of the throttle controlled air entrance, yieldable means acting on said moving wall to oppose the movement in response to said variable suction downstream of said throttle and mechanism connecting said escape valve with said moving wall.

4. A fuel injection pump and control therefore comprising a reciprocating rod, a cylinder, an annular free piston slidably mounted in said cylinder and surrounding said rod and spaced apart therefrom, a disc extending from and carried by said rod and engaging with the inner end of said piston so as to close the central opening in the piston during its pumping stroke and to open the said central opening during the suction operation of said pump, a passage to deliver fuel under pressure from said cylinder pressure release means engaged by the outer end of said rod toward the end of its pumping stroke to check the discharge of fuel, a second one way connection from said rod to said piston adapted to engage with the other end of said annular free piston so as to leave the middle of the piston free to permit fuel to freely flow therein during its suction stroke and in which

there is a rotating release valve consisting of a rotating cylindrical drum, a formed port in the wall of said drum, a stationary escape port located in the outlet from said fuel pump and aligned with said formed port, the rotation of said drum being so timed that fuel is not delivered until said formed port has moved out of alignment with said escape port, and in which there is also an air chamber, a moving wall forming one wall of said air chamber, a passage from said air chamber to a source of variable pressure below atmospheric, yieldable means acting on said moving wall and opposing the suction acting in said air chamber on said moving wall, said moving wall being adapted to cause said rotating cylindrical drum to move axially with an increase in suction to restrict the fuel fed by said pump by allowing more fuel to escape through said formed port.

5. A fuel injection pump and control therefor, comprising a reciprocating rod, a cylinder, an annular free piston slidably mounted in said cylinder and surrounding said rod and spaced apart therefrom, a disc extending from and carried by said rod and engaging with the inner end of said piston so as to close the central opening in the piston during its pumping stroke and to open the said central opening during the suction operation of said pump, a passage to deliver fuel under pressure from said cylinder, pressure release means engaged by the outer end of said rod towards the end of its pumping stroke to check the discharge of fuel, a second one way connection from said rod to said piston adapted to engage with the other end of said annular free piston so as to leave the middle of the piston free to permit fuel to freely flow therein during its suction stroke and in which there is a rotating release valve consisting of a rotating cylindrical drum, a formed port in the wall of said drum, a stationary escape port located in the outlet from said fuel pump and aligned with said formed port, the rotation of said drum being so timed that fuel is not delivered until said formed port has moved out of alignment with said escape port, and in which there is an air chamber, a moving wall forming one wall of said chamber, a passage from said chamber to a source of variable pressure below atmospheric, yieldable means opposing the motion of said moving wall in response to the suction in said chamber, a pilot valve moved by said moving wall, a wall at one end of said rotating drum, said pilot valve being slidably mounted in the center of said wall, a cylinder closed at one end and having said rotating drum sliding in the other, means for admitting operating fluid under pressure to the inside of said cylinder to move said drum axially, yieldable means to oppose said movement, said pilot valve controlling the pressure inside said cylinder so that the drum follows the movement of said pilot valve and the formed port in the wall of said drum is also moved with said pilot valve so as to allow more fuel to escape as the suction in said air chamber increases as the air pressure falls.

6. A fuel injection system, a source of variable air pressure, a source of fuel under pressure, a metering pump comprising a cylindrical pump chamber, a fuel entrance thereto, a flanged plunger reciprocating therein, a loose piston spaced apart from said plunger and slidably mounted in and closely fitting said cylinder and engaged by said flange on the pumping stroke of said plunger, an element projecting laterally, from said plunger and located on the other side of said piston so as to engage therewith on the suction stroke of said plunger after a certain travel of said plunger, a discharge outlet delivering fuel to the source of variable air pressure, a relief port in said cylinder, a valve to close said port and a projection from said plunger long enough to strike said valve so as to open said port when the plunger approaches the end of its pumping stroke and in which there is an escape port leading out of the discharge passage, a relief valve therein, means moveable in unison with said plunger to open and close said relief valve during the first portion of the injection period, means responsive to variable air pressure to vary this first portion of the injection period as the said pressure varies so as to increase the dicharge period with an increase in said air pressure.

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