

Feb. 19, 1963

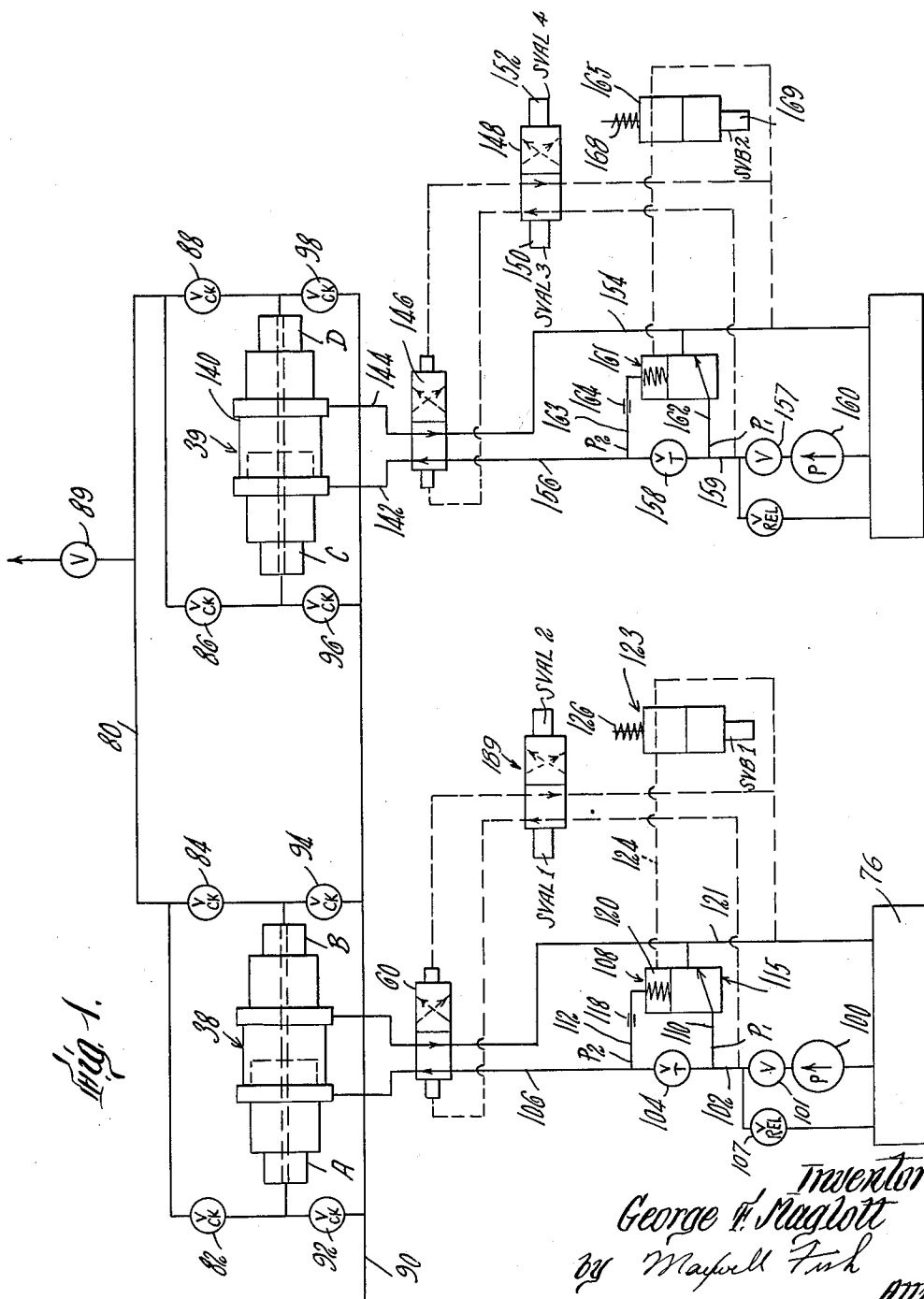
G. F. MAGLOTT

3,077,838

PIPELESS PUMPING

Filed Dec. 30, 1960

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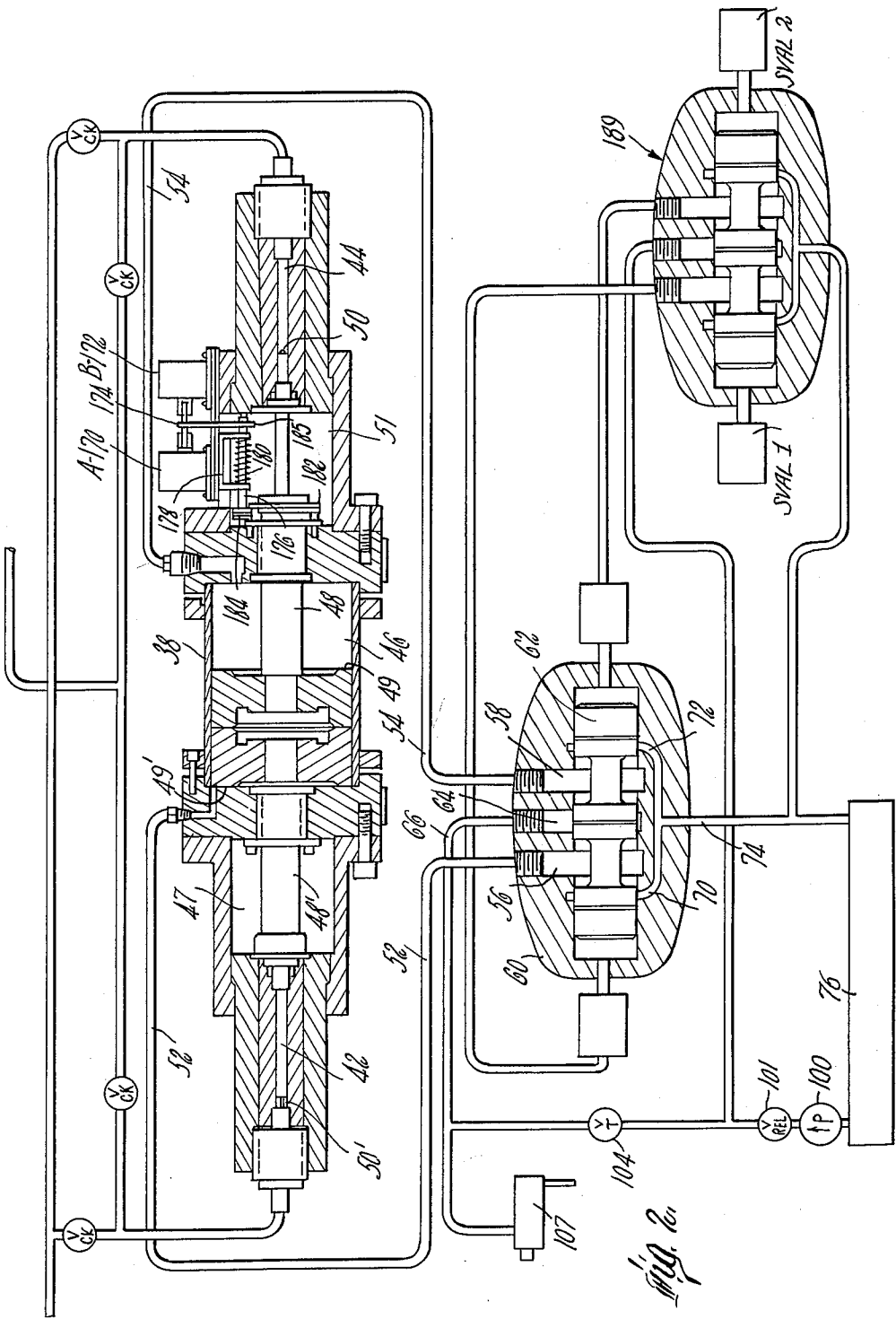
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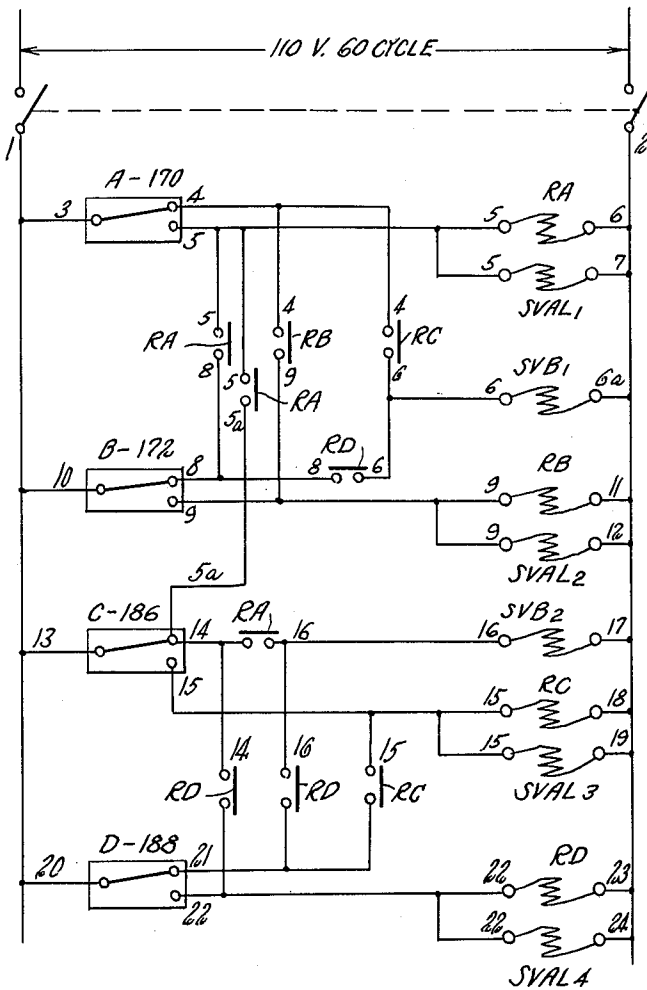
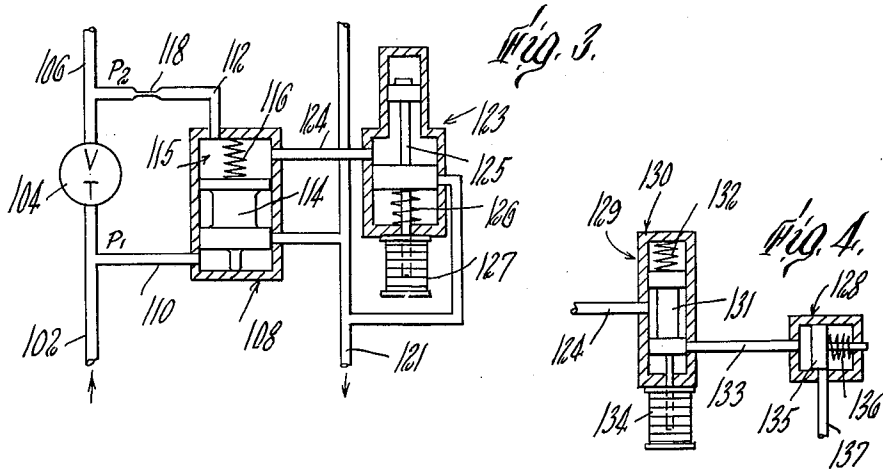
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Filed Dec. 30, 1960

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Feb. 19, 1963

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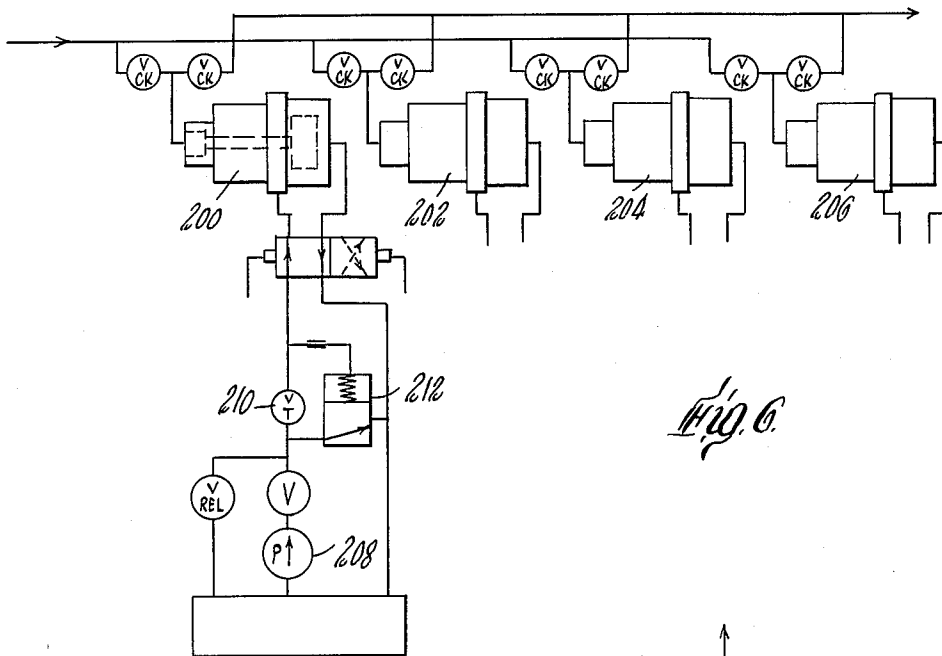


Fig. 6

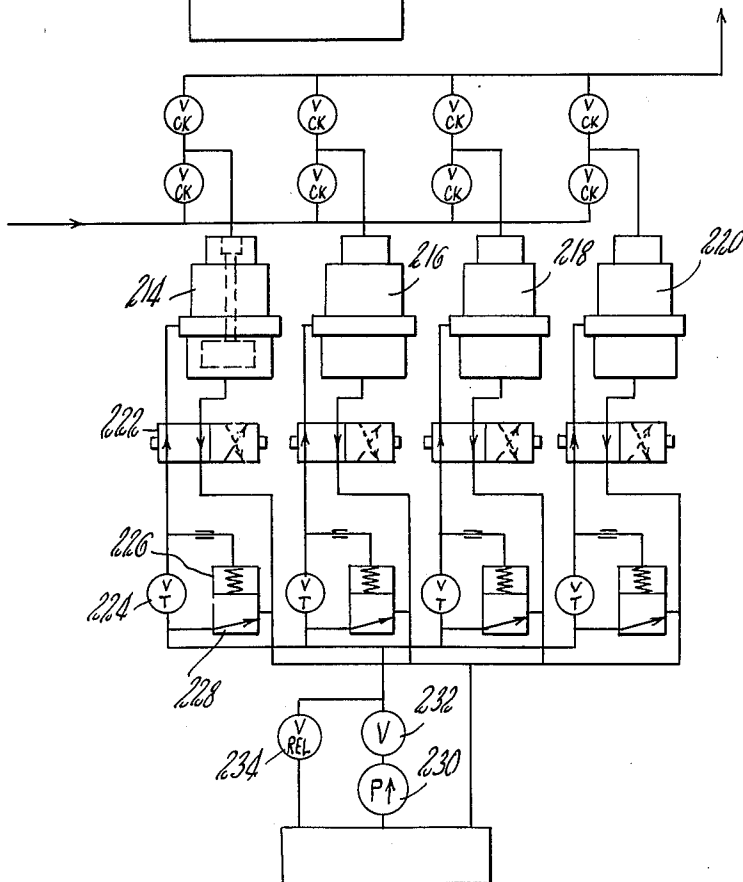


Fig. 7

1

3,077,838

PIPELESS PUMPING

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The present invention relates to an improved system for delivering a continuous and steady flow of compressible fluid at a pre-determined high delivery pressure.

The illustrated system for delivering a continuous flow of a compressible fluid at a pre-determined delivery pressure is of the general type shown in a U.S. Patent No. 2,819,835 to Newhall comprising a plurality of intensifier piston faces of small area, and associated therewith low pressure piston faces of larger area arranged for moving the respective high pressure piston faces in opposed delivery and retracting directions. In the prior art construction referred to a non-compressible fluid medium is supplied to the low pressure piston faces alternatively at a pre-delivery or loading pressure and thereafter at a full delivery pressure by means of two separate pumps which are individually adjusted and controlled to deliver the fluid at said respective pressures. The fluid is delivered to the low pressure piston faces in a pre-determined sequence and from one or the other of said pumps at the desired pressures by suitable control means which may for example be an electrical circuit including a series of on-and-off microswitches.

It is a principal object of the present invention to provide a control system for said low pressure piston assembly which will operate with a greater degree of certainty and precision than the systems known in the prior art to maintain an even uninterrupted flow of compressible fluid to the process, which may at the same time be of a substantially simpler construction, which is more readily adaptable to the requirements of the process to which the compressible fluid is supplied, and which in general will present wider possibilities of use.

The organization of my improved system for delivering a continuous flow of compressible fluid at a continuous uninterrupted delivery pressure comprises a plurality of intensifier units which in the preferred embodiment of the invention illustrated are shown as double intensifier units, each said double unit having a pair of high pressure intensifier piston faces of small area, and co-operating low pressure piston faces of larger area which are adapted to be operated in sequence.

Each of the double intensifier units referred to is provided with a separate self-sufficient hydraulic operating and control system so that any desired number of such units may be connected in series, or one or more such units may be held in reserve to replace any unit which may have become inoperative without interruption or delay in supplying the process. In the preferred form of the invention shown a liquid pressure control system for said low pressure piston assembly is provided which comprises for each double intensifier unit a fluid pressure pump adapted to deliver a non-compressible fluid at a uniform pressure designated as P_1 , and fluid pressure connections between the pump and said low pressure piston assembly including a four-way reversing valve for the low pressure piston assembly, a throttle valve means between said four-way valve and the pump adapted to supply said non-compressible fluid from the outlet connection of said throttle valve to the respective low pressure faces of the intensifier unit following a pre-determined pressure drop across said throttle valve means at a pre-determined delivery pressure designated as P_2 , a pilot relief valve and shut-off means therefor associated with said throttle valve

2

means. Said pilot relief valve acts when rendered operative to further increase the pressure drop across said throttle valve means, and thereby acts to reduce the said output pressure P_2 by a small amount in order to establish a slightly lower pre-delivery pressure to the low pressure piston faces of the intensifier unit.

With the above and other objects in view as may hereinafter appear the several features of the invention consist in the devices, combinations and arrangement of parts hereinafter described and claimed which, together with the advantages to be obtained thereby, will be readily understood by one skilled in the art from the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a somewhat diagrammatic view of two double intensifier units arranged in parallel having the high pressure chambers thereof connected to a common delivery manifold and having the low pressure chambers thereof connected through suitable reversing and throttle valve devices to separate intensifier pump units;

FIG. 2 is an enlarged detailed view partly in section of one of the double intensifier units above illustrated and of a four-way valve and pilot valve mechanism for supplying a non-compressible fluid medium at a regulated low pressure to the low pressure chambers of the intensifier unit;

FIG. 3 is an enlarged detailed view of the compensating valve, speed control throttle, and pilot and cutoff valve assembly, and resistance which comprises the control system for each said intensifier unit assembly;

FIG. 4 is a detail view of the relief valve and cutoff valve assembly showing a different arrangement of these valves from that shown in FIG. 3;

FIG. 5 is a full line diagram of the electrical connections shown in FIG. 1;

FIG. 6 is a diagrammatic view showing a modification of my improved high pressure pumping system in which individual intensifier units are employed in sequence to produce a uniform pressure output; and

FIG. 7 shows a still further modification having only one low pressure pump for supplying said non-compressible fluid.

The invention is herein disclosed as embodied in a high pressure system which is adapted for delivering a continuous flow of a compressible fluid at high pressure to a process under uniform conditions without interruption and at a pressure which is kept at an even level within narrow limits.

As an example it may be assumed that the compressible fluid is delivered to a process at 30,000 lbs. pressure per square inch, and that this pressure must be maintained within a small fraction of one percent, and free from even momentary pressure changes or pips. The high pressure pumping system herein disclosed is in many respects similar to the system disclosed in the prior United States Patent No. 2,819,835, above referred to.

The illustrated construction comprises generally a group of at least four intensifier units which in the embodiment shown take the form of two double intensifier unit assemblies, each said double unit assembly comprising a pair of non-compressible fluid pistons and a corresponding pair of high-pressure delivery pistons connected respectively to said non-compressible fluid pistons to be driven thereby simultaneously in the same direction, one of said pistons in a pressure stroke and the other in a recovery stroke.

In the embodiment of the invention shown, particularly in FIG. 1, and as further illustrated by the illustration of FIG. 2, two double acting intensifier units designated respectively at 38 and 39 are provided connected in functional parallelism. Since all of the double intensifier

units shown are identical in construction only the unit 38 will be specifically described in connection with the detailed illustration of FIG. 2.

Intensifier unit 38 consists of an outer shell or valve body having at the two ends thereof high pressure compression chambers 42, 44 of relatively small diameter, and an intervening low pressure chamber 46. Mounted within the valve body is a piston having two end portions of small diameter slidably fitted within the high compression chambers, 42, 44, and a middle portion 48 of larger diameter which is fitted to slide within the low compression chamber 46.

Leakage chambers 47 and 51 interposed between the low pressure chamber 46 and the high compression chambers 42, 44 provide a convenient means for taking care of leakage of both high and low pressure fluids in the unit. As shown in FIG. 2 the piston 48 is made up of two separate members 48, 48', each consisting of a low pressure piston face, 49 and 49' respectively, and a high pressure face at 50 and 50' respectively, said members being normally in contact with one another to operate as a single unit.

The two ends of the low pressure chamber 46 are connected by pipe connections 52 and 54 with ports 56 and 58, respectively, formed in the casing 60 of a four-way valve generally indicated in FIG. 1 and illustrated in further detail in FIG. 2. The casing 60 is formed with a cylindrical aperture to receive a movable valve body 62. The casing 60 is also provided with a centrally disposed pressure inlet port 64 which is connected by means of a pipe 66 with a regulated supply pressure system which forms a principal feature of the invention and which will be hereinafter more fully described. Two exhaust ports 70 and 72 in the casing 60 connect with one another and with an exhaust pipe 74 with a reservoir or sump 76. The valve body 62 is formed with spool portions at each end and midway of the valve body 62, said spools being separated by two land portions. The valve body 62 is constructed and arranged so that movement of the valve body 62 to the right from the theoretical neutral position shown in FIG. 2 causes the pipe connection 54 with the right hand end of the low pressure chamber 46 to be connected with the exhaust port 72, and the pipe connection 52 with the left hand end of the low pressure chamber 46 to be connected with the supply port 64. Under these conditions the piston 48 of the intensifier unit is moved to the right. Movement of the four-way valve body 62 to the left operates in the reverse manner to move the valve body 48 of the intensifier unit to the left.

The high pressure chambers of the several units indicated respectively at A, B, C and D in FIG. 1 are connected in parallel relation into a delivery manifold 80. A check valve is provided in each connection, the several check valves referred to being indicated respectively at 82, 84, 86 and 88. Each check valve is set to prevent back flow of fluid of the compressible fluid which is forced into the manifold 80 at the delivery pressure. It will be understood that the delivery pressure in the delivery manifold 80 is determined by the back pressure in the process. In order to indicate this arrangement a back pressure valve 89 in the process is shown in the diagrammatic FIG. 1.

The high pressure chambers A, B, C and D are also connected with a supply 90 by means of which the fluid is supplied to the high pressure chambers at a lower supply pressure. The supply connections to the high pressure chambers A, B, C and D have provided therein check valves indicated respectively at 92, 94, 96 and 98. The supply line check valves 92, 94, 96 and 98, inclusive, are set to permit the compressible fluid to be drawn freely through said valves into the high pressure chambers at a less than delivery pressure. As hereinafter more fully pointed out, it is intended that the intensifier pistons shall be operated in a predetermined sequence so that

compressible fluid is drawn or sucked into each high pressure chamber in turn, and is subsequently discharged therefrom at delivery pressure.

My improved hydraulic control system for supplying a non-compressible fluid at either of two selected pressures to the low pressure chambers of the intensifier units will be described as follows:

Referring to FIGS. 1 and 3 of the drawings, fluid pressure is supplied to the low pressure chambers of intensifier unit assembly A by means of a pump 100 which is connected by a regulating valve 101 and a pipe line 102 with a throttle valve 104 which is in turn connected by a pipe line 106 with the inlet port of the four-way valve casing 60. A relief valve 107 is provided in line 102 to prevent overloading of the pump.

A compensating valve 108 is connected across the throttle valve 104, being connected by an input pipe line 110 with the line 102 and by a sensing line 112 with the line 106. The compensating valve includes a valve spool 114 vertically movable in a valve chamber 115 and a spring 116 which acts upon the spool 114 in a direction to keep the valve closed. A resistance 118 is provided in the sensing line 112 from the spring supporting portion of chamber 115 of the compensating valve 108. A spill line 121 connects the lower portion of the valve chamber 115 with the oil sump 76.

It is a function of the compensating valve 108 to maintain a constant, differential pressure across the throttle valve. It does this by automatically spilling the excess pump flow, not required by the throttle setting. Like a relief valve, it is normally closed by the spring 116. Fluid enters from upstream of the throttle valve 104 through pipe line 102, direct from hydraulic pump 100, providing a pressure P_1 which acts on the end area of the valve spool 114. Output pressure designated as P_2 from just beyond the throttle valve acts through the sensing line 112 against the opposite face of valve spool 114 in combination with the spring 116. The valve spool 114 is in balance when pressure P_2 plus the spring effect is exactly equal to pump pressure P_1 . If pressure P_2 should fall a little, as for example from a reduced work load at the intensifier, the input pressure P_1 overbalances it, pushing the valve-spool 114 a little more open, spilling more pump excess until the system is again in balance and vice versa. In this manner the downstream pressure P_2 , as determined by the setting of the back pressure valve 89 in the process, is always held at a constant value. In this system the force characteristic of spring 116 is always equivalent to a constant differential pressure across the throttle valve 104 thereby assuring a uniform rate of flow therethrough.

The compensating valve 108 also operates in conjunction with a combined pilot relief and shutoff valve 123, hereinafter to be described. When the combined pilot relief and shutoff valve 123 is operative and is now adjusted so that it opens at a pressure lower than the pressure P_2 in the spring chamber 115, the compensating valve 108 is opened to spill the flow thus reducing the operating pressure P_2 to the intensifier 38.

The pilot relief valve 123 as shown in FIG. 3 is connected to the spring chamber 115 of the compensating valve 108 by a connecting pipe 124. The valve 123 comprises a piston 125 which is biased upwardly to close against the fluid pressure P_2 transmitted through spring chamber 115 and pipe 124 by means of a spring 126. Assuming that the pilot relief and shutoff valve 123 is in operation and that the force characteristic of the spring 126 is slightly lower than that which would be required to balance the P_2 pressure on the downstream side of the throttle valve 104, the pilot valve will open spilling to exhaust through line 121. Because of the restriction 118 in sensing pipe 112 the pressure in the spring chamber 115 will drop very rapidly causing an immediate reaction in the compensating valve 108 to effect a readjustment of the pressure drop across the throttle valve 104. A bal-

ance is now established in the system in which a larger pressure drop is maintained across the throttle valve 104 determined by the setting of the pilot relief and shutoff valve 123, and a lower downstream pressure replaces the P_2 delivery pressure, said reduced pressure being hereinafter referred to as predelivery pressure.

In order to shift between a delivery pressure P_2 and a lower predelivery pressure of the non-compressible fluid supplied to the low pressure piston faces of the intensifier units it is necessary only to render the pilot relief valve 123 operative or inoperative as desired. In the embodiment shown in FIG. 3 the solenoid 127 provides a convenient means for rendering the pilot valve 123 alternatively operative and inoperative. The pilot valve thus has two separate and distinct functions since it operates as a regulating valve, and alternatively as a shutoff valve when the solenoid 127 is energized. For operation as a regulating valve the spring 126 is adjusted to cause the valve to open at a pressure slightly lower than the established delivery pressure P_2 . The fluid under pressure confined in the chamber 115 between piston 114 and the restriction 118 as above noted is very rapidly exhausted thus opening spill line 110, 121, to the sump 122, and causing the pressures P_1 and P_2 to drop to a value determined by the setting of the pilot valve spring 126.

A different form of the pilot valve and cutoff valve assembly is shown in FIG. 4, wherein the pilot valve designated at 128 and the cutoff valve designated at 129 are shown as separate units. Fluid under pressure passes from the compensating valve chamber 115 to a valve chamber 130 in cutoff valve 129. A valve spool 131 in said chamber is normally pressed downwardly by means of a spring 132 to an open position in which fluid passes through a connecting pipe 133 to said pilot valve 128. A solenoid 134 acts when energized to move the cutoff valve stem 131 upwardly to close the valve. The pilot valve 128 shown in FIG. 4 comprises a piston 135 which is acted upon by a spring 136 to control the amount of spill from the pilot valve through spill pipe 137 to the sump 76. When the cutoff valve solenoid 134 is energized the pilot valve 128 is rendered inoperative and the pressure regulation of P_1 , P_2 is controlled entirely by the throttle valve 104 and compensating valve 108 to maintain P_2 at the desired delivery pressure level.

The second intensifier unit assembly shown generally at 39 in FIG. 1 is in every respect a duplicate of the first intensifier unit assembly 38 above described. This intensifier unit assembly thus comprises the intensifier unit casing 140 housing two pistons which are shaped to provide respectively the low pressure faces and opposed high pressure faces of the intensifier unit. The low pressure faces of the unit are connected in the identical manner of the first intensifier unit assembly by means of supply pipes 142 and 144 with a four-way valve 146 adapted to be controlled by a reversing valve 148 shiftable between reverse running positions by means of two solenoids 150, 152. The four-way valve is connected by a pipe 154 to exhaust, and through an inlet pipe 156, throttle valve 158, and a pipe 159 with a second low pressure incompressible fluid pump 160 and associated regulating valve 157, which is a duplicate of the pump 100 associated with the first intensifier unit assembly identified as 38.

A compensating valve 161 is connected across the throttle valve 158 being connected by an input pipe line 162 with the line 159 and by a sensing pipe line 163 with the downstream line 156. A resistance 164 is provided in the sensing line 163. A small pilot relief and cutoff valve 165 is provided with a movable valve spool, not shown, which is loaded by means of a spring 163 and is adapted to be moved positively to a closed position by means of a solenoid 169. When the solenoid 169 is de-energized, the pilot relief valve 165 becomes self-adjusting to operate at a pressure lower than P_2 in the spring chamber of compensating valve 161 thus reducing the operating pressure P_2 to the intensifier 39. In view of the very full descrip-

tion of the identically similar intensifier unit assembly 38, further detailed description of the second intensifier unit assembly is omitted.

The electrical system by means of which the double intensifier units 38 and 39 are operated in the manner above described as best shown in FIGS. 1, 2 and 5 includes four micro-switches, two of which are mounted on each of the intensifier units. The micro-switch A-170 and a micro-switch B-172 are mounted on the double intensifier unit 38 in spaced relation to one another to be engaged by a vertically disposed switch contact arm 174 which projects upwardly between the two switches, and at its lower end is mounted on a shifting rod 176 carried on a U-shaped bracket 178 within the leakage chamber of the double intensifier unit 38. Centering springs 180 coiled about the shifting rod 176 between the arms of the bracket 178 tend normally to maintain the shifting rod and switch contact arm 174 normally in an intermediate neutral position. A contact member 182 supported to move as a unit with the intensifier piston 48 is arranged upon movement of the piston to the left hand limit of movement to engage a stop 184 on the shifting rod 176 to engage the switch contact arm 174 with the micro-switch A-170. Movement of the piston 48 to the right hand limit of movement causes the lug 182 to engage with a depending stop 185 formed integrally with the switch arm 174 to move the switch arm into engagement with the micro-switch B-172. It will be understood that the second intensifier 39 as shown in FIG. 1 is similarly provided with micro-switches C-186 and D-188 (see FIG. 5) which are arranged to be automatically operated in a manner similar to that above described for micro-switches A-170 and B-172.

The four-way valve, generally designated at 60, is arranged to be actuated by a reversing valve 189 which is in turn controlled by two solenoids SVAL₁ and SVAL₂. The four-way valve 146 and reversing valve 148 associated with the second intensifier unit 39 are controlled by means of two solenoids SVAL₃ and SVAL₄. The predelivery low pressure is controlled by means of a pilot relief valve shutoff solenoid SVB₁ and the pilot relief valve shutoff valve associated with the second intensifier unit 39 is similarly controlled by means of a solenoid SVB₂. There are also included in the electrical circuit a number of relay solenoids designated in FIG. 5 at RA, RB, RC and RD, respectively.

The operation of the electrical circuit will be briefly described in connection with the electrical diagram of FIG. 5 as follows:

As the piston 48 approaches the limit of its movement to the left delivering compressible fluid at delivery pressure it will be understood the micro-switch A-170 will be in its normally disengaged position with switch contact 3-4 closed and contact 3-5 open.

Solenoid SVB₁ for the pilot relief and shutoff valve 123 is energized causing the valve spool to be held in its closed position in which the full delivery pressure P_2 as determined by the setting of the throttle valve 104 and compensating valve 108 is supplied to the intensifier unit 38, and solenoid SVB₂ which controls the valve spool 167 for the pilot relief valve 165 of the intensifier unit 39 is de-energized so that said latter pilot relief valve 165 is operative to supply pressure to the second intensifier unit 39 at the pre-delivery level from the associated pump 160.

It will be understood also at this time that the solenoid SVAL₃ for the four-way valve 146 associated with the second intensifier unit 39, and designated in FIG. 1 at 150, is energized and that solenoid SVAL₄ for valve 146 designated in FIG. 1 at 152 is de-energized so that the piston of the second intensifier is being urged to the left to charge high pressure chamber C at the pre-delivery compression level through fluid supplied from the pump 160.

When the piston of the first intensifier unit 38 reaches the left hand end of its travel the switch arm 174 is shifted to the left causing the arm of micro-switch A-170 to be

shifted so that the normally closed contact 3—4 is open and the normally opened contact 3—5 is closed. Relay RA is energized. Contact RA 5—8 closes forming a holding circuit through the normally closed control contact 10—8 of the micro-switch; B—172. RA contact 5—5a closes thus forming a holding circuit through the normally closed contact C—186. RA contact 14—16 closes energizing the control solenoid SVB₂ for the second pilot relief valve 165 thus causing said pilot relief valve to be rendered inoperative. The full delivery pressure P₂ is now delivered to the second intensifier unit 39. The movement of the piston thereof is now continued to the left at the full delivery pressure so that the delivery to the delivery manifold 80 is maintained without pulsation or break.

Next in the order of operation it will be assumed that the piston associated with the second intensifier unit 39 reaches the limit of its movement to the left delivering compressible fluid at delivery pressure from the high pressure chamber C. The micro-switch C—186 is actuated in the manner described in connection with micro-switches A—170 and B—172 breaking the normally closed contact 13—14 and closing the normally opened contact 13—15. Solenoid SVB₂, associated with the pilot relief valve 165 is de-energized causing the pressure P₂ delivered to the intensifier unit 39 to be reduced to the predelivery level. Contact 13—15 of micro-switch contact C—186 closes energizing relay RC. RC contact 15—21 closes forming a holding circuit through the normally closed contact 20—21 of micro-switch D—188. Solenoid SVAL₃ of the four-way valve 146 for the second intensifier unit is energized shifting the four-way valve to the left so that the low pressure fluid is directed to the left hand end of the second intensifier unit 39 to move the same toward the right causing high pressure chamber D to be charged at predelivery pressure. Solenoid SVB₁ for the pilot valve 123 is energized causing said valve to operate supplying the low pressure fluid at the full delivery level from the pump 100. Compressible fluid is now delivered at delivery pressure to the manifold 80 from the high pressure chamber B.

Next in order of operation it will be assumed that the piston 48 of intensifier 38 reaches the limit of its movement to the right completing its discharge of compressible fluid at delivery pressure from high pressure chamber B to manifold 80. Micro-switch B—172 is actuated opening contact 10—8 and closing contact 10—9. The opening of the normally closed contact 10—8 de-energizes relay RA and also solenoid SVB₁ activating pilot valve 123 causing low pressure fluid to be delivered to intensifier unit 38 to charge high pressure chamber A at the predelivery level. The closing of micro-switch contact 10—9 energizes relay RB. RB contact 4—9 closes thus forming the holding circuit through the normally closed contact 3—4 of micro-switch A—170. Solenoid SVAL₂ is energized shifting the position of four-way valve 60 and reversing the direction of the intensifier plunger 48. Control solenoid SVB₂ is energized so that pilot valve 165 is rendered inoperative and low pressure fluid is supplied at delivery level from pump 160 to the second intensifier unit 39. At this time the four-way valve 146 is conditioned to drive the intensifier piston to the right for delivery of the compressible fluid from high pressure chamber D at the full delivery pressure. As the piston of the second intensifier 39 reaches the limit of its movement to the right completing its delivery of fluid at delivery pressure from high pressure chamber D to the manifold 80, the normally closed contact of micro-switch D—188 contact 20—21 is opened and contact 20—22 is closed. The opening of contact 20—21 breaks the holding circuit to relay RC which is de-energized together with solenoid SVAL₃ for the four-way valve 146. Control solenoid SVB₂ is similarly de-energized causing pilot valve 165 to be rendered inoperative. The closing of micro-switch 20—22 energizes relay RD, contact 14—22 closes forming a holding circuit through the normally closed contact

13—14 of micro-switch C—186. Solenoid SVAL₄, associated with four-way valve 146 is energized shifting the four-way valve and reversing the second intensifier unit 39 which is now moved to the left to charge the high pressure chamber C at the predelivery level. RD contact 8—6 closes energizing control solenoid SVB₁ thus activating pilot valve 123 so that low pressure fluid is supplied to the first intensifier unit 38 at the delivery pressure.

SVAL₁ of the four-way valve 60 is energized to reverse the flow of the low pressure fluid to the first intensifier unit A. At the same time the opening of the usually closed contact 3—4 of micro-switch A—170 causes solenoid 1A to be de-energized which in turn causes solenoid ADR—6 to be opened thus the energizing permits SVD₁ for the pilot valve 123 to reduce the pressure P₂ supplied to the first intensifier unit to the low pressure re-charge level. The opening of micro-switch A—140 is also affected to de-energize solenoid SVAL₂.

With the operation above described, it will be appreciated that four-way valve 60 associated with the first intensifier unit 38 has been reversed so that its piston is traveling to the right, the pilot valve 123 associated with intensifier unit A has been rendered operative so that high pressure chamber B of the intensifier unit 38 is being charged at the pre-delivery level, and pilot relief valve 165 associated with intensifier unit B has been rendered inoperative so that the fluid pressure is being supplied to the said second intensifier unit B at the full compression delivery level P₂.

While the invention has been described and illustrated in a preferred form as embodied in a constant flow high pressure delivery system having a plurality of double intensifier units, each equipped with a separate noncompressible fluid pressure supply pump and throttle valve means adjustable to advance the piston units serially at a predelivery pressure and thereafter at a delivery pressure, it will be understood that the invention in its broader aspects is not limited to the particular system illustrated. It is contemplated, by way of example, that a plurality of single intensifier units, 200, 202, 204, 206, may be provided in place of the double intensifier units shown. Such individual intensifier units as shown in FIG. 6 may be supplied by separate low pressure pumping units 208, each of which will operate in combination with a throttle valve means 210 and an associated pilot relief valve 212 of the general type above described to supply an incompressible fluid alternatively at a predelivery pressure and at a delivery pressure to the low pressure piston face of said unit.

In a further modification it is contemplated that an adequate supply of incompressible fluid at the required delivery pressure may be obtained from either a single pump or from a relatively small number of fluid pressure supply pumps which would operate in combination with suitable pipe connections to the several intensifier units. In the modification proposed as indicated in FIG. 7, four individual intensifier units 214, 216, 218, and 220 are shown each having low pressure non-compressible fluid supply connections which include a four-way valve, the valve 222 being associated with the intensifier unit 214 together with a throttle valve means 224, a compensating valve 226, and a pilot relief valve and valve cutoff means 228. Identical low pressure fluid supply connections are provided for each of the intensifier units 216, 218 and 220. Low pressure fluid is supplied from a single low pressure pump 230 together with its regulating valve 232 and relief valve 234 which pumps said fluid from a supply reservoir 236 and distributes same to each of said identical sets of low pressure feed connections to the respective intensifier units.

In as much as the several components of the modified low pressure non-compressible fluid pressure systems above generally referred to are identical with similar components employed in the system above described in detail in connection with FIGS. 1—5 inclusive no further

description thereof is believed necessary and is accordingly omitted herefrom.

The invention having been described what is claimed is:

1. In an intensifier assembly comprising a plurality of intensifier units each having a low pressure piston face and a high pressure piston face, a high pressure manifold, and pipe connections from each said high pressure piston face to said high pressure manifold, and means for supplying a compressible fluid at a precompression pressure to said high pressure piston faces, the combination of means for supplying a non-compressible fluid at low pressure to said low pressure piston faces which includes a non-compressible fluid pump adapted to supply said non-compressible fluid at a constant predetermined pressure, pipe connections from the pump to a said low pressure piston face, a throttle valve in said pipe connection adapted to produce a predetermined pressure drop from an upstream pressure to a downstream pressure across said throttle valve, a pilot relief valve having an operative connection with said throttle valve whereby said pilot relief valve is operable to further increase the pressure drop across the throttle valve and thereby to reduce the downstream pressure to said low pressure piston face from a delivery to a predelivery pressure level, and means for rendering said relief valve operative and inoperative and thereby to effect an adjustment of said downstream pressure from one to the other of said predelivery and delivery pressure levels.

2. In an intensifier assembly comprising a plurality of intensifier units each having a low pressure piston face and a high pressure piston face, a high pressure manifold, and pipe connections from each said high pressure piston face to said high pressure manifold, and means for supplying a compressible fluid at a precompression pressure to said high pressure piston faces, the combination of means for supplying a non-compressible fluid at low pressure to said low pressure piston faces which includes a non-compressible fluid pump adapted to supply said non-compressible fluid at a constant predelivery pressure, pipe connections between said pump and a said low pressure piston face including a regulating valve, and a throttle valve in said pipe connections adapted to produce a predetermined downstream pressure drop across the throttle valve, a compensating valve having an upstream connection with exhaust and a sensing pipe connection including a restriction with said downstream side of said throttle valve, a pilot relief valve connected with said sensing pipe connection operable to further increase the pressure drop across said throttle valve, and cutoff valve means in said connections between said pilot relief valve and said sensing pipe connection operable to render said pilot relief valve operable and inoperable and thereby to shift said downstream pressure between a predelivery and a delivery pressure.

3. In an intensifier assembly comprising a plurality of intensifier units each having a low pressure piston face and a high pressure piston face, a high pressure manifold, and pipe connections from each said high pressure piston face to said high pressure manifold, and means for supplying a compressible fluid at a precompression pressure to said high pressure piston faces, the combination of means for supplying a non-compressible fluid at low pressure to said low pressure piston faces which comprises a plurality of low pressure fluid supply assemblies each comprising a noncompressible fluid pump adapted to supply said noncompressible fluid at a constant predetermined pressure, pipe connections from the pump to said low pressure piston faces, a throttle valve in each said pipe connections adapted to produce a predetermined pressure drop from an upstream pressure to a downstream pressure across said throttle valve, a pilot relief valve having an operative connection with said throttle valve whereby said pilot relief valve is operable to further increase the pressure drop across said throttle valve and thereby to reduce the downstream pressure to said low

pressure piston face from a delivery to a predelivery pressure level, means for rendering each said relief valve operative and inoperative, and control means for rendering each said relief valve operative and inoperative serially and thereby to effect an adjustment of said downstream pressure from one to the other of said delivery and predelivery pressure levels.

4. In an intensifier assembly comprising a plurality of intensifier units each having a low pressure piston face and a high pressure piston face, a high pressure manifold, and pipe connections from each said high pressure piston face to said high pressure manifold, and means for supplying a compressible fluid at a precompression pressure to said high pressure piston faces, the combination of means for supplying a non-compressible fluid at low pressure to said low pressure piston faces which includes a source from which a non-compressible fluid is supplied at a constant predetermined pressure, pipe connections including a plurality of throttle valves each adapted to produce an identical pressure drop from an upstream pressure to a downstream pressure across each said throttle valve connecting said power source with said low pressure piston faces, a pilot relief valve having an operative connection with each said throttle valve whereby said pilot relief valve is operable to further increase the pressure drop across said throttle valve and thereby to reduce the downstream pressure to said low pressure piston face from a delivery to a predelivery pressure level, means for rendering each said pilot relief valve operative and inoperative and thereby to effect an adjustment of said downstream pressure from one to the other of said delivery and predelivery pressure levels, and control means for rendering each said pilot relief valve operative, and thereafter inoperative, serially to advance each low pressure piston serially first at a predelivery pressure and thereafter at a delivery pressure to supply a compressible fluid at a constant high pressure through said manifold.

5. In a fluid pressure system for delivering a continuous and steady flow of compressible fluid at a predetermined high delivery pressure, the combination of at least two double intensifier units adapted to operate in sequence, each said unit comprising a low pressure non-compressible fluid actuated reciprocating piston assembly, a pair of high pressure fluid delivery pistons attached to said low pressure piston assembly to be driven simultaneously in the same direction, a separate constant pressure supply means for each said double intensifier unit including a pipe connection including a reversing valve connected with said double intensifier unit, throttle valve means in said pipe connection adapted to produce a predetermined pressure drop between the upstream and downstream side of said throttle valve means, a pilot valve having an operative connection with said throttle valve means operable to increase said pressure drop and thereby to reduce said downstream pressure by a small amount, and means to render the pilot valve operative and inoperative, and thereby to effect an adjustment of said downstream pressure from one to the other of said delivery pressure and said reduced downstream pressure.

6. In a fluid pressure system for delivering a continuous and steady flow of compressible fluid at a predetermined high delivery pressure, the combination of at least two double intensifier units adapted to operate in sequence, each said double intensifier unit comprising a low pressure non-compressible fluid actuated reciprocating piston assembly, a pair of high pressure fluid delivery pistons attached to said low pressure piston assembly to be driven simultaneously in the same direction, and a liquid pressure control system for said low pressure piston assembly comprising for each said double intensifier unit a fluid pressure pump for supplying a non-compressible fluid at a constant pressure including means for regulating the output pressure from said pump, and a reversing valve connected between said pump and said double in-

tensifier unit for directing the low pressure fluid selectively to the individual units of said double intensifier unit, a throttle valve connected between said pump and said low pressure piston assembly adapted to produce a predetermined pressure drop between the upstream and downstream side of said throttle valve, a compensating valve connected across said throttle valve, a pilot relief valve connected with said compensating valve operable to increase said pressure drop and thereby to reduce said downstream pressure by a small amount and thereby to shift the downstream pressure to said low pressure assembly from a delivery pressure to a predelivery pressure, and means to render the pilot valve operative and inoperative.

7. In a fluid pressure system for delivering a continuous and steady flow of compressible fluid at a predetermined high delivery pressure according to claim 6, the combination of a control means for said double intensifier units which comprises means operative when any said low pressure non-compressible fluid actuated reciprocating piston assembly reaches the end of its stroke in each direction to reverse same, means operative simultaneously with said reversal to render the pilot relief valve connected with said reversed reciprocating piston assembly operative to reduce said downstream pressure, and means operative simultaneously with said reversal to render the pilot valve of the next double intensifier unit in said sequence inoperative, and thereby to complete the stroke of the reciprocating piston assembly of said latter double intensifier unit at full delivery pressure.

8. In a fluid pressure system for delivering a continuous and steady flow of compressible fluid at a predetermined high delivery pressure according to claim 6, the combination of an electrically operated control means for said double intensifier units which comprises an actuating switch in each low pressure reciprocating piston assembly adapted to be actuated by movement of said piston assembly to the limit of its stroke in each direction, solenoid operated means actuated by each said actuating switch to reverse the reversing valve of the low pressure reciprocating assembly in which said switch is located, solenoid operated means actuated by said actuating switch to render the pilot relief valve of the low pressure reciprocating assembly in which said switch is located operative to reduce said downstream pressure to predelivery level, and solenoid operated means actuated by said actuating switch simultaneously with said reversal to render the pilot valve of the next double intensifier unit in sequence inoperative, and thereby to continue the stroke of the reciprocating piston assembly

of said latter double intensifier unit at full delivery pressure.

9. In a fluid pressure system for delivering a continuous and steady flow of compressible fluid at a predetermined high delivery pressure, the combination of at least two double intensifier units adapted to operate in sequence, each said double unit comprising a low pressure non-compressible fluid actuated reciprocating piston assembly, a pair of high pressure fluid delivery pistons attached to said low pressure piston assembly to be driven simultaneously in the same direction, one of said pistons in a pressure stroke and the other of said pistons in a recovery stroke, a fluid pressure control system for said low pressure piston assembly comprising for each said double unit a fluid pressure pump, a fluid pressure connection between said pump and said low pressure piston assembly, including in said connection a four-way reversing valve for said low pressure piston assembly, a throttle valve, and a compensating valve connected across said throttle valve adapted to maintain a predetermined pressure drop between the upstream and downstream sides of said throttle valve, and additional valve means in said fluid pressure connection operable to further increase said pressure drop to reduce said downstream pressure, valve cutoff means in said fluid pressure connection to said additional valve means shiftable to render said additional valve means operative and inoperative and thereby to adjust the downstream pressure of said compensating valve between predelivery pressure and delivery pressure, and means controlled by the movement of any one of said low pressure piston assemblies to a limit position to shift the valve cutoff means associated with the next in sequence of said double intensifier units to delivery pressure.

10. In an intensifier assembly comprising a plurality of intensifier units according to claim 3, the combination of separate individual low pressure fluid supply assemblies connected with each said intensifier unit, said supply assemblies being rendered operative serially to supply a compressible fluid at a constant high pressure to said manifold.

11. In an intensifier assembly comprising a plurality of intensifier units according to claim 4, the combination of a single pump and individual pipe connections from said pump to each of said intensifier units.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,077,838

February 19, 1963

George F. Maglott

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the heading to the drawings, Sheets 1, 2, 3 and 4, line 2 thereof, and in the heading to the printed specification, line 2, for "PIPELESS PUMPING", each occurrence, read -- PIPELESS PUMPING --.

Signed and sealed this 10th day of December 1963.

SEAL)
Attest:
ERNEST W. SWIDER

Attesting Officer

EDWIN L. REYNOLDS
Acting Commissioner of Patents