Feb. 15, 1966 R. M. DOUGLAS ET AL 3,234,882

INTENSIFIER ASSEMBLY SYSTEM AND METHOD

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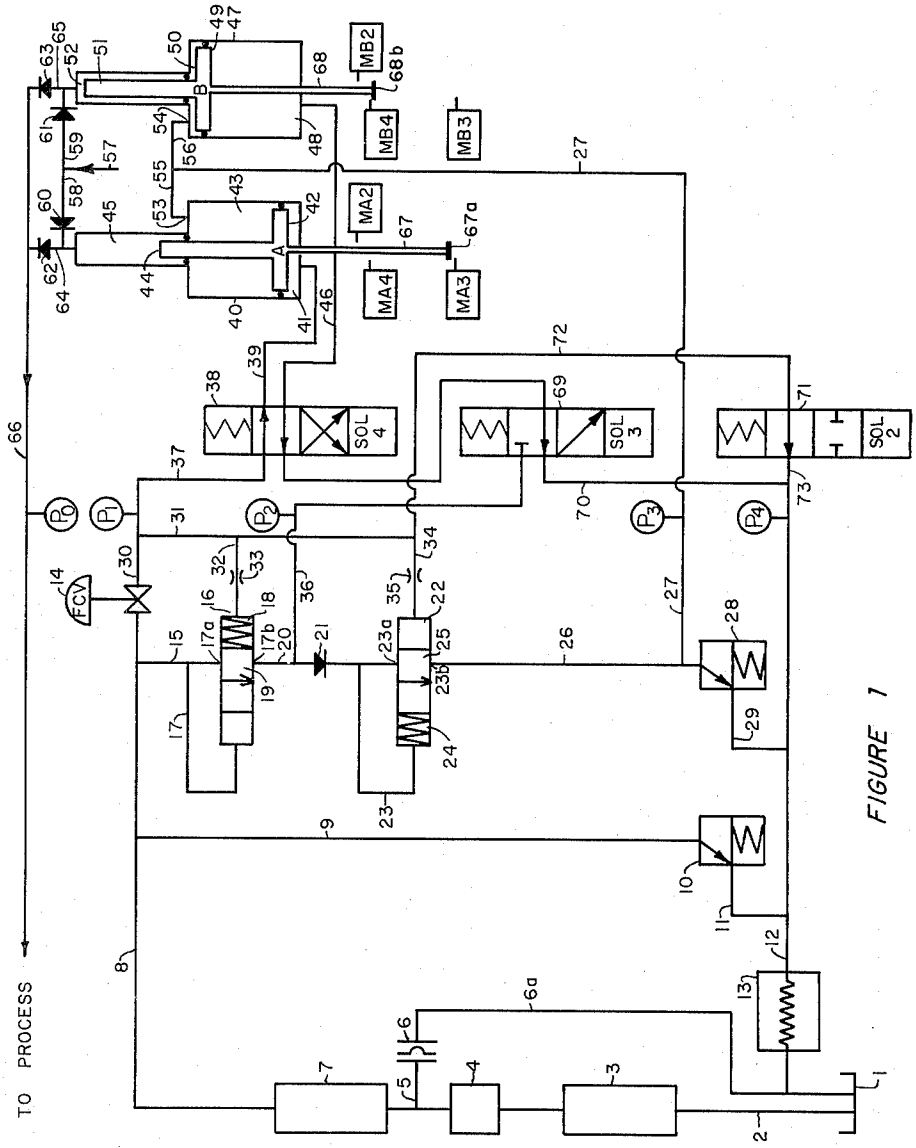


FIGURE 1

ROBERT M. DOUGLAS
DAROLD P. SLATER

INVENTORS

BY Fred S. Valles
ATTORNEY

INTENSIFIER ASSEMBLY SYSTEM AND METHOD

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2 Sheets-Sheet 2

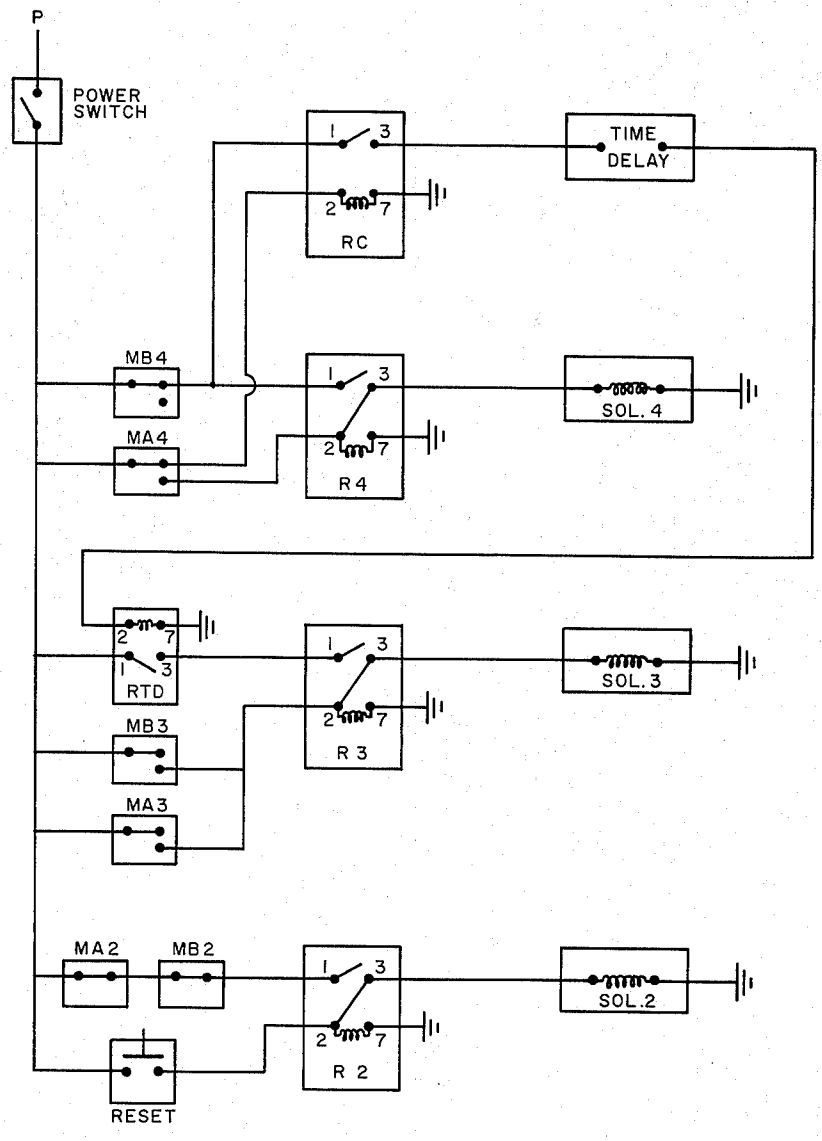


FIGURE 2

ROBERT M. DOUGLAS
DAROLD P. SLATER

INVENTORS

BY Fred S. Valla
ATTORNEY

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3,234,882

INTENSIFIER ASSEMBLY SYSTEM AND METHOD

Robert M. Douglas, Dumont, N.J., and Darold P. Slater, Odessa, Tex., assignors to Rexall Drug and Chemical Company, Los Angeles, Calif., a corporation of Delaware

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15 Claims. (Cl. 103—49)

This invention relates to a novel arrangement of an intensifier assembly for delivering a continuous and steady flow of a fluid to a high pressure area and to a method and includes the employment of differential pressure establishing systems which, in combination with the establishment of a plurality of pressure levels, permits maximum utilization of energy supplied in the form of fluid pressure and flow. The invention as defined in the specification and claimed is an improvement with respect to commercially available intensifier systems for introducing a fluid under high pressure to an area where such high pressures are required.

Heretofore, high pressure fluid delivery systems of the type with which this invention is concerned (to be referred to herein simply as intensifiers) have included in combination either single or double acting enclosed intensifier units with enclosed low and high pressure piston faces and conduit connections for supplying hydraulic or essentially non-compressible fluids to the low pressure piston faces of the intensifiers. In intensifiers of this type, the delivery pressure from the high pressure piston faces (also called the discharge pressure) is related to the hydraulic pressure by the build-in area ratios of the high pressure piston face and low pressure piston faces. In prior art intensifiers, as well as those commercially available, the available energy supplied by means of a pump, for example, in the form of a hydraulic fluid pressure, the energy was inefficiently utilized with respect to the low pumping capacity range of these systems (usually 1 to 40 gallons per hour on the process side). Thus, in systems of this nature, a fixed capacity pump was usually used with various valve arrangements providing for the by-pass or diversion of excess energy not required for the intensifier operation, the energy being by-passed to a reservoir or sump with a consequence that all this energy was lost. Moreover, in the prior art, where a plurality of intensifiers was employed, in order to operate in a "pipless" fashion, usually each double acting intensifier required a fixed capacity pump, or where single acting intensifiers were arranged in series, a plurality of fixed capacity pumps was likewise required for service with respect to operation in "pipless" fashion with the consequence that the inefficiency with respect to use of hydraulic energy was enhanced. To operate, therefore, in the "pipless" fashion or without flow fluctuations, it was necessary to employ at least four high pressure piston faces operating in sequence for delivering a substantially continuous discharge fluid to a high pressure area.

It is an object of this invention to provide a method for operation of an intensifier assembly whereby maximum use of energy available is made, such energy being supplied by a pump system.

It is a further object of this invention to provide an intensifier system employing a minimum of high pressure piston faces which are capable of maintaining a continuous and uninterrupted flow of fluid to a high pressure area.

It is a still further object of this invention to provide a novel arrangement of flow diverting valves in combination with a novel arrangement of pressure differential regulation means for maximum utilization of energy as supplied by a single hydraulic fluid delivery system.

It is yet another object of this invention to provide two single acting intensifier units which operate in sequence in discharge, suction and recompression strokes and by means of a novel method of establishing a plurality of pressure levels, is capable of maximum utilization of energy as supplied by the single pump system.

The objects hereinabove stated are provided by an improvement in an intensifier and a method comprising providing at least two single acting intensifier units having low and high pressure piston faces, a high pressure manifold and conduit connections from each of said high pressure piston faces to the high pressure manifold, conduit connections for supplying a fluid to said high pressure piston faces and conduit connections for supplying a hydraulic fluid to said low pressure piston faces, said improvement comprising a novel arrangement of means for establishing a plurality of hydraulic fluid pressure levels for use in operating said intensifier units in sequence in discharge, suction and recompression strokes. In this arrangement, a first differential pressure regulating means is provided across an orifice in said hydraulic fluid conduit to establish a fixed differential pressure across said orifice and a pressure P_1 downstream thereof, means are further provided for diverting said P_1 pressure supply to the discharge stroke of one of said intensifiers and means for by-passing excess hydraulic fluid from said first differential pressure regulating means and for establishing a second pressure level P_2 below said first P_1 level. A second differential pressure regulating means in association with said first means for maintaining said P_2 pressure level below said P_1 level is provided, and means for diverting said P_2 pressure level to the recompression stroke of one of said intensifiers. Finally, a by-pass means in association with said second differential pressure regulating means is provided to establish a third pressure level P_3 and means for diverting said P_3 pressure level to the suction stroke of one of said intensifier units.

The method of this invention in general therefore comprises the actuation continuously and in sequence of at least two single acting intensifier units by the establishment and maintenance of three distinct fluid pressure levels for operation of said units, said sequence for each of said units comprising discharge, suction and recompression steps and the method of operation involving the diversion of a first pressure level to the discharge step of one of said units, the diversion of a second pressure level to the recompression step of the other of said units and finally, the diversion of the third pressure level to aid in the suction stroke of one of said units, the three fluid pressure levels being derived from a single supply or pumping source.

In order to explain the function of the various pressure levels with more clarity, reference is made to FIGURE 1 of the attached drawing where P_0 indicates the process pressure delivery supply; P_1 indicates the hydraulic process pressure supply (also referred to as reference pressure or pilot reference pressure P_1, or delivery pressure P_1); P_2 indicates the hydaulic recompression pressure supply; P_3 indicates the hydraulic suction stroke pressure supply and P_4 indicates the reservoir or sump pressure supply. The P_0 process pressure is, as will be understood, the pressure at which a fluid such as a liquid containing an initiator is delivered to a high pressure system such as an ethylene polymerization reaction at high pressures. The remainder of the pressure levels, P_1 through P_4 and their function, will be explained in more detail hereinafter.

Briefly, the intensifier assembly system of this invention includes two single acting enclosed intensifiers having enclosed cylindrical high and low pressure piston faces of small and large diameter respectively with various conduits or pipes for supplying process and hydraulic

fluid to the system and the combination of a first differential pressure regulating valve placed across a flow control valve and serving to establish a fixed differential pressure across said flow control valve and to maintain a first pressure level P_1 which is used to drive the low pressure piston faces of the units. A by-pass conduit is provided with the first differential pressure regulating valve to divert excess flow from the hydraulic pump and this excess flow is used to establish the P_2 pressure level which is always below the P_1 pressure level by at least the force of a spring constant in the second pressure differential regulating valve. The second differential pressure regulating valve also has conduit connections to the first valve and serves to limit the P_2 pressure level by the spring force constant in this valve and is further provided with a by-pass conduit to divert flow from the P_2 level to the P_3 level. A pressure relief valve is utilized in association with this second differential pressure regulating valve to limit the maximum value of the P_3 level and a by-pass conduit is provided with said relief valve to divert any momentary excess flow (in excess of the P_3 level) to a reservoir.

The attached drawings, FIGURES 1 and 2, which form part of this invention, are representative preferred arrangements of the novel combination of intensifier assemblies (FIGURE 1) and electrical circuitry in association with said assemblies (FIGURE 2).

As briefly alluded to hereinabove, the intensifiers of this invention are useful for delivering a high pressure process fluid to a polymerization reaction typically illustrated by a high pressure ethylene polymerization reaction. In ethylene polymerizations, for example, either gases or liquids can be utilized at pressures ranging from 15,000 up to 60,000 p.s.i. It is obvious that to be able to deliver a process fluid to a reactor at these high pressures, intensifiers of the type herein are required and in addition to this, it is usually a prerequisite that any fluid being delivered to a reactor at high pressures, be delivered continuously and without pressure or flow fluctuations. The intensifiers of this invention are capable of operation in this manner, even though they have use for other high pressure operations. Reference will be made to the delivery of a liquid from the discharge stroke of the high pressure piston faces in this preferred embodiment of the invention, while the essentially non-compressible fluid delivered to the low pressure piston faces will be merely referred to as a hydraulic oil or just an oil.

By virtue of being able to utilize the maximum of the energy available from the pump which provides the hydraulic fluid to the low pressure piston faces, it is likewise understood that the capacity for delivering process fluid at the P_0 level is likewise enhanced as will be understood from the fact that the volume of hydraulic fluid being circulated at the P_1 level by the hydraulic pump is proportional to the volume of fluid delivered from the high pressure piston faces in the same manner that the intensification ratio of hydraulic fluid versus discharge process fluid is determined.

Briefly, with respect to FIGURE 1, numeral **1** indicates a sump tank or reservoir for maintenance of the hydraulic fluid (oil). Conduit **2** is used to take up the hydraulic fluid which passes through a strainer **3** (filter) and then to hydraulic pump **4** which can be a pump of essentially fixed capacity output used to supply the necessary energy for the low pressure piston faces of the intensifiers and also to provide the other pressure levels P_2 and P_3 as will be described hereinbelow. Item **6** leading from line **5** is a rupture disc for safe operation of the system and to prevent damage to the pump, said rupture disc being operable to divert flow from the hydraulic pump to the sump via conduit or line **6***a*. Immediately downstream of the hydraulic pump **4**, a second filter **7** can be placed in the conduit to make sure that the hydraulic fluid contains no extraneous particles which could damage the various high pressure hydraulic valves, etc. employed in the system. Hydraulic fluid is delivered via conduit **8** to the intensifier low pressure piston faces as will be described herein. Line **9** is connected to a relief valve **10** which is set at a certain maximum pressure. When the pressure of the relief valve is exceeded, hydraulic fluid will be diverted to the sump via line **11** to line **12** through heat exchanger **13** to the sump. On conduit **8** is placed flow control valve **14**. Flow control valve is of the variable orifice type and is used to control the amount of hydraulic fluid passing therethrough which is required for the particular quantity of high pressure fluid being delivered from the high pressure piston faces. A conduit **15** upstream of flow control valve **14** leads to the first differential pressure control valve **16** which is an enclosed valve containing inlet and outlet ports. A by-pass conduit **17** is provided with this valve (may be placed internally or externally as shown) for its operation as will also be described hereinafter. Spool **19** located within valve **16** is a dynamically operated piston which controls the flow through the valve (see for example, U.S. Patent 3,077,838 illustrating a typical spool and spring valve within a chamber). The position of the spool with respect to inlet and outlet ports **17***a* and **17***b* respectively is determined by the dynamic location of the spool with reference to the various forces acting upon it. These forces which are exerted on the spool are those from the fluid in conduit **17** and those from the fluid in conduit **32** plus a constant force such as the constant spring force of spring **18**. A by-pass conduit **20** leads from differential pressure regulator valve **16** to a check valve **21** and thence to a second enclosed differential pressure regulating valve **22**. Differential pressure regulating valve **22** is similar to valve **16**, but operates in reverse of valve **16**. Thus, whereas port **17***a* of valve **16** is normally closed in the absence of forces acting on it, it will open when its established differential pressure is exceeded (the exceeding force being the fluid pressure from lines **8** and **17**). Valve **22** is normally open via its port **23***a* in the absence of forces acting on it, but will close when its differential pressure is exceeded (the exceeding force being the fluid pressure from lines **31** and **34**). As indicated, differential pressure regulating valve **22** is provided with inlet port **23***a* and outlet port **23***b*. These ports (similarly to ports **17***a* and **17***b* of valve **16**) control the flow into and out of valve **22**. Fluid pressure from lines **17** and **23**, as well as lines **32** and **34** serve to create the necessary pressures for dynamic pressure balance of spool valves **19** and **25** of valves **16** and **22**, while spring **24** of valve **22** is of equivalent function to spring **18** of valve **16**. The novel arrangement of these valves is disclosed and claimed in copending application Serial Number 375,157, filed June 15, 1964, and assigned to the assignee of the instant invention.

The operation of these valves **16** and **22** is such that they utilize pressure level P_1 as a reference pilot pressure which controls an upstream pressure level in conduits **17** and **23** respectively via the spool valves **19** and **25** movement. This relative upstream fluid pressure in conduits **17** and **23** serves also as a secondary pilot pressure and is regulated by the effective loading of the springs **18** and **24**. In valve **16**, the spring **18** force per unit area is added to the pressure P_1 and this must equal the upstream pressure of line **8**. The fixed differential pressure maintained across the flow control valve **14** is at least therefore the value of spring force per unit area. If the pressure in line **8** exceeds this established differential pressure, spool **19** moves to the open position, thus diverting more flow through inlet port **17***a* and outlet port **17***b* until the dynamic balance between pressures of lines **8** and **30** is obtained. If the pressure in line **8** should drop below the established differential pressure, the spool piece **19** moves in the closing direction, thereby reducing the by-pass flow and increasing the line **8** pressure level until a dynamic balance is again established between pressures in lines **8** and **30**. This occurs irrespective of whatever pressure

changes may occur in line 30. In valve 22 the pressure in line 34 (considered a pilot reference pressure) minus the springs 24 force per unit area establishes the maximum value of the upstream operating pressure. In operation, as indicated above, this valve functions in reverse of valve 16 so that when the fluid pressure in line 23 plus the spring 24 pressure exceeds the P_1 pressure level, the valve will open and by-pass fluid through ports 23*a* and 23*b* to line 26. Where the fluid pressure in line 23 plus the spring 24 pressure is less than the P_1 pressure, the valve will close. A pressure level is thus established between valves 16 and 22 in line 36 referred to herein as the P_2 level and this P_2 level establishes the pilot operating pressure in line 23. The P_2 pressure level can never exceed the P_1 pressure level and it will always be below that level by at least the amount of pressure exerted by the spring 24 force per unit area. The operation of these two valves to establish the pressure level in lines 8 and 15 and the pressure level P_2 and the use of these pressure levels to control flow across valve 14 for recompression will be described with reference to the various 2-, 3- and 4-way solenoid operated valves below. Solenoid operated valves 3 and 4 are typical reversing valves known in the art. Between differential pressure regulating valves 16 and 22 in line 20 there is located a check valve 21 which functions to prevent the valve 22 from slamming closed when the pressure drops rapidly in lines 20 and 36 in response to operation of the 3-way solenoid valve.

In the above scheme of operation, conduit 26 leads directly to the suction stroke of either of the intensifier assemblies through conduit 27 or to relief valve 28 which is set to dump at a certain pressure and thence to line 29, discharge line 12 and the sump.

As noted from the above description, line 31 which serves as the pilot reference pressure with respect to valves 16 and 22 is connected to valve 16 through line 32 and constriction 33 and also to line 34 and constriction 35 leading to the second differential pressure regulating valve 22. In between the two differential pressure valves, a conduit 36 is provided for diverting fluid at the P_2 pressure level to a 3-way solenoid valve, as indicated hereinabove. Fluids from flow control valve 14 is taken directly to the intensifier assemblies via line 37, 4-way solenoid valve 38, line 39 and a first single acting intensifier assembly designated at 40. The intensifier assemblies 40 and 47 are typical enclosed single acting units containing with respect to 40, a low pressure chamber 41, low pressure piston face 42, low pressure chamber 43 and the piston face area enclosed in this chamber, and high pressure piston face 44, as well as high pressure chamber 45. The 4-way solenoid valve 38 provides conduit connections 46 to the second intensifier unit 47, having equivalent enclosed chambers and equivalent low and high pressure piston faces, and areas 48, 49, 50, 51 and 52. It will be noted that the piston faces in enclosed chambers 43 and 50 are of smaller surface area than those of 42 and 49 by the amount of the area of faces 44 and 51. Discharge ports from the low pressure chambers 43 and 50 are located at 53 and 54 respectively, said chambers connecting with conduit lines 55 and 56 and then with conduit or line 27 leading back to the sump. Fluids from the P_3 pressure level in either chamber is rediverted through these ports and conduits to the other chamber during the discharge and suction strokes of the units respectively. For convenience, intensifier units 40 and 47 will be referred to hereinafter as Drive A and Drive B respectively. Drive A is provided with piston rod 67 and Drive B with piston rod 68 with projections indicated generally at 67*a* and 68*b* for contacting the microswitches indicated in the drawing as MA–2, 3 and 4 and MB–2, 3 and 4. In Drive A operation, rod 67 contacts microswitch MA–3 at the end of the suction stroke, MA–4 at the end of the discharge stroke and if MA–4 should fail, it activates MA–2 which diverts flow of hydraulic fluid in a direction to be indicated hereinafter to prevent damage to the units. Similarly in Drive B operation rod 68 activates microswitches MB–3, 4 and 2 upon failure of MB–4.

In FIGURE 1, numeral 69 represents a 3-way solenoid valve with conduit means 70 leading to the sump. Unit 71 is a third solenoid operated valve except that in this case it is a 2-way valve and is connected to conduit 34 via conduits 72 and 73 to the sump.

The suction liquid for the high pressure piston faces is supplied through line 57 to either intensifier assembly through conduits 58 and 59 and check valves 60 and 61. Check valves 62 and 63 are provided for delivery of high pressure fluid through lines 64 and 65 and thence to high pressure manifold 66.

All of the foregoing units are standard commercial items available on the market, for example, the 4-, 3- and 2-way solenoid operated valves, the flow control valve, the relief and rupture valves, as well as differential pressure regulating valve 16. Differential pressure regulating valve 22 is a modification of valve 16 in that it is placed in this operation to function in reverse fashion with respect to valve 16, as will be understood by those skilled in the art. It is not necessary that the arrangement of these valves be as illustrated, since alternative methods and units for accomplishing the same purpose will be referred to at the end of this specification.

FIGURE 2, the operation of which will be described in more detail, relates to the electrical circuitry and is suitably illustrated in the drawing. In the drawing, the symbol M is used generally to designate a microswitch; A or B when used in conjunction with M designate Drive A or Drive B respectively, while the letter R designates generally a relay. SOL in the drawing indicates a solenoid and the numerals 2, 3 and 4 designate the solenoids of the units 38, 69 and 71 respectively of FIGURE 1. The letters TD designate a time delay arrangement provided herein, while the numerals associated with the MA and MB microswitches indicate: 2, hydraulic deactivation; 3, end of suction stroke and 4, end of discharge stroke respectively and as further illustrated in FIGURE 1 of the drawing. A typical power supply is a 110 volt, 60 cycle connection.

In operation, starting with Drives A and B as indicated in the drawing, Drive A is shown as recompressed and just beginning its discharge stroke. Solenoid valve of 4-way reversing valve 38 (a suitable 4-way valve is illustrated in U.S. Patents 2,819,835 and 3,077,838; however, as indicated hereinabove, solenoid valves whether 4-, 3- or 2-way are standard in the art) is ported as indicated by the arrows in the drawing. The solenoid at this point was reactivated by virtue of piston rod 67 through projection 67*a*, having activated microswitch MA–3. Drive B is at the end of its discharge stroke and just beginning its suction stroke. Solenoid valve 69 is ported as indicated in FIGURE 1 leading back to the sump or reservoir. The solenoid of this 3-way valve was deactivated in view of the fact that piston rod 68 through projection 68*b* has just activated microswitch MB–4. Two-way solenoid valve 71 is a normally open valve as shown in FIGURE 1 and is activated during the operation of the pump. This valve is opened or deactivated only on the occurrence of a malfunction by activation of MA–2 or MB–2 microswitches or turning off the control circuit power supply.

Under the above conditions, a controlled hydraulic oil flow provided by pump 4 is passing through flow control valve 14 and being routed to low pressure compression chamber 41 of Drive A via the 4-way solenoid valve 38. The energy being diverted through the 4-way solenoid valve 38 is only a fraction, for example from 5 to 80% of the total energy available and which is supplied from hydraulic pump 4. The excess oil flow capacity is diverted through line 15 and differential pressure regulating valve 16. Since the 3-way solenoid valve 69 is closed as indicated in the drawing by the arrow, the pres-

sure in conduit 36 builds up to a pressure P_2 just below the P_1 or delivery pressure maintained downstream of flow control valve 14. As indicated before, the pressure build-up in conduit 36 is controlled by differential pressure regulator 22. Once the pressure in line 36 has reached a maximum called its controlled pressure or P_2 below the pressure P_1, the excess flow is diverted through valve 22 (by virtue of the pressure in line 23 plus the spring force pressure 24 exceeding the P_1 pressure level in line 34, thereby moving spool 25 to discharge), to conduit 26 to a third pressure level P_3, also called the suction stroke pressure level which can be just above the sump or reservoir pressure as determined by the setting of relief valve 28. When the above occurs, the available flow capacity through valve 22 combined with an equivalent capacity through valve 14 and chamber 43 being delivered to chamber 50 forces Drive B to complete its suction stroke. It should be understood that while Drive A is undergoing its discharge stroke, the fluid in chamber 43 is being diverted through port 53 and conduits 55 and 56 to port 54 and chamber 50 to aid in the suction stroke. This arrangement of flow diversion from the P_1 pressure level means that the hydraulic Drive B is returned at the maximum rate of the volume output of the hydraulic pump. It further means that the speed of the piston during the suction stroke is controlled and does not exceed a linear velocity that would reduce packing life.

With Drive B having completed its suction stroke, it activates microswitch MB–3 through contact of projection 68*b* and this in turn activates or energizes the 3-way solenoid valve 69 and diverts the P_2 pressure supply to Drive B for recompression. The P_2 pressure level momentarily drops to the P_3 level and closes off port 23*a* via spool 25 movement and then gradually builds up to the P_2 pressure control level at which time Drive B has completed its recompression motion and idles until Drive A has completed its discharge stroke. As indicated above, this is accomplished by differential control valve 22 closing when the P_2 pressure level has dropped below its control point. Check valve 21 placed on inlet port 23*a* of valve 22 prevents damage to the spring and spool piece when the pressure decreases rapidly as heretofore mentioned. During the idling period of the recompression stroke and due to the increase of the P_2 pressure level, valve 22 is again forced to open due to the movement of the spool and momentarily during this period the excess oil is diverted to the P_3 level and since at this time neither hydraulic Drive A or B is undergoing a suction stroke, the oil is vented through relief valve 28 to the sump.

On the completion of the discharge stroke of Drive A, microswitch MA–4 is activated by contact with projection 67*a* and this in turn energizes the solenoid of the 4-way valve 38, while essentially at the same time the solenoid of 3-way valve 69 is deactivated diverting the Drive A fluid back to the sump. To accomplish the correct timing so that the 4-way valve 38 has reversed before the 3-way valve has reversed, it is necessary to incorporate an electric time delay as illustrated in FIGURE 2. Upon this reversal occurring, the sequence is repeated as before, except that nomenclature of Drives A and B are reversed and the 4-way valve 38 is to be deactivated instead of activated.

Referring now to FIGURE 2 and the operation of the various microswitches in connection with the charge and discharge strokes of Drives A and B, the reference starting point for the cycle selected for description is the same as the sequence described above for operation of the intensifier units 40 and 47.

In this sequence the power supply switch is closed and the solenoid of 2-way valve 71 is activated by pressing the re-set button. All of the microswitches are in the normally open or closed position as indicated on the drawing. All of the relays R4, R3 and R2 are of the normally open contacts. In this sequence, holding relay RC and relay RTD are activated and therefore the contacts are closed. Upon closing the contacts, power is provided to contact 1 of relay R3, this relay thus being de-energized. Under this condition, hydraulic flow of the delivery pressure level (P_1) is being diverted to Drive A as shown in FIGURE 1 and the oil in chamber 48 of Drive B is being diverted to the sump. On the completion of the suction stroke of Drive B, microswitch MB–3 is activated and will therefore supply power to relay R3, thus reversing 3-way solenoid valve 69 and diverting the recompression pressure level P_2 to Drive B.

The next microswitch to be activated will be MA–4 upon completion of the discharge stroke of Drive A and this, in turn, will activate relay R4 holding coil and, in turn, activates solenoid 4 of 4-way valve 38 and thus reverses the oil flow of Drives A and B. At the same time, it will momentarily break the normally closed contact of microswitch MA–4, open relay RC, which in turn deactivates holding relay R3 via the time delay device. The time delay device is a standard item normally used in the art (it is equivalent to an electrical surge tank) and comprises a series of capacitors and resistors which function to delay the response of relay R3 holding coil, which thereby allows solenoid valve 38 to completely reverse prior to reversal of solenoid valve 69 as indicated before. This arrangement therefore avoids the possibility of venting the recompression P_2 level to the reservoir prematurely.

After the deactivation of the relay R3 via the time delay device, Drive A continues its suction stroke until it activates microswitch MA–3. This again energizes holding relay R3 and activates the solenoid of 3-way valve 69 to start the recompression stroke of Drive A. The electrical system stays in this combination until Drive B completes its discharge and activates microswitch MB–3. When this occurs, it deactivates holding relay R4 which reverses the 4-way valve of solenoid valve 38, thus starting the same sequence over again.

Although the above describes a preferred arrangement and embodiment of the various differential pressure control valves, as well as the solenoids, there are certain modifications which can be incorporated and substitutions made for the individual units, which modifications and substitutions are not a departure from the principle of this invention. In this connection, reference is made to the following alternate embodiments or modifications to this system.

In one modification, instead of the differential pressure regulating valve 22 functioning in reverse fashion with respect to valve 16, it could be arranged to function in identical manner as 16 (or a pilot operated relief valve could be substituted in its place), but in this case a different pilot reference pressure would be used which could be established in the following manner: a side steam of regulated flow from line 8 located upstream of flow control valve 14 would be provided to lead through a pressure reducing regulator, the outlet pressure of which would be the pilot reference pressure, to the second mentioned valve similar to valve 16. This would mean that the regulated downstream pressure of the reducing valve would always be a fixed value below the upstream P_1 value. The flow regulation through the pressure reducing regulator would then be controlled by a downstream constriction (a micro flow regulator).

Also instead of operation with a flow control system as illustrated in FIGURE 1, a pressure control system could be adapted to function under the broad scope of the method described herein by changing flow control valve 14 to a pressure controlled valve. A further alternative would be to disconnect line 31 from 30 and connect it to an automatically controlled pilot pressure regulator by tapping or withdrawing a side stream from line 8 similarly achieved as in the above paragraph. Under this condi-

tion valve 14 would be removed or left in the normally open flow position.

A still further modification with respect to the preferred method of operation herein includes the provision of a constriction in line 36 to offer sufficient resistance to line 36 flow so that any instantaneous overshoot of valve 22 would not be sensed by the drive undergoing recompression.

Other modifications can be made which will not depart from the spirit and scope of the invention and the appended claims.

What is claimed is:

1. In an intensifier assembly system comprising at least two single acting intensifier units having low and high pressure piston faces, a high pressure manifold and conduit connections from each of said high pressure piston faces to the high pressure manifold, conduit connections for supplying a fluid to said high pressure piston faces and conduit connections for supplying a hydraulic fluid to said low pressure piston faces, the improvement comprising a novel arrangement of means for establishing a plurality of hydraulic fluid pressure levels for use in operating said intensifier units in sequence in discharge, suction and recompression strokes, said improvement comprising the combination of means for establishing a first hydraulic fluid pressure level P_1 upstream of said intensifier units and a conduit for delivery of said P_1 fluid pressure level to the discharge stroke of one of said intensifiers, a conduit for by-passing hydraulic fluid in excess of that required for said P_1 fluid pressure level to a second fluid pressure level P_2, a valve in association with a fixed force constant for maintaining said P_2 fluid pressure level below said P_1 fluid pressure level by at least the fixed force constant of said valve, a conduit in association therewith for delivery of said P_2 fluid pressure level to the recompression stroke of the other of said intensifier units and a by-pass conduit in association with said valve for by-passing fluid in excess of that required for the P_2 fluid pressure level to a third fluid pressure level P_3.

2. In an intensifier assembly system comprising at least two single acting intensifier units having low and high pressure piston faces, a high pressure manifold and conduit connections from each of said high pressure piston faces to the high pressure manifold, conduit connections for supplying a fluid to said high pressure piston faces and conduit connections for supplying a hydraulic fluid to said low pressure piston faces, the improvement comprising a novel arrangement of differential pressure regulating means to operate said units in sequence in discharge, suction and recompression strokes, said improvement comprising a first differential pressure regulating means across an orifice in said hydraulic fluid conduit to establish a fixed differential pressure across said orifice and a first fluid pressure level P_1 downstream thereof, a by-pass conduit for by-passing hydraulic fluid in excess of the fluid pressure level P_1 to a second fluid pressure level P_2, a valve in association with a fixed force constant for maintaining said fluid pressure level P_2 below said P_1 fluid pressure level by at least the fixed force constant of said valve and a by-pass conduit in association with said valve for by-passing hydraulic fluid in excess of that required for the P_2 pressure level to a third fluid pressure level P_3.

3. In an intensifier assembly system comprising at least two single acting intensifier units having low and high pressure piston faces, a high pressure manifold and conduit connections from each of said high pressure piston faces to the high pressure manifold, conduit connections for supplying a fluid to said high pressure piston faces and conduit connections for supplying a hydraulic fluid to said low pressure piston faces, the improvement comprising a novel arrangement of differential pressure regulating means to operate said units in sequence in discharge, suction and recompression strokes, said improvement comprising a first differential pressure regulating means for establishing a fixed differential pressure across a variable flow orifice on said hydraulic fluid conduit and for maintaining a first hydraulic fluid pressure level P_1 downstream of said orifice, conduit means for delivering said P_1 fluid pressure to the low pressure piston face of one of said intensifiers during the discharge stroke thereof, a by-pass conduit in association with said first differential pressure regulating means to divert fluid in excess of that required to maintain said P_1 fluid pressure level, said fluid being diverted to a second fluid pressure level P_2 below said first pressure level P_1, a second differential pressure regulating means for maintaining said P_2 fluid pressure level below said P_1 pressure level, conduit means for delivering said P_2 fluid pressure level to the recompression stroke of one of said intensifiers, a by-pass conduit in association with said second differential pressure regulating means to divert fluid in excess of that required to maintain said P_2 fluid pressure level, said fluid being diverted to a third fluid pressure level P_3 and conduit means for delivering said P_3 fluid pressure to the suction stroke of one of said intensifiers.

4. The improvement in the intensifier assembly of claim 3 wherein the first and second differential pressure regulating means comprise a movable spool valve in an enclosed chamber and a spring force constant, said first differential pressure regulating means adapted to open and by-pass fluid to a by-pass conduit in association therewith and with said second differential pressure regulating means by movement of the spool valve when the pressure upstream thereof and the spring force constant exceed said first fluid pressure level P_1, and said second differential pressure regulating means being adapted to open and by-pass fluid to a by-pass conduit in association therewith by movement of the spool valve therein when the pressure level P_1 exceeds the spring force constant and the pressure from the by-pass conduit in association with said first pressure regulating means.

5. The improvement in the intensifier assembly of claim 3 wherein the P_3 fluid pressure level diverted to one of said intensifiers is rediverted by said intensifier to the suction stroke of the other intensifier through port and conduit means when said intensifier is undergoing its discharge stroke.

6. The improvement in the intensifier assembly of claim 3 wherein the sequence of delivering the hydraulic fluid pressure levels P_1, P_2 and P_3 to the discharge, recompression and suction strokes of said intensifiers is controlled by employment of 4- and 3-way solenoid operated reversing valves, said 4-way solenoid operated reversing valve adapted to divert the P_1 pressure level to the discharge stroke of one of said intensifiers and said 3-way solenoid operated reversing valve adapted to divert the P_2 pressure level to the recompression stroke of the other of said intensifiers.

7. The improvement in the intensifier assembly of claim 3 wherein a relief valve is employed in association with said second differential pressure regulating means to by-pass fluid in excess of the P_3 fluid pressure level to a reservoir.

8. The improvement in the intensifier assembly of claim 6 wherein a time delay means is adapted to reverse the 4-way solenoid operated valve prior to reversal of the 3-way solenoid operated valve during the reversal from discharge stroke to suction stroke of one of said intensifier units.

9. In an intensifier assembly system comprising at least two single acting intensifier units having low and high pressure piston faces, a high pressure manifold and conduit connections from each of said high pressure piston faces to the high pressure manifold, conduit connections for supplying a fluid to said high pressure piston faces and conduit connections for supplying a hydraulic fluid to said low pressure piston faces, the improvement comprising a novel arrangement of differential pressure regulating means to operate said units in sequence in discharge, suction and recompression strokes, said improve-

ment comprising a first differential pressure regulating valve in association with a spring force constant upstream of said intensifiers for establishing a fixed differential pressure across a variable flow orifice in said hydraulic fluid conduit and a first fluid pressure level P_1 downstream of said orifice, a by-pass conduit in association with said first valve for diverting fluid flow in excess of that required for said P_1 pressure level to a second fluid pressure level P_2 maintained below said P_1 pressure level, a second differential pressure regulating valve in association with a spring force constant and said by-pass conduit of said first valve, said second valve adapted to open to by-pass to a third fluid pressure level P_3 when said P_2 pressure level is exceeded, a relief valve in association with said second valve, said relief valve adapted to open to by-pass fluid to a reservoir when the P_3 fluid pressure level is exceeded and 4- and 3-way solenoid operated reversing valves for delivering said P_1 and P_2 fluid pressure levels to the discharge and recompression strokes respectively of said intensifiers.

10. The improvement in the intensifier assembly of claim **9** wherein the P_2 pressure level is maintained below the P_1 pressure level by at least the spring force constant of the second differential pressure regulating valve.

11. The improvement in the intensifier assembly of claim **9** wherein the said intensifier units are associated with ports and conduits for rediverting the hydraulic field from the P_3 pressure level from one to the other during the discharge and suction strokes respectively.

12. In a process for delivering a fluid at an elevated pressure to a high pressure process area wherein said fluid is discharged sequentially and continuously from two enclosed high pressure cylindrical surface areas of small diameter and wherein a non-compressible fluid is provided to drive two enclosed low pressure cylindrical surface areas of larger diameter in association with said high pressure cylindrical surface areas, in a sequence comprising fluid discharge, suction and recompression steps for each of said low pressure cylindrical surface areas, the improvement which comprises maintaining a first non-compressible fluid pressure level for delivery to the discharge step of one of said low pressure cylindrical surface areas, maintaining a second non-compressible fluid pressure level below said first fluid pressure level for delivery to the suction step of the other of said low pressure cylindrical surface areas and maintaining a third non-compressible fluid pressure level for delivery to the recompression step of one of said low pressure cylindrical surface areas.

13. The improvement in the process of claim **12** wherein said first, second and third fluid pressure levels are derived from a single fluid pressure delivery supply.

14. The improvement in the process of claim **12** wherein the non-compressible fluid from the third pressure level delivered to the suction step of one of said large cylindrical surface areas is rediverted to he suction step of the other of said large cylindrical surface areas when the former is undergoing its discharge step.

15. The process of claim **12** wherein the second fluid pressure level is maintained below the first fluid pressure level by a fixed force constant and wherein the delivery of the first and second fluid pressure levels to the discharge and recompression steps of said cylindrical surface areas is controlled by reversing the flow of the first fluid pressure level from one surface area to the other in sequence during the discharge and recompression steps respectively and by delivering the flow of the second fluid pressure level to the cylindrical surface area during its recompression step only.

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DONLEY J. STOCKING, *Primary Examiner.*