Jan. 2, 1945. M. A. CROSBY 2,366,388

MULTIPLE STAGE PUMPING SYSTEM

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FIG. 1

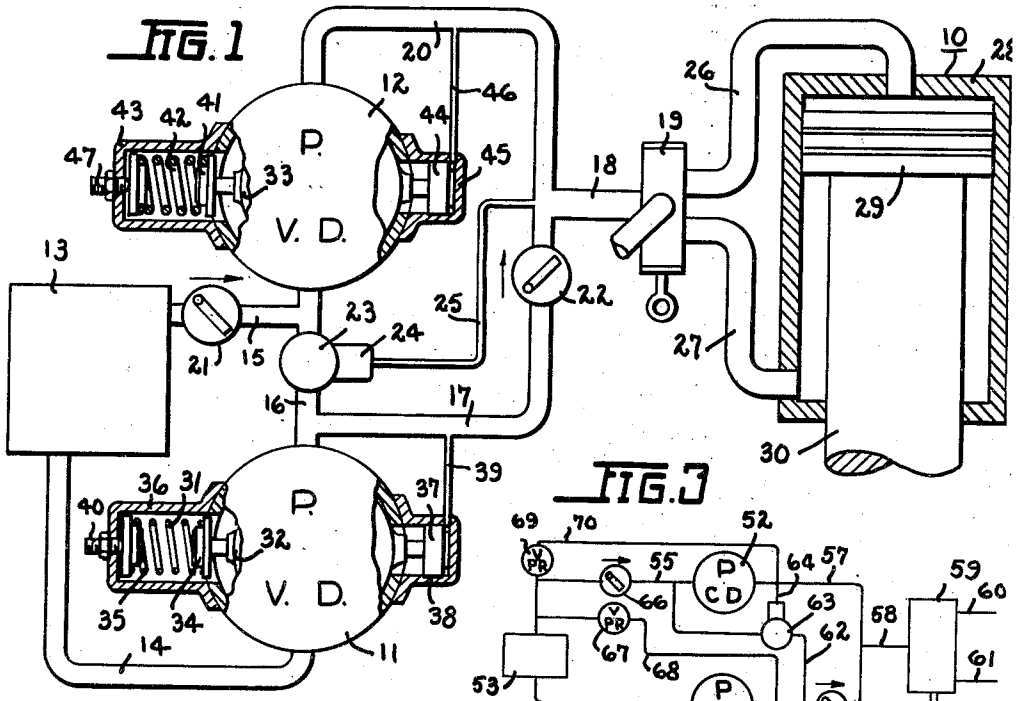
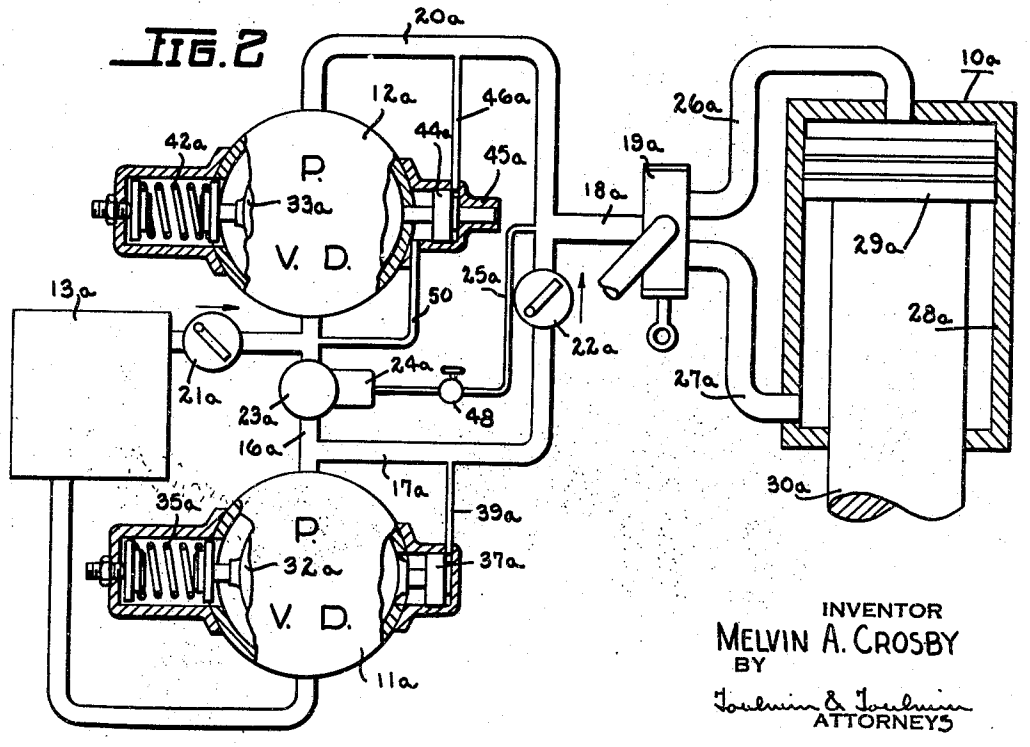



FIG. 3




FIG. 2




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## MULTIPLE STAGE PUMPING SYSTEM

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3 Claims. (Cl. 103—11)

This invention relates to a fluid supply system for placing fluids under pressure and for delivering the fluids to a fluid actuated apparatus. Specifically, the invention relates to a pumping system for placing liquid under pressure which is supplied to a hydraulically actuated apparatus.

An object of the invention is to provide a fluid pressure system which is capable of delivering large volumes of fluid at low pressure and relatively smaller volumes of fluid at high pressure while utilizing the full output of the complete pumping system.

It is another object of the invention to provide a fluid pumping system which can supply a large volume of low pressure fluid or a somewhat smaller volume of high pressure fluid without bypassing any of the output of the system when shifting from delivery of a large volume low pressure fluid to a low volume high pressure fluid.

It is another object of the invention to provide a fluid pumping system utilizing a plurality of pumps for delivering their fluid in parallel until a predetermined pressure is reached in the system, and then shifting the arrangement of the pumps so that they will deliver in series and thereby permit the production of a much higher fluid pressure.

Another object of the invention is to provide a liquid pumping system utilizing a plurality of pumps wherein the delivery from the pumps is in parallel until a predetermined pressure is reached, after which one of the pumps maintains the predetermined pressure upon another of the pumps for delivering the liquid through the plurality of pumps in series so that the pressure differential between the inlet and outlet of the pumps will not be carried above the pressure developed in the system when the pumps were operating in parallel.

Another object of the invention is to provide a fluid pumping system utilizing a plurality of pumping units associated with one another in a manner that one of the pumping units maintains a predetermined pressure upon another of the pumping units so that said other pumping unit will produce a predetermined pressure differential across the unit regardless of the pressure of the fluid admitted to the unit.

Another object of the invention is to provide a plurality of variable delivery pumps associated with one another in a manner that the pumps will deliver a fluid under pressure in parallel until a predetermined pressure is reached, after which the pumps will be arranged in series so that one of the pumps will supply fluid under pressure to the other of the pumps whereby the pump being supplied with fluid under pressure can operate to increase the pressure in the delivery portion of the system without causing any increase in pressure differential over that established prior to the change from parallel flow to series flow.

Another object of the invention is to provide a pumping system in accordance with the foregoing object wherein the change-over from parallel to series flow of the pump units is accomplished automatically and in response to the pressure in the pumping system.

It is another object of the invention to provide a fluid delivery system using a pair of variable delivery pumps associated with one another in a manner that the pumps will deliver either in parallel or series flow arrangement whereby the system can supply a large volume of low pressure fluid when the pumps are in parallel arrangement and a small volume of high pressure fluid when the pumps are in series arrangement without materially effecting the bearing load of the pumps regardless of whether they are in series or parallel flow arrangement.

Another object of the invention is to provide a fluid delivery system constructed and arranged in accordance with any of the foregoing objects wherein the fluid pumps are of the constant delivery type.

Another object of the invention is to provide a fluid pressure delivery system wherein the bearing loads upon the pumping units are not increased above a normal load when using the pump singly, even though the pressure developed by the pumping system is greater than either of the pumps alone could produce without developing abnormal bearing load conditions.

Further objects and advantages will become apparent from the drawing and the following description.

In the drawing:

Figure 1 is a schematic view of the pumping system of this invention using variable delivery pumps as the sources for developing fluid pressure.

Figure 2 is a schematic view similar to Figure 1 showing a modified arrangement of the pumping system.

Figure 3 is a schematic view of a pumping system, similar to that disclosed in Figure 1, showing the manner in which constant delivery pumps can be applied to the system.

This invention relates to pumping systems for developing fluid pressure and for transmitting the

fluid under pressure to a pressure actuated apparatus. Particularly the invention relates to a pumping system for placing liquid under pressure and for delivering the liquid under pressure to a hydraulically actuated device.

Many pressure operated devices are required to have different rates of travel in various portions of their cycle of operation. In order to vary the rate of travel of a pressure operated device which has a substantially constant increase in its volumetric displacement as it moves, it is required to supply a relatively large volume of fluid to the device. If the device meets with work resistance pressure will build up in the device until the normal capacity of the fluid supplying system is reached. Thereafter it is many times desirable to increase the pressure of the fluid supplying system to cause the working stroke of the pressure actuated device.

Normally, this has been accomplished by the use of a single pump delivering pressure fluid to the pressure actuated device. When a single pump is used for supplying the pressure the pressure differential across the pump is from zero to the maximum pressure being developed which thereby imposes a considerable load upon the bearings of the pump. Also, as the pressure within the pump increases the efficiency of the pump falls off. Therefore the maximum pressure that can be developed by a pump depends considerably upon the load that can be carried by the bearings without causing any harmful result. Such a single pumping system, however, will only have the volumetric displacement of the single pump used.

If, however, the pumping system is arranged so that two or more pumps are placed in series, then the maximum pressure developed by the system is greatly increased, since each of the pumps can develop pressure to its maximum practical limit. The first pump can deliver its fluid at its maximum practical pressure limit into the suction side of the second pump so that the second pump can deliver fluid at an increased pressure from that delivered by the first pump and yet the bearing loads on the second pump will not be extremely great because the maximum pressure differential across the second pump will be the same as the maximum pressure differential across the first pump. Such a system is limited by the volumetric displacement of the second pump.

However, this invention associates a pair of pumps together in a circulatory system in a manner that the advantage of large volume delivery at low pressure is obtained by placing the pumps in parallel flow arrangement and the advantage of high pressure delivery at a somewhat reduced volume is also obtained by placing the pumps in series, the system being constructed and arranged with suitable controls for producing the change-over automatically. This system therefore has the advantage of being able to traverse a pressure operated device rapidly until the work resistance met by the device increases to a predetermined maximum, after which the pumping system will automatically change over into a series pumping arrangement for delivering fluid to the pressure actuated device at a much higher pressure but at somewhat reduced volume. Such a system is particularly advantageous when used in combination with hydraulically actuated pressing rams wherein the initial part of the stroke of the ram can be carried forward by means of a large volume of fluid under relatively low pressure. When the ram meets work resistance caused by exertion of effort upon the work it is then desirable that the pressure be increased upon the ram to overcome the work resistance. At this time the system of this invention will automatically change over from a parallel flow delivery system to a series system for producing the increased pressure without increasing any added load upon the pump units.

In order to set forth the manner in which this invention is used the pumping system is disclosed in combination with a pressure actuated ram 10 which may be the ram of a hydraulic press, and will be so described. It is to be understood, however, that while the subsequent description will refer to a hydraulically actuated ram which is adapted to meet work resistance in forming various materials that the invention is also applicable to gas operated devices without changing the inherent operation of the system.

Referring now to Figure 1, the pumping system consists of a pair of variable delivery pumps 11 and 12. The suction sides of the pumps 11 and 12 are connected to a fluid storage tank 13 by means of conduits 14 and 15 respectively. The discharge side of the variable delivery pump 11 connects to the suction side of the variable delivery pump 12 by means of a conduit 16. The conduits 15 and 16 both supply the suction side of the variable delivery pump 12 at different times and under different conditions as will be hereinafter described.

A conduit 17 connects the discharge conduit 16 of the variable delivery pump 11 with a supply conduit 18 for a 4-way valve 19. The pump 12 is provided with a discharge conduit 20 which also connects with the supply conduit 18 for the 4-way valve 19.

A check valve 21 is located in the supply conduit 15 for the pump 12 and is adapted to close when pressure fluid is supplied to the conduit 15 in a manner hereinafter described. A similar check valve 22 is placed in the conduit 17 and is adapted to be closed when pressure in the conduit 20 rises above the pressure in the conduit 17 in a manner which will be hereinafter described. An admission valve 23 is provided in the conduit 16 between the connecting points of conduits 15 and 17 and is normally closed. The admission valve 23 is constructed and arranged in the manner of a conventional pressure operated valve which is actuated to open when pressure is applied upon the actuating element of the valve. Such pressure actuated valves which are opened by a predetermined pressure and closed when pressure is released therefrom are well-known in the art and any one of such valves would suffice as the admission valve 23. The pressure actuating element 24 of the admission valve 23 is connected by means of a conduit 25 with the conduit 20 so that the valve 23 is opened in response to the pressure existing in the conduit 20.

Fluid directed to the 4-way valve 19 is supplied to the ram 10 through conduits 26 and 27 to opposite ends of a cylinder 28. A piston 29 operates within the cylinder 28 and carries a suitable plunger 30 for moving suitable apparatus for performing work upon various types of material.

The pumps 11 and 12 are of the variable delivery type as heretofore mentioned. These pumps may be of any conventional construction, such as a vane pump, a radial pump, a roller type pump or any other of the various types of pumps adapted for variable delivery of fluid.

The pump 11 is provided with a conventional shift ring 32 for shifting the pumping elements

thereof toward or away from neutral to vary the displacement of the pump and thus change its delivery. A similar shift ring 33 is provided for the variable delivery pump 12.

The shift ring 32 of the pump 11 has a plunger 34 extending therefrom which engages a spring 35 retained in a casing 36 for urging the shift ring toward full stroke position whereby the volumetric displacement of the pumping elements of the pump 11 are positioned at their maximum displacement. The opposite side of the shift ring 32 is connected to a piston 37 which reciprocates in a cylinder 38. The cylinder 38 is supplied with pressure fluid through a conduit 39 connected to the discharge conduit 17 of the pump 11. Pressure in the cylinder 38 urges the shift ring 32 toward neutral position when the pressure in the discharge conduit 17 rises sufficiently high to equal and overcome the resistance of the spring 31. The pressure developed by the pump 11 is thus controlled by its discharge pressure to reduce the delivery of the pump when the pressure reaches a predetermined maximum. This discharge pressure can be changed by varying the compression of the spring 35 through means of the adjusting nut 40 which is in engagement with the spring 35.

The variable delivery pump 12 is provided with a similar control system consisting of the plunger 41 and the spring 42 disposed within the casing 43 for urging the shift ring 33 toward full stroke position. A piston 44 working in a cylinder 45 opposes the spring 42 to shift the pump 12 toward neutral when the pressure in the discharge line 20 reaches a predetermined maximum and is transmitted to the cylinder 45 by means of the conduit 46. The discharge pressure of the pump 12 can be changed by varying the compression of the spring 42 by means of the adjusting nut 47.

The spring 42 of the pump 12 is considerably stronger than the spring 45 of the pump 11 so that the pump 12 will not be shifted to neutral at the same time shifting would occur in the pump 11. Assuming that it is desired to produce a fluid pressure of 2000 P. S. I. and that the pumps 11 and 12 are designed to operate under a maximum pressure differential condition of 1000 P. S. I. then it can be seen that the spring 42 will need to be twice the strength of the spring 35.

With the assumption that the pumps 11 and 12 are designed to work against a pressure differential across the pump of 1000 P. S. I. it becomes apparent that when the pumps are arranged in parallel flow arrangement that the maximum pressure delivered to the ram 10 will be 1000 P. S. I. However, when the discharge pressure of the pump 11 is applied upon the suction side of the pump 12 it then becomes apparent that if the suction pressure for pump 12 is 1000 P. S. I. that the discharge pressure of the pump 12 can be 2000 P. S. I. without any increase in the bearing load of the pump 12 over that developed when it was working in parallel with pump 11, since the pressure drop across the pump is 1000 P. S. I. Since the pressure drop across the pump determines the bearing load and not the total effective pressure developed by the pump it becomes apparent that when the two pumps are arranged in series that the maximum pressure developed in the system can be greatly increased. However, when the pumps are placed in series the volume delivered to the system by the pump 12 then falls to approximately half the delivery when the pumps were working in parallel.

Such an arrangement is advantageous for use upon hydraulic presses wherein a large volume of low pressure fluid is required for a fast traverse of the ram to close upon the work piece and produce the initial formation on the article being worked on and then as the work resistance builds up it is desirable to increase the pressure upon the ram and slow down its movement so that the work piece can be completely formed by the increased pressure upon the ram.

The system of this invention accomplishes the automatic change-over from large volume low pressure to small volume high pressure delivery automatically. As heretofore mentioned, the admission valve 23 is normally closed. Therefore, when the pumps begin to supply fluid through the 4-way valve 19 to the press ram 10 through the conduit 26 both pumps 11 and 12 will have their suction sides connected to the supply tank 13 through the conduits 14 and 15, respectively. The discharge from these pumps will be through conduits 17 and 20 respectively and the total volume displaced by both pumps 11 and 12 will be supplied to the supply conduit 26 and thus to the ram 10. A large volume of low pressure is therefore supplied to the ram for rapidly advancing the same. As the work resistance increases the pressure in the discharge conduits 17 and 20 of the pumps 11 and 12 respectively increases until the maximum pressure for which the pumps were designed has been reached, namely, our assumed figure of 1000 P. S. I. At this time the admission valve 23 will open because the pressure in the conduit 20 is supplied to the actuating element 24 of the admission valve 23 through the conduit 25, and the admission valve has been designed or adjusted so that it will open when the pressure in the conduit 20 reaches 1000 P. S. I.

When the admission valve 23 opens fluid under pressure of 1000 P. S. I. is supplied from the pump 11 to the suction side of pump 12, thereby closing check valve 21. Since the work resistance continues to build up against the ram 10 the pressure in conduit 20 increases above the 1000 P. S. I. existing in conduit 17 and thereby closes check valve 22. The pump 12 now receiving its suction fluid at 1000 P. S. I. can increase the pressure of that fluid to 2000 P. S. I. and discharge the same through conduit 20 to the ram 10. The load carried by the pump 12 in increasing the pressure from 1000 P. S. I. to 2000 P. S. I. is 1000 P. S. I. Therefore, the two pumps in series can produce a higher pressure than either of the pumps singly. The automatic change-over from parallel flow arrangement of the pumps 11 and 12 to the series flow arrangement is accomplished solely by the opening of the admission valve 23.

It has previously been mentioned that the spring 42 is twice the strength of the spring 35. This is provided so that the pump 12 will not shift to neutral before the pressure in conduit 20 reaches the maximum pressure capable of being developed in this system.

The pump 11 is designed with a slightly greater displacement than the pump 12 to insure a positive pressure in the suction side of the pump 12 when the pumps are in series arrangement. Since the spring 35 controls the pressure developed by the pump 11 the capacity of the pump 11 will be matched exactly to the capacity of the pump 12 because any pressure increase above 1000 P. S. I. will tend to shift the pump 11 toward neutral, whereby its delivery capacity will be

maintained in a balanced relationship with the intake capacity of the pump 12.

In Figure 2 there is shown a modified arrangement of the fluid pumping system of this invention that is somewhat similar to the system disclosed in Figure 1 so that the elements of Figure 2 that are identical with the elements of Figure 1, and serve the same purpose, will be referred to by the same numeral as indicated in Figure 1 but with the suffix "a."

In this modification the pump 11a is provided with a control spring 35a opposed by a control piston 37a for shifting the pump 11a between full stroke and neutral position. The pump 12a is provided with a control spring 42a and a control piston 44a for shifting the pump 12a between full stroke and neutral position. The conduit 25a for the admission valve 23a is provided with a manually operated shut off valve 48 to prevent transmission of pressure from the conduit 20a to the pressure actuating element 24a for the admission valve 23a. When the valve 48 is closed the pumps 11a and 12a will operate continuously on high volume low pressure delivery since the admission valve 23a cannot open to permit the pumps 11a and 12a to be interconnected in series arrangement.

One side of the control piston 44a for the pump 12a is connected to the discharge conduit 20a of the pump 12a by means of the conduit 46a whereby the control piston 44a urges the shift ring 33a to neutral position when the pressure in the conduit 20a reaches the compression resistance of the spring 42a.

To aid the spring 42a in its control function a conduit 50 connects the suction conduit 16a between the pumps 11a and 12a with the control cylinder 45a of the pump 12a, the conduit 50 entering the cylinder 45a on the opposite side of the control piston 44a from that assumed by the conduit 46a. Therefore, the pressure in the suction conduit 16a is transmitted to the lefthand end of the control piston 44a when the admission valve 23a is open so that the pressure in the suction conduit 16a adds its effect to the control spring 42a.

When the admission valve 23a and the pumps 11a and 12a are operating, the discharge from the pumps will be in parallel in the manner heretofore disclosed with regard to Figure 1. As the work resistance met by the ram 10a increases the pressure in the discharge conduits 17a and 20a increases until the admission valve 23a opens in the manner heretofore described with regard to Figure 1. When the admission valve 23a opens the discharge pressure of the pump 11a is applied upon the suction side of the pump 12a and is transmitted through the conduit 50 to the lefthand end of the control piston 44a. The control springs 35a and 42a of the pumps 11a and 12a respectively are constructed with equal degrees of force in the modification shown in Figure 2 so that when the pumps are arranged in parallel arrangement they will both be shifted to neutral when the pressure in the discharge conduits of the pumps reaches the maximum pressure for which the pumps were designed.

However, when the discharge pressure from the pump 11a was applied to the lefthand end of the control piston 44a an added pressure was applied to the control piston which was equal to the pressure existing in the discharge conduit 16a between the pumps 11a and 12a. Therefore, the pump 12a will increase the pressure in the discharge conduit 20a until the pressure on the righthand end of the control piston 44a is greater than the pressure on the lefthand end of the control piston 44a by an amount equal to or greater than the effect of the spring 42a whereupon the shift ring 33a will be shifted to neutral. Regardless of what pressure is applied upon the suction side of the pump 12a by the pump 11a the pressure increase developed by the pump 12a will be equal to the setting of the spring 42a so that it can always maintain a predetermined pressure differential between the inlet and outlet thereof.

Aside from the functioning of the control element for the pump 12a the system disclosed in Figure 2 functions in the same manner as heretofore described with regard to Figure 1.

In Figure 3 there is shown another slightly modified arrangement of the fluid pressure system of this invention wherein constant delivery pumps are used for producing either a large volume low pressure delivery or a small volume high pressure delivery. In this modification the constant delivery pumps 51 and 52 receive fluid from the storage tank 53 by means of conduits 54 and 55 respectively. The discharge conduits 56 and 57 respectively from the pumps 51 and 52 deliver fluid to a supply conduit 58 which connects to a 4-way control valve 59 having supply conduits 60 and 61 which connect to a suitable pressure operated device. A conduit 62 connects the discharge conduit 56 of the pump 51 with the suction conduit 55 of the pump 52. The conduit 62 has an admission valve 63 therein responsive to the pressure in the discharge conduit 57 of the pump 52 through means of a conduit 64. A check valve 65 is disposed in the conduit 56 to prevent pressure fluid from flowing from conduit 57 into conduit 56. A similar check valve 66 is provided in the suction conduit 55 for the pump 52 to prevent flow of pressure fluid from the conduit 62 into the storage tank 53. A pressure relief valve 67 is placed in by-pass line 68 which connects the discharge conduit 56 for the pump 51 with the fluid storage tank 53 and is set to open when the pressure in the discharge conduit 56 is equal to the maximum pressure for which the pump 51 was designed to deliver.

A similar pressure relief valve 69 is placed in the by-pass line 70 for the pump 52 to discharge pressure fluid from the pump 52 to the storage tank 53 when discharge pressure of the pump 52 rises to the maximum for which the pump was designed to produce.

The system as shown in Figure 3 functions substantially like the system shown in Figure 1. The admission valve 63 is normally closed so that both constant delivery pumps 51 and 52 withdraw fluid from the tank 53 and discharge the same through their discharge lines 56 and 57 to the supply line 58 for the 4-way valve 59. When the pressure increases in the discharge conduits 56 and 57, due to the increased work resistance met by the pressure operated device, the pressure will open the admission valve 63 when a predetermined maximum pressure is reached in the discharge conduits 56 and 57.

When the admission valve 63 opens the check valves 65 and 66 close whereby the pressure fluid delivered by the pump 51 will be directed into the suction side of the pump 52, whereby the pump 52 can increase the pressure delivered in the same manner as heretofore described in Figure 1, referring to pump 12.

The pump 51 will be of slightly greater capacity than the pump 52 to insure positive pressure being retained upon the suction side of the pump

52. When the pressure in the discharge conduit 56 for the pump 51 tends to rise because of its greater delivery then the pressure relief valve 67 will open to by-pass this slight excess whereby the pressure in the conduit 56 is maintained relatively constant.

While the forms of the invention disclosed and described herein are preferred forms, yet it is to be understood that the arrangement of the apparatus can be modified without departing from the spirit of the invention and that such modification as fall within the scope of the appended claims are intended to be included herein.

Having thus fully described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. A fluid pressure system including a plurality of pumping elements, conduit means connecting the discharge side of said pumping elements for parallel discharge flow, conduit means connecting the discharge side of one of the pumping elements with the intake side of another of the pumping elements having fluid flow control means therein responsive to the discharge pressure of the pumping elements when in parallel flow arrangement to open the conduit means controlled thereby when the parallel flow discharge pressure reaches a predetermined maximum and place the pumping units in series flow arrangement, and individual control means for each of said pumping elements responsive solely to the discharge pressure developed by the element for regulating the maximum pressure developed thereby, the control element for the pumping unit receiving discharge pressure from the other pumping unit when in series flow arrangement having means responsive to the fluid pressure in the conduit interconnecting the pumping units in series flow arrangement for increasing the range of operation of the control element by an amount equal to the fluid pressure in said interconnecting conduit.

2. A fluid pressure system including a pair of variable delivery pumps, individual pressure actuated means for regulating the stroke of each of the pumps and thus controlling the maximum pressure developed by each of the variable delivery pumps to a predetermined amount from a zero pressure setting, conduit means interconnecting said pumps in series or parallel flow arrangement, and means actuated solely by the pressure in the fluid pressure system when the pumps are in parallel flow arrangement for shifting the pumps into series flow arrangement upon development of a determined maximum pressure in the fluid pressure system not greater than the maximum capable of being delivered by the pumps, one of said pumps delivering fluid under pressure into the other of said pumps when in series flow arrangement whereby said other pump can increase the maximum pressure developed in the fluid pressure system to a pressure substantially greater than the pressure at which it receives its inlet fluid, and means connecting said control means for said high pressure pump to the inlet pressure for said pump whereby to raise the pressure setting of said control means by an amount equal to the fluid pressure existing on the inlet side of said pump to maintain control of the pressure differential across said pump not greater than when said pump was operating in parallel with the pump now delivering fluid under pressure thereto.

3. A fluid pressure system including a plurality of pumping elements, conduit means connecting the discharge side of said pumping elements for parallel discharge flow, conduit means connecting the discharge side of one of the pumping elements with the intake side of another of the pumping elements having fluid flow control means therein responsive to the discharge pressure of the pumping elements when in parallel flow arrangement to open the conduit means controlled thereby when the parallel flow discharge pressure reaches a predetermined maximum and place the pumping units in series flow arrangement, and individual control means for each of said pumping elements operable at the same effective operating pressure and responsive solely to the discharge pressure developed by the element that it is to control for regulating the maximum pressure developed thereby, the control element for the pumping unit receiving discharge pressure from the other pumping unit when in series flow arrangement having means responsive to the fluid pressure in the conduit interconnecting the pumping units in series flow arrangement for increasing the range of operation of the control element by an amount equal to the fluid pressure in said interconnecting conduit, and means for rendering the said discharge pressure effective or ineffective on the said control unit to obtain selective operation of said pumping elements either in parallel or in series flow arrangement.

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