

April 17, 1956

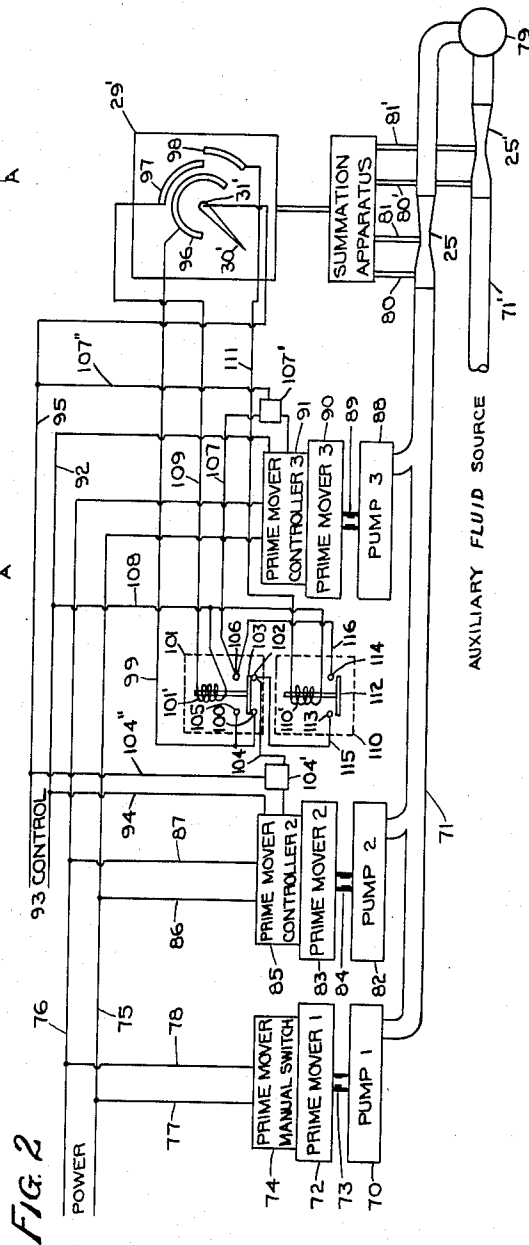
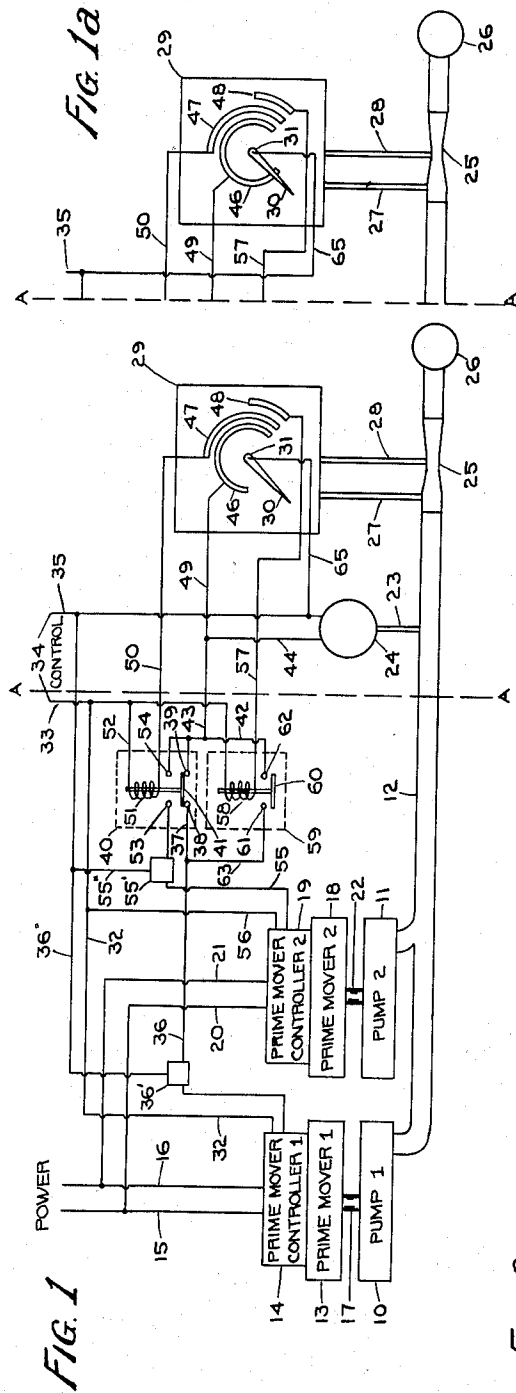
M. C. SMITH

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PUMPING SYSTEM

Filed June 18, 1949

2 Sheets-Sheet 1



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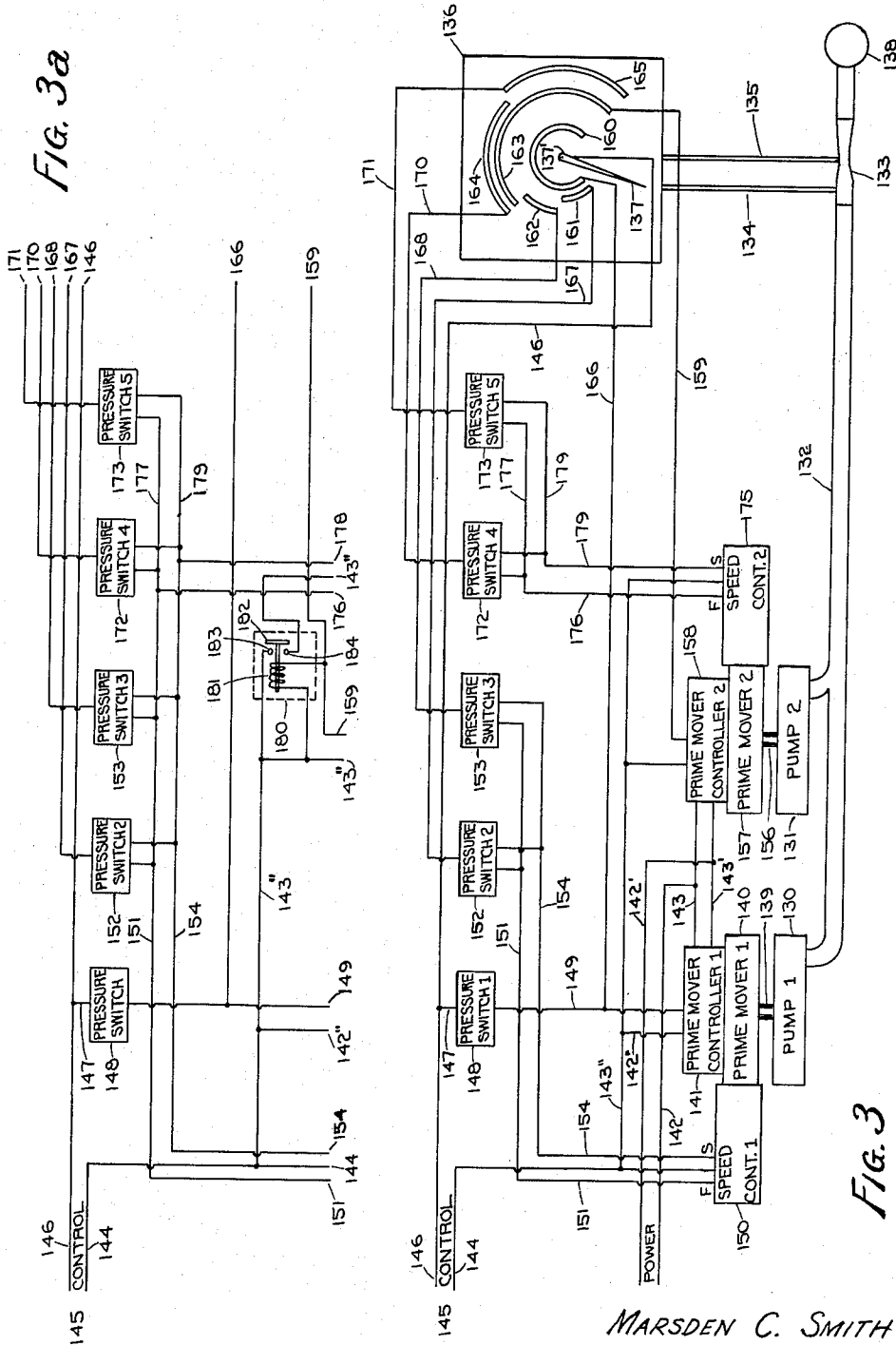
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PUMPING SYSTEM

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12 Claims. (Cl. 103—11)

This invention relates to pumping systems and, more particularly to a novel control system whereby pumping apparatus is operated to transmit a fluid medium under varying conditions.

The invention comprises provisions for bringing a pump into operation in response to withdrawal of fluid from a discharge system and for bringing one or more other pumps into operation in response to increased rates of withdrawal of fluid from said system; and/or stopping said pump or pumps in response to decreased rates of withdrawal of fluid from said system.

The invention also provides a pumping system wherein the bringing of pumps into operation may be placed under the sole control of flow conditions in the pump discharge system.

In a more specific aspect, one embodiment of the invention illustrated herein comprises a pump brought into action by a pressure switch in response to a drop in discharge system pressure below a predetermined amount; in combination with means responsive to flow of fluid to the discharge system for transferring to rate of flow all further control over the bringing into action, maintaining in action, and stopping, of one or more pumps or pump combinations.

In another embodiment herein illustrated, a specific feature of the invention comprises a pump operating continuously, independently of pressure in the discharge system, in combination with provisions for bringing into action and stopping one or more additional pumps under control of the rate of flow to said discharge system.

A further specific feature, illustrated in a further embodiment of the invention, comprises provisions for bringing into action and stopping one or more pumps in response to rate of flow and also for controlling the operation of one or more of said pumps in such a manner as to maintain a predetermined pressure in the discharge system as desired, as a function of the rate of flow of fluid in said discharge system.

Other features and advantages of the invention will be hereinafter described and claimed.

In the accompanying drawings:

Fig. 1 is a diagrammatic view showing one form of pumping system embodying the invention.

Fig. 1a is a diagrammatic view showing a modification of the embodiment illustrated in Fig. 1.

Fig. 2 is a diagrammatic view showing a further alternative embodiment of the invention.

Fig. 3 is a diagrammatic view illustrating still another embodiment.

Fig. 3a is a diagrammatic view showing a modification of the embodiment illustrated in Fig. 3.

Referring to the drawings, and more particularly to Fig. 1 thereof, there are shown pumps 10 and 11, adapted to receive fluid from any suitable supply source and to discharge said fluid through their outlets into a discharge conduit 12.

A prime mover 13, for convenience here assumed to be an electric motor, is provided with a controller or starter

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14, which is connected to a source of electrical supply by leads 15 and 16. A drive shaft 17 actuated by prime mover 13 actuates the pump 10, which may be of any suitable or conventional type such as a centrifugal pump.

Another prime mover, for convenience here assumed to be an electric motor 18, is provided with a controller or starter 19, which is connected through leads 20 and 21 to the above-mentioned source of electrical supply. A drive shaft 22 actuated by the prime mover 18 actuates the pump 11, which, like pump 10, may be of any suitable or conventional type such as a centrifugal pump.

The discharge conduit 12 communicates through pipe 23 with a pressure switch 24 of conventional type for responding to the pressure in said conduit 12. In addition, the conduit 12 contains a Venturi tube 25 or other known means for creating changes in conditions as a function of the rate of flow. Said conduit 12 discharges into a system 26, which, if desired, may lead to a conventional storage tank in accordance with customary practice or may have various distribution lines connected thereto for conducting fluid to desired points, or both.

Pipes 27 and 28 communicate with the upstream side and throat, respectively, of the Venturi tube 25, and with the interior of a flow meter 29 responsive in conventional manner to the differential pressure across the Venturi tube 25, and positioning a shaft 31 in correspondence with the rate of fluid flow through the conduit 12. A switch arm 30, which may be secured to the shaft 31, is thus positioned by meter 29 in accordance with the rate of flow of fluid through said conduit 12.

While the particular connections for controlling the pumps may assume a wide variety of forms, one system which may be employed is illustrated in Fig. 1 and may be arranged conveniently as follows:

A conductor 32 extends from one terminal of the controller 14 to a conductor 33 which leads to a source of electrical energy 34. Another conductor 36 extends from the other terminal of the controller 14 and is connected by conductor 37 to a contact 38 of a switch 40. This conductor may, if desired, include a time-delay relay 36' for a purpose later to be noted. A movable contact 41 of said switch normally connects the contact 38 with another contact 39, which, in turn, is electrically connected to a wire 42, and thence, through wires 43 and 44, to a terminal of the pressure switch 24. The opposite terminal of said switch 24 is connected by a wire 35 with the electrical energy source 34.

The switch arm 30, operable by the flow meter 29 in accordance with the rate of flow in the conduit 12, is adapted to engage a plurality of stationary (either fixed or adjustable) arcuate contacts 46, 47, and 48 of said flow meter. The contact 46 is connected by a wire 49 with the aforementioned wire 43. Contact 47 is connected by wire 50 with a coil 51 of the switch 40, which coil in turn is connected by wire 52 with the aforementioned wire 33. Said coil 51, when energized, disengages the movable switch contact 41 from contacts 38 and 39, and engages said movable contact 41 with another pair of contacts 53 and 54. The contact 53 is connected through a wire 55 with one terminal of controller 19, the other terminal of which controller is connected through wire 56 with wire 32 and thence with the supply wire 33. Contact 54 is connected to the aforementioned wire 42, and thus with wires 43 and 49. Wire 55 may, if desired, have included therein a time-delay relay 55' for a purpose later to be noted.

The arcuate contact 48 of the flow meter 29 is connected by wire 57 to a coil 58 of a switch 59, said coil 58 being in turn connected to the supply wire 33. The coil 58, when energized, actuates a movable contact 60 into engagement with stationary contacts 61 and 62 of said switch 59. Contact 61 is connected through wire

63 to the previously mentioned wire 36, while contact 62 is connected to the aforementioned wire 42.

The supply wire 35 from the source of electrical energy 34 is connected by wire 65 with the movable switch arm 30 of the flow meter 29.

When there is no flow in the discharge line conduit 12, or a rate of flow below a predetermined value, the switch arm 30 of the flow meter is out of engagement with all of the arcuate contacts 46, 47, and 48, as shown in Fig. 1.

In the operation of the system above described, and assuming the flow-meter switch arm 30 to be out of engagement with the aforementioned arcuate contacts, it may first be noted that, so long as the pressure in the discharge line 12 is above a predetermined value, both of the pumps 10 and 11 are out of action, since the pressure switch 24 is open. When, however, the pressure drops below said predetermined value, the pressure switch 24 responds and closes a circuit from supply wire 35, through wires 44 and 43, switch contacts 39 and 38, wires 37 and 36, controller 14, wire 32, and wire 33. The controller 14 is thereby energized, placing the prime mover 13 in service to operate the pump 10 and supply fluid to the discharge line 12.

The flow of fluid in said line 12 under the action of the pump 10 causes the flow meter to respond and its switch 30 to engage the arcuate contact 46. If desired, the pressure switch 24 may be of the well-known type embodying a conventional holding or "time-delay" means (such as a heater or a time clock) for maintaining said switch closed for a definite time, regardless of discharge pressure, in order to insure that the flow from said pump 10 will bring said flow meter switch arm 30 into engagement with contact 46.

Thereupon, the pump 10 controller supply is shunted around the pressure switch 24, and the pump operation continues exclusively under the control of the rate of flow in the line 12. Specifically, upon the engagement of switch arm 30 and contact 46 current flows from the energy source 34 through wire 35, wire 65, arm 30, contact 46, wires 49 and 43, contacts 39 and 38, wires 37 and 36, controller 14 and thence through wires 32 and 33 to the energy source 34. The pump 10 thus continues in operation independently of the condition of the pressure switch 24.

If, due to increased demand, the withdrawal of fluid from the main 26 increases, the rate of flow in the conduit 12 likewise increases, with consequent further clockwise movement of the arm 30 in Fig. 1. When said switch arm 30 engages the contact 47, the coil 51 of switch 40 is energized by way of wires 50 and 52. The movable contact 41 of said switch 40 is thereupon disengaged from contacts 38 and 39 and is engaged with contacts 53 and 54. As a result, the circuit through controller 14 is broken, and pump 10 is thrown out of action. Also, a circuit is established through controller 19 as follows: from source 34 through supply wire 35, wire 65, arm 30, contact 46, wires 49 and 43, contacts 54 and 53, wire 55, controller 19, wire 56, and wires 32 and 33, back to said energy source 34. It will be noted that the contact 46 continues to be engaged by arm 30 when the latter is in engagement with contact 47.

The pump 11, which is of greater capacity than pump 10, now comes into action and supplies fluid to the conduit 12 and main 26. Should the flow rate in the line or conduit 12 increase further, bringing the arm 30 into engagement with contact 48, the pump 11 remains in action (since the arm 30 remains in engagement with contacts 46 and 47) but the pump 10 is additionally brought into action so that both pumps discharge into the conduit 12. When the arm 30 engages contact 48 the coil 58 of switch 59 is energized by way of wire 57. Thereupon the movable contact 60 of switch 59 engages contacts 61 and 62. Current can then flow from source 34 through wires 35 and 65, arm 30, contact 46, wires 49, 43 and 42, contacts 62 and 61, wires 63 and 36,

controller 14, and thence through wires 32 and 33 back to the source 34.

Should the demand now be met so that the flow rate increases no further the arm 30 moves no further clockwise. It will, of course, be apparent that, if desired, additional pumps and flow meter contacts may be provided so as to throw one or more additional pumps into action in case of further flow rate increase in the line 12. If the flow rate should now decrease sufficiently for the arm 30 to move counter-clockwise out of engagement with contact 48, the coil 58 of switch 59 is de-energized, in consequence of which the circuit through the controller 14 is broken at the contacts 61 and 62, and the pump 10 is thrown out of action.

The pump 11 remains in action until, upon decrease in flow rate sufficient to disengage arm 30 from contact 47, the coil 51 of switch 40 is de-energized, breaking the circuit through controller 19 at contacts 53 and 54, and establishing a circuit through controller 14 at contacts 38 and 39. Pump 11 is thus now out of action and pump 10, of lesser capacity, is in action. Should the flow rate now decrease sufficiently to disengage arm 30 from contact 46, current cannot flow to the controller 14 by way of arm 30, but said controller will remain energized if at the time the pressure in the line 12 has dropped sufficiently low for the pressure switch 24 to be closed. If said pressure in line 12 is above the value for closing switch 24, at the time arm 30 disengages contact 46, no current can flow through controller 14 and the pump 10 is thrown out of action until the pressure in line 12 drops below the value at which the pressure switch 24 closes.

The time delay relay 36', which, as above noted, may be inserted in the wire 36, is of a well-known standard type, and has a terminal continuously connected by wire 36'' to the supply wire 35. Its purpose is to maintain the controller 14 energized for an appreciable period of time after engagement of flow-meter switch arm 30 with contact segment 47, so as to continue pump 10 in operation until pump 11 comes up to speed. Thus, when, in its clockwise movement pursuant to increased flow in conduit 12, the switch arm 30 comes into engagement with contact 47, the resultant breaking of the circuit through contacts 38 and 39 of switch 40 will not immediately terminate the operation of pump 10; but the latter will continue in operation, through a flow of current from supply wire 35, wire 36'', time-delay relay 36', controller 14, and wire 32 to supply wire 33. This operation continues for a period sufficient for pump 11 (which is thrown into operation upon engagement of contact arm 30 with contact 47) to come up to speed, whereupon the time-delay relay 36' breaks the circuit through the controller 14 and pump 10 is thrown out of action. Said relay 36' does not delay the bringing of the pump 10 into operation through the engagement of contacts 38 and 39 by contact 41, or the engagement of contacts 61 and 62 by contact 60. Relays of this type, which do not delay establishment of a circuit upon engagement of control contacts, but which delay disestablishment of the circuit upon opening of said contacts, are well-known in the art and need not be specifically described.

The time-delay relay 55', which, is previously noted, may be included in the wire 55, is of the same type as relay 36', and has a terminal connected through wires 55'' and 36'' to supply wire 35. Its purpose is to maintain the controller 19 energized for an appreciable period of time after disengagement of flow-meter switch arm 30 from contact segment 47, so as to continue pump 11 in operation until pump 10 comes up to speed. Thus, when, in its counter-clockwise movement pursuant to decreased flow in conduit 12, the switch arm 30 leaves contact 47, the resultant breaking of the circuit through contacts 53 and 54 of switch 40 will not immediately terminate the operation of pump 11; but the latter will continue in operation, through a flow of current from supply wire 35, wire 36'', wire 55'', time-delay relay 55', controller 19,

and wire 56 to supply wire 33. This operation continues for a time sufficient for pump 10 (which was thrown into operation upon disengagement of arm 30 from contact 47) to come up to speed, whereupon the time-delay relay 55' breaks the circuit through the controller 19 and throws pump 11 out of action. Said relay 55' does not delay the bringing of pump 11 into operation upon engagement of contact 41 of switch 40 with contacts 53 and 54.

In Fig. 1a I have shown a modification of the arrangement illustrated in Fig. 1. Fig. 1a is the same as Fig. 1 insofar as the parts to the left of line A—A in Fig. 1 are concerned, but differs with respect to certain parts at the right of said line A—A. More particularly, in Fig. 1a the pressure switch 24 of Fig. 1 is omitted, and the contact segment 46 is extended so as to be engaged by the flow-meter switch arm 30 even at zero flow rate. Thus, the pump 10 is in operation irrespective of the pressure in the line. This is advantageous where no storage reservoir is available.

Otherwise, the operation of the arrangement shown in Fig. 1a is the same as above described with respect to Fig. 1. When the flow rate increases sufficiently to bring arm 30 into engagement with contact segment 47, the coil 51 of switch 40 is energized, bringing pump 11 into operation, and causing pump 10 to be thrown out of action after an interval determined by relay 36'. When arm 30, in response to further increase in flow rate, engages contact segment 48, pump 10 is thrown into operation (through energization of coil 58 of switch 59) while pump 11 remains in operation. Upon decrease in flow rate, arm 30 moves counter-clockwise, and when said arm moves out of engagement with segment 48, the pump 10 is again thrown out of action (by deenergization of coil 58). Continued counterclockwise movement of arm 30, sufficient to disengage said arm from segment 47, deenergizes coil 51 of switch 40 so that pump 10 is again in operation, and pump 11 is caused to be thrown out of operation after an interval determined by relay 55'. Pump 10 then remains in operation, regardless of pressure in the conduit 12, until the flow rate again increases sufficiently to cause said pump to be thrown out of action pursuant to engagement of the flow-meter arm 30 with segment 47.

In the embodiment illustrated in Fig. 2, no pressure switch is employed. A pump 70 is continuously operated to maintain a predetermined minimum pressure in the discharge line 71. For that purpose the prime mover or motor 72 which operates said pump 70, through shaft 73, is controlled by a manually operated switch 74, which, when closed, establishes operation of said motor 72 from supply lines 75, 76 and connecting wires 77, 78. Thus, so long as said manual switch is closed, the pump 70 continues to supply fluid to the conduit 71 and system 79. This is of particular utility where no storage reservoir is available and pressure is to be maintained in the system regardless of demand.

The discharge conduit 71, like conduit 12, has a Venturi section 25 or other flow-responsive means as previously noted. Pipes 80 and 81 are connected to the upstream and throat portions, respectively, of said Venturi section and, if desired, may communicate directly with the interior of a flow meter 29', which may be the same as flow meter 29, in its response to the rate of flow of fluid in conduit 71. Switch arm 30', which may be secured to shaft 31' of flow meter 29', may thus be positioned in correspondence with the rate of flow in said conduit 71.

In the embodiment illustrated in Fig. 2, however, the pipes 80 and 81 are shown communicating with a summation apparatus of well-known conventional type for totalizing the rates of flow in different conduits and operating a flow meter in correspondence with the sum of said flow rates. In the example illustrated, said summation apparatus is also in communication with pipes 80', 75

81', connected respectively to the upstream and throat portions of a Venturi section 25' of another conduit 71' through which fluid is also supplied to the system 79. Thus, said summation apparatus totalizes the rates of flow in said conduits 71 and 71' and actuates the flow meter 29' correspondingly, in well known manner, so that the position of the switch arm 30' represents the sum of said flow rates.

A pump 82 is operated by a prime mover or motor 83, through a shaft 84. Said motor 83 is rendered effective to actuate said pump by a controller or starter 85, which may be connected to the supply line 75, 76, through wires 86 and 87. A third pump 88, is operated through shaft 89 by prime mover 90, rendered effective to actuate said pump through controller or starter 91, which may be connected to said supply line 75, 76.

A terminal of each of the controllers 85 and 91 is shown connected to a wire 92, which leads to a source of electrical energy 93. As shown, controller 85 is connected to wire 92 through a wire 94, while controller 91 is directly connected to said wire 92. Another wire, 95, from said source 93, is connected to switch arm 30' of the flow meter 29'.

While the connections for controlling the operation of the pumps 82 and 88 from the flow meter may be widely varied, one system of connections which may be employed is illustrated in Fig. 2 and may be conveniently arranged as follows:

The switch arm 30' of the flow meter is adapted to engage either fixed or adjustable arcuate contacts 96, 97 and 98 of said flow meter during clockwise movement of said arm in response to increasing flow rates. The contact 96 is connected by a wire 99 to a contact 100 of a switch 101. The contact 100 is one of a pair of contacts 100, 102, which normally are engaged by movable contact 103 of said switch. Contact 102 is connected by wire 104 with another terminal of the controller 85. If desired, a time-delay relay 104' may be included in said wire 104. A coil 101' of said switch 101, when energized, disengages the movable contact 103 from contacts 100, 102, and engages said movable contact with another pair of contacts 105, 106. Contact 105 is connected to the aforementioned wire 99, while contact 106 is connected through wire 107 with one of the terminals of controller 91. A time-delay relay 107' may be included in said wire 107.

One terminal of the coil 101' is connected through wire 108 with supply wire 92, while the other terminal of said coil is connected through wire 109 with arcuate contact 97 of the flow meter 29'.

Said wire 108 is also connected to a terminal of a coil 110' of a switch 110, the other terminal of which coil is connected by wire 111 with arcuate contact 98 of the flow meter. Said coil 110', when energized, shifts a movable contact 112 into engagement with stationary contacts 113, 114 of said switch. The contact 113 is connected through wire 115 to contact 102, and thus to wire 104; while the contact 114 is connected through wire 116 to contact 106, and thus to wire 107.

In the system, shown in Fig. 2, as previously noted, the pump 70 is in operation continuously as long as the manual switch 74 is closed. The switch arm 30' of flow meter 29' is in the position shown as long as the sum of the rates of flow of fluid in the conduits 71 and 71' is below a certain value. Upon increased demand for fluid in the system, the sum of said flow rates increases and the arm 30' moves clockwise. When said arm engages the arcuate contact 96, current flows from energy source 93 through supply wire 95, arm 30', contact 96, wire 99, contacts 100, 103 and 102, wire 104, controller 85 and wires 94 and 92, back to said source 93. Controller 85 is thereby energized and motor 83 rendered effective to operate the pump 82. Thus said pump is brought into action and supplies fluid to the discharge conduit 71.

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Should the demand for fluid increase and the sum of the flow rates in conduits 71, 71' thereby increase further, so that the arm 30' engages contact 97, the coil 101' of switch 101 is energized by way of arm 30', contact 97, and wire 109. Thereby the movable contact 103 is disengaged from contacts 100 and 102 and is engaged with contacts 105 and 106. As a result of the disengagement of contact 103 from contacts 100 and 102, pump 82 is thrown out of action. However, current now flows from source 93 through supply wire 95, arm 30', contact 96 (which remains engaged by arm 30') wire 99, contacts 105 and 106, wire 107, controller 91, and thence through wire 92 back to the source 93. Controller 91 is thus now energized and renders motor 90 effective to operate pump 88. The latter, which is of greater capacity than pump 82, thus pumps fluid into the discharge conduit 71.

Should the sum of the rates of flow in conduits 71 and 71' increase further, until arm 30' engages contact 98, a circuit is closed through said arm 30', contact 98, wire 111, and coil 110' of switch 110. The movable contact 112 is thus engaged with contacts 113 and 114. At the same time the switch arm 30', in moving into engagement with contact 98, moved out of engagement with contact 97, thus de-energizing coil 101' of switch 101, with resultant engagement of movable contact 103 with contacts 100 and 102.

Through the contacts 100 and 102 the controller 85 is energized, while through the contacts 113 and 114 the controller 91 is energized. Thus both pumps 82 and 88 are now actuated to supply fluid to the discharge line 71.

Upon decrease of the sum of the rates of flow of fluid in conduits 71 and 71', sufficient to cause arm 30' to move counter-clockwise out of engagement with contact 98 and into engagement with contact 97, the coil 110' of switch 110 is deenergized, and movable contact 112 is disengaged from contacts 113 and 114. However, coil 101' is now energized, bringing movable contact 103 out of engagement with contacts 100 and 102 and into engagement with contacts 105 and 106, so that controller 91 remains energized and pump 88 remains in action. In consequence of the disengagement of contact 103 from contacts 100 and 102, controller 85 is deenergized and pump 82 is thrown out of action. Upon decrease in the sum of the flow rates in conduits 71 and 71' sufficient for arm 30' to become disengaged from contact 97, the coil 101' is deenergized, and movable contact 103 is disengaged from contacts 105 and 106 and is engaged with contacts 100 and 102. In consequence of the disengagement of contact 103 from contacts 105 and 106, the controller 91 is deenergized and pump 88 thrown out of action; but due to the engagement of said contact 103 with contacts 100 and 102, the controller 85 is energized and the lower capacity pump 82 is placed in operation. If the sum of the flow rates now decreases further so that arm 30' is disengaged from contact 96, the controller 85 is deenergized and pump 82 thrown out of action, so that the only pump remaining in operation is the pump 70.

It will, of course, be apparent that, if desired, the flow meter 29' may, like flow meter 29 in Fig. 1, respond only to the flow rate in one conduit; in which event the summation apparatus in Fig. 2 may be omitted and said flow meter 29' be connected directly to the pipes 80 and 81 to respond only to the rate of flow in the conduit 71.

The time delay relays 104' and 107' may be of the same type as the relays 36' and 55' previously referred to in connection with Fig. 1. Relay 104' has a terminal connected by a wire 104'' to the supply wire 95, while relay 107' also has a terminal connected to said supply wire by a wire 107''.

The purpose of relay 104' is to maintain controller 85 energized for an appreciable period of time after engagement of the flow meter switch 30' with contact 97 so as to continue pump 82 in operation until pump 88

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comes up to speed. Thus, when, in its clockwise movement the switch arm 30' comes into engagement with said contact 97, the resultant breaking of the circuit through contacts 100 and 102 of switch 101 will not immediately terminate the operation of pump 82; but the latter will continue in operation, through a flow of current from supply wire 95, wire 104'', time-delay relay 104', controller 85, and wire 94 to supply wire 92. This operation continues for a time sufficient for pump 88 (which is thrown into operation upon engagement of contact arm 30' with contact 97) to come up to speed, whereupon the time-delay relay 104' breaks the circuit through the controller 85 and pump 82 is thrown out of action. Said relay 104' does not delay the bringing of the pump 82 into operation through the engagement of contacts 100 and 102 by contact 103.

The time-delay relay 107' has for its purpose the maintaining of the controller 91 energized for an appreciable period after disengagement of flow-meter switch arm 30' from contact 97, in the counter-clockwise movement of said switch arm, so as to continue pump 88 in operation until pump 82 comes into operation. Thus, when, in its counter-clockwise movement, said arm 30' leaves contact 97, the resultant breaking of the circuit through contacts 105 and 106 will not immediately terminate the operation of pump 88; but the latter will continue in operation, through a flow of current from supply wire 95, wire 107'', time-delay relay 107', controller 91, and back to supply wire 92. This operation continues for a time sufficient for pump 82 (which was thrown into operation upon said disengagement of arm 30' from contact 97) to come up to speed, whereupon the time-delay relay 107' breaks the circuit through controller 91 and throws pump 88 out of action. Said relay 107' does not delay the bringing of pump 88 into action through the engagement of contact 103 with contacts 105 and 106, or the engagement of contact 112 with contacts 113 and 114.

It will be understood that, if desired, the conduit 71' may be supplied with fluid from one or more pumps under the control of the flow meter 29'. For instance, the pumps 70 and 82 might discharge into conduit 71' instead of into conduit 71; and the conduit 71 might be arranged to receive fluid from the pump 88 only.

In the embodiment shown in Fig. 3, conventional pumps 130 and 131 deliver fluid to a discharge conduit 132, having a Venturi section 133 or other flow-responsive means as previously noted. Pipes 134 and 135 are connected to the upstream and throat portions respectively of Venturi section 133 and also to the interior of a flow-meter 136, which may be the same as flow meters 29 in its response to the rate of flow of fluid in conduit 132.

The switch arm 137, which may be secured to shaft 137' of said flow-meter moves clockwise in response to increased rate of flow and assumes a position corresponding to the rate of flow and assumes a position corresponding to the rate of flow in the discharge conduit 132. The latter communicates with a system 138, which, in turn, may be connected to distribution lines, or, if desired, to a storage tank in accordance with customary practice, or both.

The pump 130, which may be of the centrifugal or any other desired type, is driven through shaft 139 by a prime mover 140, which may be an electric motor. The latter is thrown into and out of operation by a conventional controller or starter 141 adapted to establish and disestablish connection between the pump motor 140 and a suitable power source, such as a source of electrical power supply, connected to said controller by wires 142, 142' and 143, 143'. The control of said starter or controller 141 may be effected from another energy source, such as source 145 of electric energy; for which purpose a terminal of said controller is connected through wires 142'', 143'', and 144 to one side of said source, and another terminal of said controller is connected through wire 149,

pressure-switch 148, wire 147, and wire 146 to the opposite side of said source 145.

The embodiment illustrated in Fig. 3 includes provisions for controlling the operation of the pumps in such manner (as, for example, by varying their speed) as to maintain a predetermined pressure in the discharge system, as a function of the rate of flow of fluid in said discharge system. For that purpose, the speed of the prime mover 140 may be varied by a speed-controller 150 of conventional construction. The latter, as shown, has three terminals. One of said terminals is connected through a wire 151 to conventional pressure switches 152 and 153. These switches, like the switch 148, are connected to the discharge conduit 132 for response to the pressure therein, but the pipe connections between said switches and said conduit are omitted to avoid unnecessary complication in the drawing.

Another terminal of said speed controller 150 is connected to said switches 152 and 153 by a wire 154. The third, or common terminal, of the said speed controller is connected to the aforementioned wire 144.

The pump 131, of centrifugal or other desired type, is operated through shaft 156 by a prime mover, such as a wound-rotor, electric motor 157. The latter is thrown into and out of operation by a conventional controller or starter 158, adapted to establish and disestablish connection between the pump motor 157 and an electrical power source connected to said controller through wires 142, 142', and 143, 143'. The control of said starter or controller 158 may be effected from the electrical energy source 145, through connections presently to be described. A wire 159 connects a terminal of controller 158 to one of a set of either fixed or adjustable arcuate contacts engageable by the switch arm 137 of the flow-meter 136, while another terminal of said controller is connected through wires 143'' and 144 to said source 145.

The connections for controlling the pumps and associated parts in accordance with the rate of flow of fluid in the discharge system may take any of a variety of forms. One convenient system of connections which may be employed for the purpose is illustrated in Fig. 3 and may conveniently be arranged as follows:

The arcuate contacts of the flow-meter are designated 160, 161, 162, 163, 164, and 165, respectively. Contact 160 is connected by a wire 166 to the aforementioned wire 149. Contact 161 is connected through a wire 167 to the pressure switch 152, while contact 162 is connected through wire 168 to the pressure switch 153. Contact 163 is connected to the previously mentioned wire 159 which runs to controller 158.

The flow-meter contacts 164 and 165 are connected respectively, by wires 170 and 171 to pressure switches 172 and 173. These switches, like those numbered 148, 152, and 153, are connected by suitable piping (not shown) to the conduit 132, so as to respond to the pressure therein.

The speed of the motor 157 may be varied by a speed controller 175 of conventional type. One of the three terminals of said controller is connected through a wire 176 with the pressure switch 172, and through wires 176 and 177 with pressure switch 173. Another terminal of said speed controller 175 is connected through wire 178 with pressure switch 172, and through wires 178 and 179 with pressure switch 173. The common or return terminal of controller 175 is connected through the previously mentioned wires 143'' and 144 to one side of the electrical energy source 145.

The switch arm 137 of the flow meter is connected to the previously mentioned wire 146. When there is no flow in the conduit 132, or a flow rate below a predetermined amount, the switch arm 137 is in the position shown in Fig. 3, out of engagement with all of the arcuate contacts 160-165.

When the switch arm 137 is in the position shown, and the pressure in the conduit 132 is above a predetermined

amount, both of the pumps 130 and 131 are out of action, since the pressure switch 148 is open and no current can flow to either of the pump-operating motors 140, 157. When, however, the pressure in the conduit 132 drops below said predetermined amount, the pressure switch 148 responds and closes a circuit from one side of the source 145, through supply wire 146, wire 147, pressure switch 148, wire 149, controller or starter 141, wires 142'' and 143'', and wire 144 to the other side of said source 145. The starter 141 is thereby energized, placing the motor 140 in service to operate the pump 130 and supply fluid to the discharge system.

The flow of fluid in the line 132 under the action of the pump 130 causes the flow meter 136 to respond and its switch arm 137 to engage the arcuate contacts 160 and 161. Engagement of said arm 137 with contact 160 shunts the pump 130 controller supply around the pressure switch 148, so that the pump operation continues even though the pressure in the conduit 132 rises sufficiently for said switch 148 to open. Specifically, upon engagement of flow-meter switch arm 137 with contact 160, current flows from energy source 145 through supply wire 146, arm 137, contact 160, wire 166, wire 149, controller or starter 141, and wires 142'', 143'', and 144 back to said source 145. The pump 130 thus continues in operation independently of the condition of the pressure switch 148.

The pressure switch 148, like the previously described pressure switch 24, may, if desired, be of the well-known type embodying a conventional holding or "time-delay" means for maintaining said switch closed for a definite time regardless of discharge pressure, in order to insure that the flow from the pump 130 will bring the flow-meter switch arm 137 into engagement with contacts 160 and 161.

As previously observed, the flow-meter switch arm 137 engages the contact 161 concurrently with the contact 160. Upon engagement of said arm 137 and contact 161 connection is established between the supply wire 146 and the wire 167 which extends to the pressure switch 152. If the pressure in the conduit 132 is below a predetermined amount (as, for example, 80 pounds per square inch) the pressure switch 152 closes and thereby establishes a connection between wires 167 and 151. Current thus now flows from supply wire 146, arm 137, contact 161, wire 167, pressure switch 152, and wire 151 to one of the terminals of the speed controller 150, and thence from the return terminal of said speed controller to the return supply wire 144. The flow of current from wire 151 through the speed controller 150 to wire 144 operates the controller in conventional manner to increase the speed of the prime mover or motor 140. The pump 130 is thereby caused to run faster, thus increasing the pressure in the discharge conduit 132. If this pressure is raised above a predetermined amount (such as 84 pounds per square inch) the pressure switch 152 establishes a connection between wire 167 and wire 154 so that current now flows through the speed controller 150 from wire 154 to the common or return supply wire 144. Thereby the controller 150 is caused in conventional manner to reduce the speed of the prime mover or motor 140, thus causing the pump 130 to run slower and reduce the pressure in the discharge conduit 132.

If the flow rate in the discharge conduit increases sufficiently for the arm 137 to engage the contact 162, the controller 141 remains energized (since said arm 137 remains in engagement with contact 160). However, the pressure switch 152 is thrown out of action, since the arm 137 no longer engages contact 161. The engagement of arm 137 with contact 162 establishes a connection between the supply wire 146 and wire 168, thus bringing pressure switch 153 into action. If the pressure in the discharge conduit 132 is below an increased predetermined value (85 pounds per square inch, for example) the switch 153 establishes a connection between wires 168 and 151 so

that current flows from supply wire 146 through arm 137, contact 162, wire 168, wire 151, speed-controller 150, and return wire 144. As previously noted, the flow of current through said speed controller from wire 151 to wire 144 increases the speed of operation of the pump 130; and this speed increase is maintained so long as the pressure in the discharge conduit 132 is below a predetermined increased value (such as 89 pounds per square inch). If the pressure in said conduit rises above said value, the switch responds by connecting said wire 168 to wire 154, so that current flows through the speed controller 150 from wire 154 to wire 144, with consequent reduction of the pump operating speed. Through the pressure switch 153 the pressure in the discharge line is maintained at a higher value to overcome the higher pipe-friction at the increased flow rate, thereby maintaining the pressures at down-stream points within desired limits.

Assume now that the demand for fluid from the conduit 132 and main 138 increases still further, with consequent increase in flow rate sufficient for the arm 137 to engage the contacts 163 and 164. Through the engagement of arm 137 with contact 163, current flows from supply wire 146, arm 137, contact 163, and wire 159 to the controller 158 for the pump 131, and thence from said controller to wire 143" and the return wire 144. The controller or starter 158 now places the prime mover or motor 157 in service to actuate the pump 131, which may be of greater capacity than pump 130.

The engagement of the arm 137 with contact 164 connects supply wire 146 with wire 170 which runs to the pressure switch 172. The latter connects the wire 170 to wire 176 so long as the pressure in the discharge conduit 132 is below a still higher predetermined value (90 pounds per square inch, for example) so as to insure overcoming increased pipe-friction incident to the higher rate of flow. So long as said discharge pressure is below said increased amount, current flows from wire 176 through the speed controller 175 and thence through the return wires 143" and 144. Such flow of current through said controller 175 operates the latter to increase the speed of operation of the prime mover or motor 157, and thus of the pump 131. When a predetermined pressure value in the discharge line 132 is exceeded (94 pounds per square inch, for example), the pressure switch 172 connects said wire 170 to wire 178, so that current now flows through the speed controller 175 from wire 178 to wire 143", with resultant operation of said controller to reduce the speed of the motor 157 and pump 131.

Upon still further increase in rate of flow of fluid in the discharge conduit 132, the flow-meter switch arm 137 comes into engagement with contact 165. Pumps 130 and 131 remain in operation, since said arm 137 continues to engage the contacts 160 and 163. Since, however, arm 137 is no longer in engagement with the contact 164, the pressure switch 172 is no longer in action. At the same time, the engagement of arm 137 with contact 165 establishes connection between wires 146 and 171, and thus to pressure switch 173, which responds to a discharge pressure at a predetermined value still higher than any of the previously mentioned pressure switches.

So long as the pressure in the discharge conduit 132 is below a predetermined higher value (95 pounds per square inch, for example), the pressure switch maintains a connection between wire 171 and wire 177, so that current flows by wire 176 through the speed controller 175 to the return wires 143" and 144. The controller 175 thus causes the motor 157 and pump 131 to operate at increased speed. When a predetermined pressure value is exceeded (99 pounds per square inch, for example), the pressure switch 173 connects said wire 171 to wire 179, so that current flows by wire 178 through speed controller 175 and thence to the return wires 143" and 144. Thereby the controller 175 reduces the speed of the motor 157 and pump 131.

While, upon engagement of the flow-meter switch arm

137 with contacts 163 and 164, the pump 130 may be cut out if desired, I have shown the contact segment 160 as of sufficient extent to be engaged by said arm 137 throughout its engagement with the other contact segments, so that the pump 130 is continuously in operation from the time when arm 137 comes into engagement with segment 160 in the clockwise movement of said arm until said arm 137 is disengaged from said segment 160 in the counterclockwise movement of said arm. Thus, in this arrangement the pump 130 is in operation continuously as long as the flow rate in conduit 132 equals or exceeds that at which arm 137 is brought into engagement with contact segment 160. While neither of the pressure switches 152, 153 is in action when the switch arm 137 engages contacts 163 and 164, the pump 130 continues in operation at the speed corresponding to the setting of the controller 150 when arm 137 left engagement with segment 162. Of course, by shortening the length of the segment 160, the pump 130 could be thrown out of operation at any desired point in the clockwise movement of the switch arm 137.

Upon decrease in flow rate in the discharge conduit 132, the arm 137 moves counter-clockwise, disengaging the contact 165 and engaging the contact 164. Pressure switch 173 is thus thrown out of action and pressure switch 172 returned to operation. Upon sufficient further decrease in flow rate, the arm 137 moves out of engagement with contacts 163 and 164, and comes into engagement with contact 162. Pressure switch 172 is now thrown out of action, as is also pump 131. However, the smaller-capacity pump 130 remains in operation, due to the continued engagement of arm 130 with segment 160, and the pressure switch 153 which controls the speed of operation of said pump is restored to action by engagement of said arm with segment 162.

Still further decrease in flow rate causes said arm 137 to move out of engagement with contact 162 and to engage the contact 161, with the result that pump 130 is brought under control of the pressure switch 152 to maintain a reduced pressure in the discharge conduit. Upon sufficient further decrease in flow rate in said conduit, the arm 137 moves out of engagement with both contacts 160 and 161, so that pressure switch 152 is thrown out of operation, and current can no longer flow through the controller 141 by way of said arm 137. Pump 130 will thus be thrown out of action, unless the pressure in the discharge line 132 is below that at which the pressure switch 148 responds to establish current flow through said controller 141 by way of wires 147 and 149. Upon such response of the switch 148 to discharge line pressure the pump 130 will operate to maintain a minimum pressure in conduit 132, or to return the flow-meter switch arm 137 into engagement with contacts 160 and 161.

Preferably, the segments 161 and 162 are spaced from each other by a slight angular gap, so that the switch arm 130 will not engage both segments simultaneously. Likewise, the segments 162 and 164, also 164 and 165 are preferably separated by a slight angular gap for the same reason.

In Fig. 3a I have shown a modification of that portion of the Fig. 3 arrangement that involves the pressure switch control circuits. More specifically in Fig. 3a, the switch 172 maintains control of both pump 130 and 131 when the flow meter arm 137 is on the segment 164, while switch 173 maintains control of both of said pumps when said arm 137 is on segment 165. This is effected by connecting lines 151 and 154 of speed-controller 150 to the lines 177 and 179, respectively, as shown in Fig. 3a.

In order to prevent pressure switches 152 and 153 from attempting to control pump 131 when it is not running (i. e., when switch arm 137 is on segment 161 or 162), a relay 180 is shown in Fig. 3a, said relay having a coil 181 connected between the wire 159 and wire 143". A movable contact 182 of said relay 180 is adapted to be moved into and out of engagement with a pair of station-

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ary contacts 183 and 184 on separated parts of the portion of wire 143'' that leads to the speed controller 175. As long as the flow-meter switch arm 137 is out of engagement with segment 163, current cannot flow through wire 159 and the coil 181 of relay 180 is deenergized; under which condition the movable contact 182 of said relay is out of engagement with contacts 183 and 184. Thus, while pressure-switch 152 will control the action of the speed-controller 150 as long as switch arm 137 engages segment 161, and pressure-switch 153 will control the action of said speed-controller as long as said arm 137 engages segment 162, neither of said pressure-switches can control the pump 131, since contact 182 is out of engagement with contacts 183 and 184 under those conditions. When, however, switch arm 137 engages segment 163 and 164, pressure-switch 172 is thrown into action (through engagement of said arm with segment 164) and the coil 180 of relay 181 is energized (through engagement of said arm 137 with segment 163). Thereupon, the movable contact 182 of said relay engages the stationary contacts 183 and 184, so that the speed-controller 175 for pump 131 is connected to the wires 143'' and 144, and thus becomes subject to control by pressure-switches 172 and 173. As previously noted, said pressure-switches 172 and 173 are also connected for the control of the speed of the pump 130, since the wires 151 and 154 of the speed-controller 150 are connected to wires 177 and 179 and thus to said pressure-switches.

If desired, in Fig. 3 or Fig. 3a, there may be placed in the supply line 146, between the supply source 145 and the point of connection of wire 146 to wire 147, a conventional pressure switch, responsive to pressure in the suction or supply side of the pumps 130, 131, which switch is normally closed but opens when the suction pressure falls outside certain limits, as when no fluid supply, or insufficient fluid supply, is available for the pumps. A similar pressure switch responsive to supply line suction may be provided in either of the systems shown in Figs. 1 and 2.

It will be apparent that the number of pumps thrown into and out of action may be varied as desired from the number shown by way of example in each of Figs. 1, 1a, 2, 3, and 3a. Also, if desired, various combinations of fixed and variable speed pumps may be employed. For instance, in Fig. 3, the pump 130 might, if desired, be operated at fixed speed by simply omitting the variable-speed controller 150, while retaining the variable-speed operation of pump 131. It will also be apparent that, if desired, the flow-meter 29 in Fig. 1 or Fig. 1a, or the flow-meter 136 in Fig. 3, may respond to the sum of flow rates in different conduits as illustrated in connection with flow-meter 29' in Fig. 2. Numerous other variations will be apparent, within the scope of the appended claims.

The terms and expressions which I have employed are used as terms of description and not of limitation, and I have no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described or portions thereof, but recognize that various modifications are possible within the scope of the invention claimed.

I claim:

1. A pumping system comprising a plurality of pumps, a discharge line connected to the outlets of said pumps, means responsive solely to the rate of fluid flow through said line during operation of one of said pumps for bringing into action another of said pumps, means responsive to pressure in said discharge line, means controlled by said pressure responsive means for varying the speed of one of said pumps, and connections controlled by said flow responsive means for bringing said pressure responsive means into operation.

2. A pumping system comprising a plurality of pumps, a discharge line connected to the outlets of said pumps, means responsive to the rate of fluid flow through said discharge line, means responsive to pressure in said dis-

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charge line, means controlled by said pressure responsive means for varying the speed of operation of said pumps, connections controlled by said flow responsive means for bringing said pressure responsive means into action, and connections controlled by said flow responsive means for bringing one of said pumps into action in response to increase in flow rate to a predetermined amount during operation of another of said pumps.

3. A pumping system comprising a plurality of pumps, a discharge line connected to the outlets of said pumps, means responsive to the rate of fluid flow through said discharge line, means controlled by said flow responsive means for varying the speed of one of said pumps in accordance with the pressure in said discharge line, means controlled by said flow responsive means for bringing a second one of said pumps into action in response to increase in flow rate to a predetermined amount in said discharge line, and means controlled by said flow responsive means for varying the speed of said second pump in accordance with the pressure in said discharge line.

4. A pumping system comprising a plurality of pumps, a discharge line connected to the outlets of said pumps, means responsive to the rate of fluid flow through said discharge line, a pressure switch for controlling the speed of one of said pumps to maintain a predetermined pressure in said discharge line, means controlled by said flow responsive means for maintaining said pressure switch in action for a predetermined range of flow rates, a second pressure switch for controlling the speed of said pump to maintain a predetermined higher pressure in said discharge line, means controlled by said flow responsive means for cutting out the first pressure switch and bringing into action the second pressure switch in response to increase in flow rate to a predetermined amount, and means controlled by said flow responsive means for bringing a second pump into action in response to a further increase in flow rate.

5. A pumping system comprising a plurality of pumps, a discharge line connected to the outlets of said pumps, means responsive to the rate of fluid flow through said discharge line, a pressure switch for controlling the speed of one of said pumps to maintain a predetermined pressure in said discharge line, means controlled by said flow responsive means for maintaining said pressure switch in action for a predetermined range of flow rates, a second pressure switch for controlling the speed of said pump to maintain a predetermined higher pressure in said discharge line, means controlled by said flow responsive means for cutting out the first pressure switch and bringing into action the second pressure switch in response to an increase in flow rate to a predetermined amount, means controlled by said flow responsive means for bringing a second pump into action in response to a further increase in flow rate, a third pressure switch for controlling the speed of said second pump to maintain a predetermined pressure in said discharge line, and means controlled by said flow responsive means for bringing said third pressure switch into action.

6. A pumping system comprising a plurality of pumps, a discharge line connected to the outlets of said pumps, means responsive to the rate of fluid flow through said discharge line, means controlled by said flow responsive means for maintaining one of said pumps in operation for a predetermined range of flow rates, means controlled by said flow responsive means for maintaining another of said pumps in operation for a predetermined higher range of flow rates, and pressure responsive means controlled by said flow responsive means for varying the speeds of said pumps to maintain different pressures in said discharge line for different rates of flow therein.

7. A pumping system comprising a plurality of pumps, a discharge line connected to the outlets of said pumps, means responsive to the rate of fluid flow through said discharge line, electrical contact means controlled by said

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flow responsive means for maintaining one of said pumps in operation for a predetermined range of flow rates, electrical contact means controlled by said flow responsive means for maintaining another of said pumps in operation for a predetermined higher range of flow rates, pressure responsive means, means controlled thereby for varying the speeds of said pumps, and electrical contact means controlled by said flow responsive means for varying the speeds of said pumps to maintain different pressures in said discharge line for different rates of flow therein.

8. A pumping system comprising a plurality of pumps, a discharge line connected to the outlets of said pumps, means responsive to the rate of fluid flow through said discharge line, pressure responsive means for regulating the speeds of operation of said pumps to maintain predetermined pressures in said discharge line, electrical contact means controlled by said flow responsive means for maintaining the respective pumps in operation through predetermined flow rate ranges in said discharge means, and means controlled by said flow responsive means for rendering said pressure responsive means effective to regulate the speeds of said pumps.

9. A pumping system comprising a plurality of pumps, a discharge line connected to the outlets of said pumps, means responsive to pressure in said line for bringing one of said pumps into operation, means responsive to rate of flow in said discharge line in excess of a predetermined amount for bringing another pump into operation and stopping the first pump, means responsive to pressure in said line for varying the operation of one of said pumps to increase the pressure in said line when said pressure is below a predetermined amount, and means responsive to rate of flow in said discharge line in excess of a predetermined amount for bringing the last mentioned pressure responsive means into action.

10. A pumping system comprising a plurality of pumps, a discharge line connected to the outlets of said pumps, means responsive to pressure in said line for bringing one of said pumps into operation, means responsive to rate of flow in said discharge line in excess of a predetermined amount for bringing another pump into operation and stopping the first pump, means responsive to a further increase in said rate of flow for again bringing the first pump into operation, means responsive to pressure in said line for varying the operation of one of said pumps to

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increase the pressure in said line when said pressure is below a predetermined amount, and means responsive to rate of flow in said discharge line in excess of a predetermined amount for bringing the last mentioned pressure responsive means into action.

11. A pumping system comprising a plurality of pumps, a discharge line connected to the outlets of said pumps, means for bringing one of said pumps into action, means responsive to rate of fluid flow in said line for bringing another pump into action, normally ineffective means responsive to pressure in said discharge line for varying the operation of one of said pumps to increase the pressure in said line, and means controlled by said rate of fluid flow for bringing said pressure responsive means into action.

12. A pumping system comprising a plurality of pumps, a discharge line connected to the outlets of said pumps, means responsive to pressure in said discharge line for bringing one of said pumps into action, means responsive to rate of fluid flow in said line for bringing another pump into action, normally ineffective means responsive to pressure in said discharge line for varying the operation of one of said pumps to increase the pressure in said line, and means controlled by said flow rate for bringing the last-mentioned pressure responsive means into action.

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