

[54] CONTROL SYSTEM
 [75] Inventor: Forrest Thomson Randell, Glasgow, Scotland
 [73] Assignee: Weir Pumps Limited, Glasgow, Scotland
 [22] Filed: Aug. 30, 1972
 [21] Appl. No.: 284,876

3,424,370 6/1969 Law 418/27
 3,478,731 11/1969 Morton 417/13

FOREIGN PATENTS OR APPLICATIONS

385,096 12/1932 Great Britain 417/19

Primary Examiner—William L. Freeh
 Attorney, Agent, or Firm—Mason, Fenwick & Lawrence

[30] Foreign Application Priority Data
 Sept. 10, 1971 Great Britain 42256/71
 [52] U.S. Cl. 417/13, 417/22, 417/47
 [51] Int. Cl. F04b 49/00
 [58] Field of Search 417/2, 18, 19, 47, 49, 417/13, 22

[57] ABSTRACT

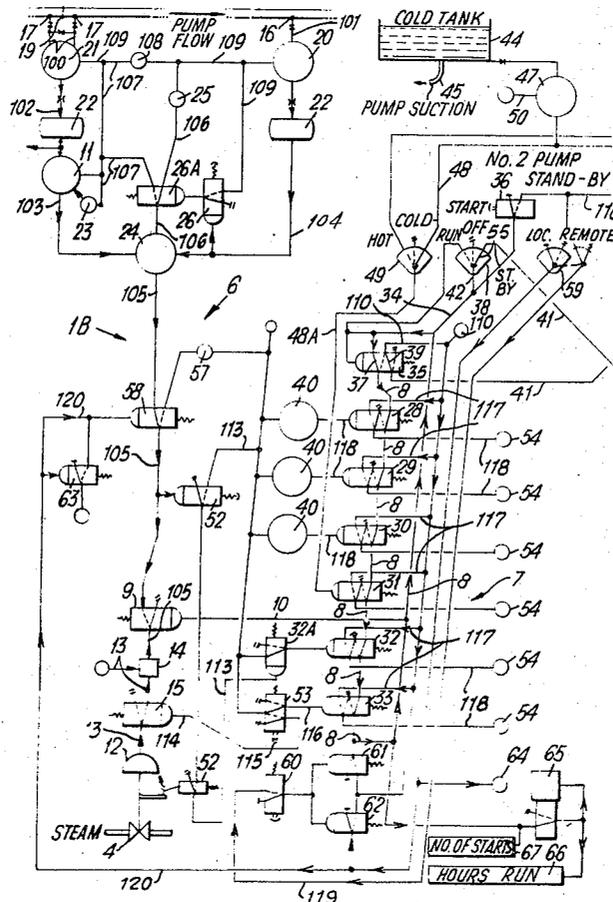
A control system for a pump installation comprising a primary feed back circuit including sensors measuring the fluid discharge pressure of the pump and possibly additionally the fluid flow in the pump discharge and regulating the speed of the pump drive to control said discharge pressure in dependence for example on the pressure requirements of boiler feed, and including additionally a secondary feed back circuit sensing further operating conditions in the pump installation e.g. water and oil pressures. The primary circuit delivers a speed control signal for actuation of control valve means of the pump drive which may be for example a steam turbine, and the secondary circuit is coupled to a gate of the primary circuit whereby in the event of any of the further conditions being unsatisfactory the control signal is interrupted and the pump stopped.

11 Claims, 4 Drawing Figures

[56] References Cited

UNITED STATES PATENTS

2,813,231	11/1957	Hyde.....	417/2
2,880,673	4/1959	Soderberg.....	417/47
2,938,536	5/1960	Ehrenberg.....	415/49
2,942,866	6/1960	Anderson.....	417/2
2,961,964	11/1960	William et al.	417/20
3,029,636	4/1962	Mullins.....	417/2
3,068,796	12/1962	Pflunger et al.	417/19
3,119,552	1/1964	Thomann.....	317/19
3,232,519	1/1966	Long.....	417/19



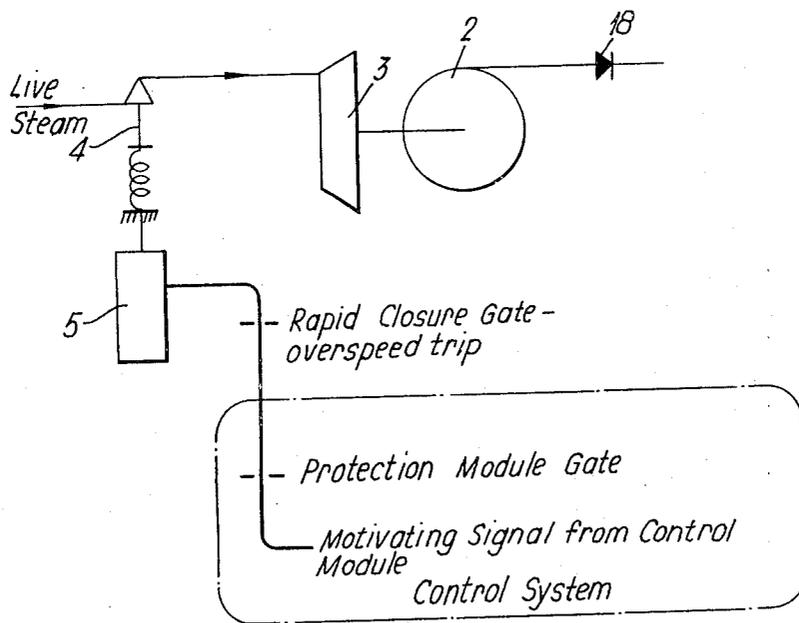
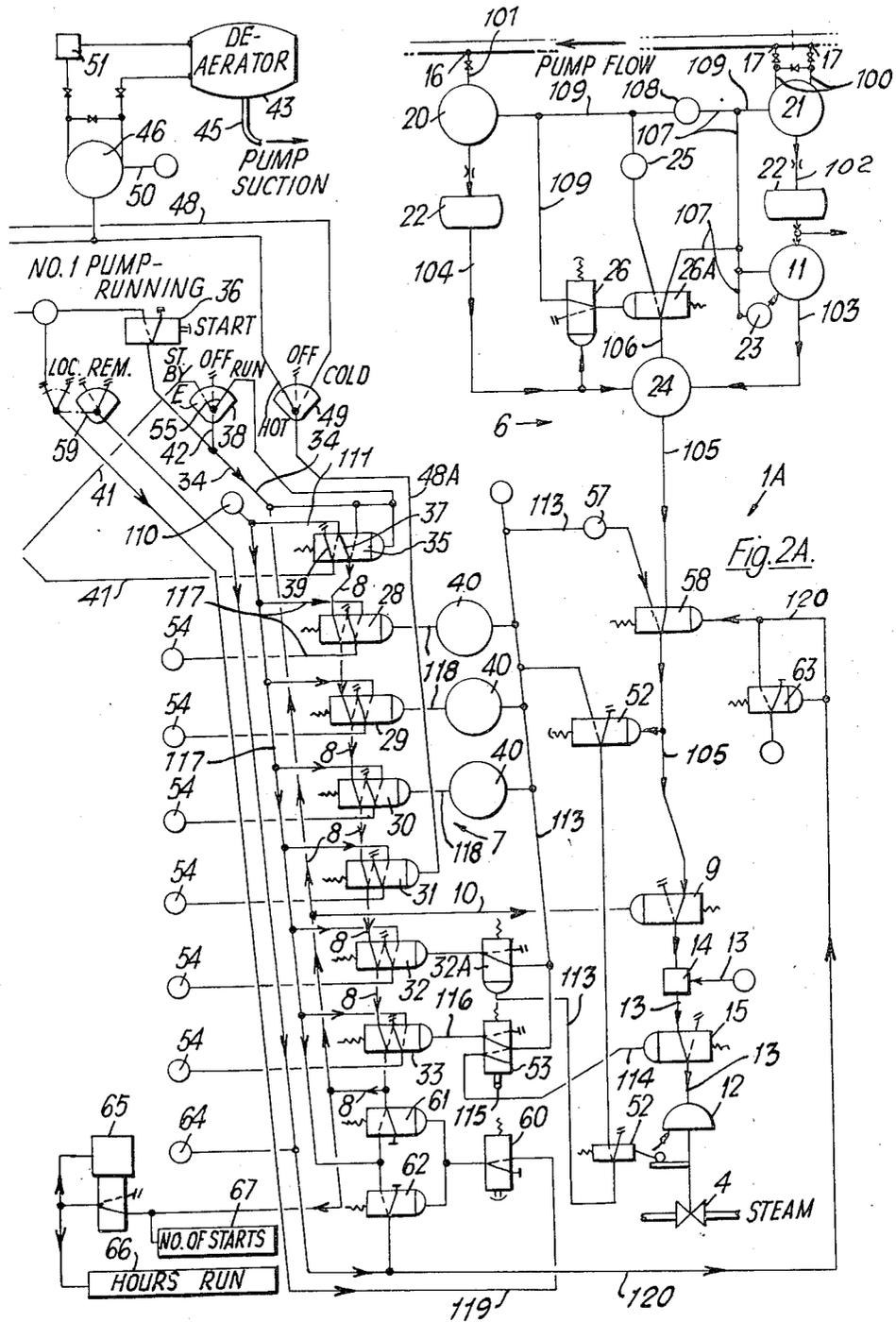
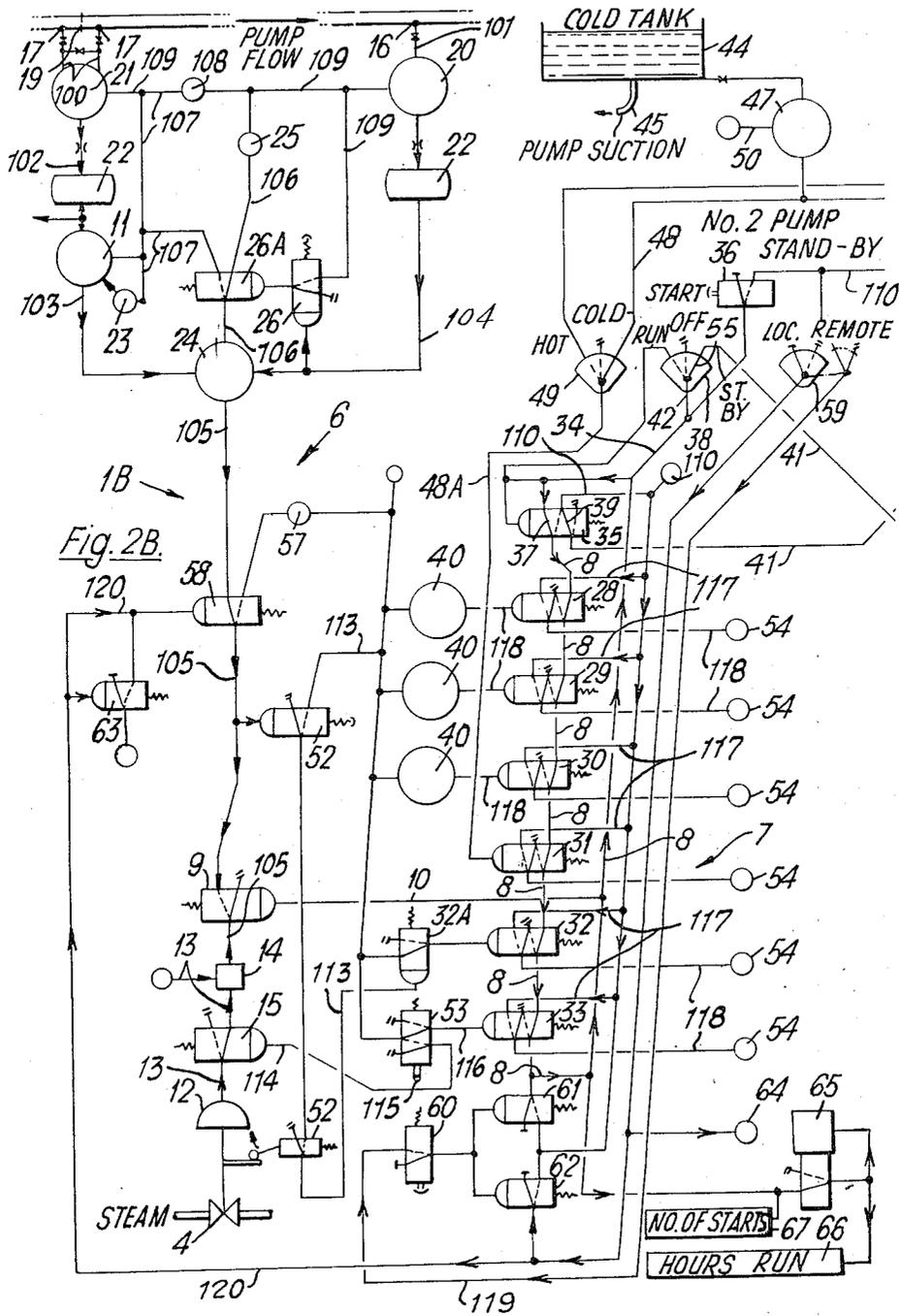
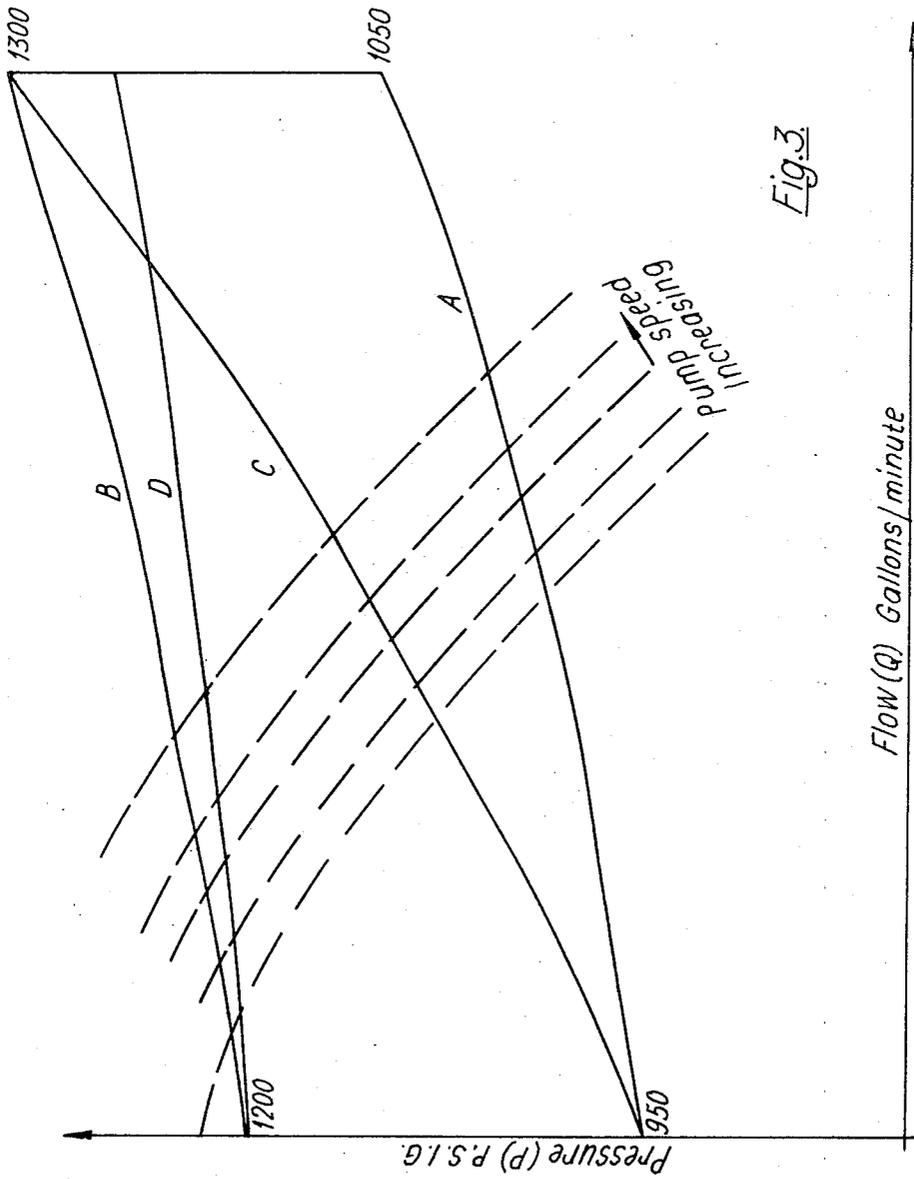


Fig. 1.







CONTROL SYSTEM

The present invention relates to a control arrangement for machine installation of the kind including a fluid handling machine having a fluid discharge and driven by a drive machine, such an installation being hereinafter referred to as a machine installation of the type aforesaid, and relates especially to a control arrangement for a turbine driven rotodynamic pump.

Machine installations are known wherein a rotodynamic pump is driven by a steam turbine, and more specifically wherein the pump serves to deliver feed liquid to a boiler. A steam boiler is usually designed to operate at a particular pressure e.g. 150 p.s.i., so that the pump will be required to supply feed at such a pressure that the feed will arrive at the boiler at the desired pressure, and this preferably requires allowing for the pressure drop resulting from the flow resistance of the pipeline network (including valves etc) between the pump and the boiler.

In previous arrangements of turbine speed control to give the required pump discharge pressure, the arrangement could simply be (a) pressure controlled; or could be (b) pressure and flow controlled. Each previous arrangement included a throttle valve in the steam supply line to the turbine which valve was controlled by signals from pressure and flow sensors at the pump discharge so that the pump discharge pressure could be controlled by variation in turbine speed. To stop the turbine in case of emergencies in the installation, a stop valve was additionally included in the steam supply line and this valve was usually manually operable. However, in the case of turbine overspeed, it is essential that the turbine be stopped very promptly (<1 or 2 seconds), and to this end a vent valve was provided to vent the supply steam in speed emergencies and so promptly stop the turbine. Further, it is customary in ship installations to have both duty and stand-by pumps, and to facilitate change over between the pumps, the steam supply of each pump drive included a pneumatic cut-in valve remotely operable through the other pump installation. To handle high pressure steam a valve requires to be of high quality and is consequently expensive, so that the need for four such valves as in the previous arrangement is very disadvantageous. Additionally it was a disadvantage that some of these valves were not completely fail safe, which is dangerous when dealing with high pressure steam. Further, it is now considered desirable that other operating conditions e.g. turbine lubricating oil pressure and temperature, be monitored and the turbine stopped if any conditions are unsatisfactory. This was done in the previous arrangements simply by observation and manual operation of the stop valve: the previous arrangements could not be suitably adapted for automatic control which is being increasingly demanded in ships and in land installations.

It is the main object of the present invention to reduce the number of high pressure steam valves used to a single stop/throttle valve, and it is a feature of the present application that this single valve can be conveniently arranged to close on failure of its associated control gear.

It is a further object of the present invention to provide a comprehensive protection system for the feed pump in respect of other operating conditions in the installation, particularly turbine speed, and particularly a protection system wherein the turbine is quickly

stopped the event of any of said other operating conditions being unsatisfactory.

According to the present invention there is provided in a machine installation comprising a rotodynamic pump, a steam prime mover having a drive shaft drivingly connected to the pump, a fluid inlet to the pump and a fluid discharge from the pump supplying pressurised fluid to a receiver, and a steam supply line to the prime mover; a control arrangement for the prime mover including a steam valve in said steam supply line controlling the steam flow to the prime mover; a controller including an actuator for regulating the opening of the steam valve; a power line supplying power to said actuator; a control relay in said power line settable to control the power supply to the actuator; primary control apparatus serving to ensure that fluid is supplied from the pump to the receiver at a required pressure, and including indicating means sensing any of the pressure and flow rate conditions of the fluid in said fluid discharge, the indicating means generating signals proportional to the sensed fluid conditions, and a comparator for comparing a sensed fluid condition value with a desired value and connected to said control relay by a primary conduit whereby a control signal based on the comparison is delivered from the comparator to the control relay for setting of the relay to control the speed of the prime mover and consequently the fluid pressure in said fluid discharge; and secondary control apparatus including switching devices operatively coupled to sensors sensing further operating conditions in the machine installation, an on-off switch in said primary conduit operatively connected to said switching devices whereby if any of said further operating conditions are unsatisfactory the on-off switch is actuated to interrupt the transmission of the control signal to the control relay and thereby cause closure of the steam valve and stoppage of the steam prime mover.

An embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 shows schematically a control arrangement for a pump, according to the present invention;

FIGS. 2A and 2B show the arrangement of FIG. 1 adapted as a discharge pressure flow control arrangement and protection system for the main and stand-by pumps in a boiler installation; and

FIG. 3 is a graph showing the feed characteristics (shown in full lines) of various boilers with the speed characteristics (shown in dashed lines) of a pump superimposed.

Referring to FIGS. 1 and 2A and 2B, a pump installation for delivery of feed water to a boiler (not shown) comprises main and stand-by units (1A, 1B) each including a centrifugal pump 2 (FIG. 1) driven by a steam-turbine 3. The steam flow to each steam turbine 3 is regulated by a pneumatically actuated throttle valve 4, and each unit 1A, 1B has a control system (FIG. 1) wherein a control module produces a signal proportional to the pressure head and volume throughflow demanded of the pump at a given instant, and this signal is passed via a control gate to the actuator 5 of the throttle valve 4 for speed control of the turbine. The gate is controlled by a protection or safety module whereby in the event of a monitored condition in the installation becoming unsatisfactory the gate is actuated to close the throttle 4. The control system includes a primary part 6 in the form of a pneumatic feed-back

control to regulate the throttle valve 4 whereby the pressure of feed discharged from the pump 2 can be regulated to maintain the desired pressure of feed delivered to the boiler, regardless of variation in the feed flow to the boiler. Further, each unit includes a secondary protection control system 7 for pump stoppage in the event of further operating conditions in the installation being unsatisfactory, the secondary control system 7 being comprised by a pneumatic circuit including a loop conduit generally indicated by reference 8 in operative connection with a control valve 9 of the primary control system 6 by conduit 10, for closure of the throttle valve 4. The setting of the throttle valve 4 is achieved through a pneumatically actuable diaphragm device 12 to which operating air is delivered from a suitable source (not shown) via line 13 and a pneumatic positioner control 14 in the feedback control 6. The throttle valve 4 is arranged to be spring loaded to close, steam loaded to close by arranging the steam flow to be down through the valve, and tripped to close by means of valve 9 on collapse of operating signal to the throttle valve actuator 12.

Referring to FIG. 3, for any given conditions of boiler feed flow, the required pressure (P_m) at pump discharge will be dependent on the set pressure (P_b) for the boiler feed and a pressure (P_q) representing the pressure drop resulting from a particular flow through the feed system between the pump and the boiler feed regulator, the pressure (P_q) being conveniently derived from the square law pressure across an orifice in the pressure discharge line of the pump 2. The characteristics for various boilers are shown in full lines in FIG. 3. Thus line A represents a medium boiler pressure/low system resistance; line B a high pressure/low system resistance; line C a medium pressure/high system resistance; and line D a high pressure/very low system resistance. The sum of P_b and P_q represent the pressure the pump should be generating at a particular flow Q. If P_m equals $P_b + P_q$ then the pump is running at the correct speed, but if P_m differs from the summation then the pump throttle valve 4 will require to be adjusted for variation in the pump speed to attain equilibrium conditions.

It is a feature of the feed-back control to achieve this running equilibrium, and the control includes sensing devices (16, 17) sensing (a) the direct static pressure (P_m) (by device 16) in the pump discharge passage prior to the usual non-return valve 18 in the passage and (b) the differential pressure (P_q) (device 17) across an orifice 19 in the pump discharge conduit. The pressure values P_m , P_q from the sensing devices 16, 17 respectively are passed via lines 100, 101 to pneumatic transducers 20, 21 producing pressure signals proportional to the values. The signal from the differential pressure transmitter 21 is fed via line 102 included volume tank 22 into an analogue computing relay which has the following action $P = P_b + (100/G)(A-K)P_q + P_q$

where P_b = base signal (from item 4)

A = DP signal output

K = reference spring (for example 3 psi)

G = gain setting.

Thus at this station the desired characteristic of the pump is set as follows:

the boiler pressure, i.e. shut valve pressure is set by setting signal (P_b) using regulator item 23 and the modulation of the flow signal to achieve $P_q =$

100/G) (A-K). By adding these the desired demand signal P_d is achieved. The summed signal ($P_b + P_q$) and the discharge pressure signal (P_m) are passed to a pneumatic controller 24 via lines 103, 104 respectively.

The controller 24 produces a control signal based on the difference between the summed signal ($P_b + P_q$) and the pressure discharge signal (P_m) for control of the pump 2 and is connected to positioner control 14 by line 105. The control signal sets the positioner control 14 for controlled air flow via line 13 to the throttle valve actuator 12 to regulate the speed of the turbine to attain equilibrium running conditions.

Under starting conditions when there is no pressure in the pump discharge, the controller 24 will saturate at its supply pressure. Since the saturation conditions are used i.e. 13-15 psi controller output as a cut-in signal, it is essential that this situation is obviated. To do this the air supply to the controller 24 is from a reduced pressure source, item 25, via line 106 until the pressure developed by the pump rises to some pre-determined level at which point the output from the pressure transmitter is sufficient to trigger the snap actor item 26 which switches gate 26A and supplies full pressure air to the controller 24 from source 108 via lines 107, the source 108 additionally supplying transducers 20, 21 by lines 109, and also items 23, 26. Since there now exists a significant pressure output from the pressure transmitter P_m the variation of this from P_d coming from the computing relay 11 saturation to the full supply pressure will not take place and the pump will run up smoothly to shut valve speed.

When the pump is shut down and the pressure output from the pressure transmitter drops, the snap actor 26 will change over and gate 26A will automatically re-set for the next start.

At the start-up of the pump, the pump discharge pressure will be much less than that required to meet boiler feed requirements, and the throttle valve actuator 12 will consequently be signalled through the feedback control 6 to fully open the throttle valve 4. The pump speed will rise and the difference between the set and measured pressure signals will be reduced, and the throttle valve 4 will close until the pump is running at the required operating speed, i.e. at shut valve speed to provide the required pressure for the boiler feed.

If more feed water to the boiler is required, the non-return discharge valve 18 in the feed water opens and an increased water flow passes through the orifice 19. Consequently the differential pressure signal (P_q) will increase and the summation signal ($P_b + P_q$) will increase thereby causing an imbalance in the system. The controller 24 will produce a control signal to open the throttle valve 4 and the pump speed will rise until the pressure signal derived from the pump discharge pressure action balances the feed water pressure requirements. Under shut-down or reduced demand conditions the feedback control 6 will act in the opposite sense.

The pump installation will be required to meet a wide range of boiler pressures, and this can be achieved by adjustment of the base signal (P_b) fed into the relay 11. This sets the shut valve head that the pump will generate when the feed-back control 6 is in balance and the pump speed stable. By increasing or decreasing the base signal, operation of the pump can be adjusted to meet any required boiler pressure. Additionally the re-

sistance of the feed system between the pump and the boiler feed regulator can vary from installation to installation and it is a feature of the control arrangement that a signal modulating function is provided in the computing relay 11 for meeting this variation in feed system resistance but other arrangements are possible for catering for systems of different flow resistance.

The secondary protection control system 7 senses if any of the following operating conditions are outwith desired limits namely:

- a. the turbine exhaust back pressure;
- b. pump water temperature;
- c. the pump oil temperature;
- d. the net positive suction head available at pump suction; and
- e. the operating load on the pump. Additionally (f) a turbine overspeed control is provided.

The secondary control system comprises a pneumatic circuit including a plurality of fluid switching devices 28-33 arranged in series in the circuit by means of the loop conduit 8 and associated with the above operating conditions (a) to (f) respectively, each device being constituted by a spring biased pneumatically operable multi-port relay slide-valve.

The pneumatic circuit 8 of the secondary control 7 is connected into the feed-back control of the primary system 6 whereby in the event of the circuit 7 being non-pressurised the delivery of control signals to the servo-positioner 14 is prevented to stop the pump. Thus, the circuit 8 is in operative communication by line 10 with the slide of the spring biased slide valve 9 controlling signals flowing to the positioner control 14 via line 105.

Control of circuit pressurising air flowing in conduit 34 from a suitable supply source 110 to the slide valves 28-33 is achieved by a similar multi-port valve 35 in the circuit 8. Actuation of the control valve is achieved by a manually operable starter valve 36 which is connected to valve 35 by line 34 and on actuation connects in inlet port 37 of the control valve 35 to the air supply source 110 via line 111, and the pressurising air can then flow through the various valves 28-33, provided they are in a "closed" position. When the circuit 8 is open, the control valve exhausts through a selection switch 38 which additionally serves to bring the pump into operation if in stand-by duty. Exhaust air from the final valve 33 of the series is recycled via line 112 to maintain the control valve 35 and selection switch 38 in the "closed" position.

In the sensing of the conditions (a) to (c) above for the turbine exhaust pressure, and water and pump oil temperatures, pneumatic trip switches 40 are provided, each in operative connection with the slide of a respective slide valves 28-30. Thus, one trip switch 40 senses the steam pressure in the exhaust branch of the turbine. To protect the pump 2 of the unit 1A from flashing under shut valve conditions, a leakage bypass flow from the glands of the pump 2 may be recycled to the pump suction inlet, and the recycled flow can be under-cooled before discharge into the suction as described in the Applicant's co-pending U.S. application Ser. No. 243,669 filed April 13, 1972. Further, the gland arrangement is preferably of the type described in Applicant's copending U.S. Application Ser. No. 282,051 filed Aug. 21, 1972. the pump water temperature control protects against failure of the bypass cooling, and the respective trip switch 40 includes sensing means

sensing the water temperature within the pump. Each turbine-pump unit preferably includes a sealed lubricating system module as described in the Applicant's co-pending U.S. Application Ser. No. 259,259 filed June 1972, and one of the trip switches 40 is in the form of a temperature sensor located in the lower oil compartment of the module and is operable when the oil temperature exceeds a predetermined value.

The control for the stand-by pump is shown in FIG. 2B and is exactly similar to the control shown in FIG. 2A, similar items having like references; and it will be understood that the roles of the running (main) and stand-by pumps can be interchanged. The stand-by pump unit can be selectively arranged to start-up automatically in the event of shut-down of the running pump unit. Thus, the selection switch 38 of control 1B has a positional internal duct 55 adjusted to receive an air flow from the control valve 35 of unit 1A via air-line 41 when valve 35 is moved to an "open" position on shut down of the pump so that port 39 communicates loop 8 with the line 41. Air is directed via line 42 of unit 1B to the port 37 of valve 35 whereby the pneumatic circuit 8 of unit 1B is pressurised and the pump of the unit is consequently started.

It is desirable the turbine-pump unit does not operate when the net positive head at pump suction falls below a predetermined value with the risk of cavitation at the pump impeller and overspeeding of the pump. The pump of each unit is supplied from a deaerator 43 (FIG. 2A) and/or a cold storage tank 44 (FIG. 2B) via line 45, and pressure sensing devices 46, 47 indicate the head available at each of the deaerator 43 and storage tank 44 respectively. Pressure signals corresponding with the head values are passed via lines 48 from the pressure devices 46, 47 to trip switches 49 of the main and stand-by units operatively connected to respective valves 31, the trip switches 49 of the main and stand-by units being connected in parallel by lines 48A. In the event of the water level in either of the storage tank 44 and deaerator 43 falling below the required value for the particular supply source chosen, the trip switch 49 will open its respective valve 31 to stop the pump. The pressure devices 46, 47 are supplied with air from a suitable source (not shown) via line 50, and the deaerator 43 includes a parallel condensing chamber 51.

Included in the primary feed-back control 6 are relay devices 52 sensing the magnitude of the control signal passing to the positioner control 14, and this relay 52 is operatively connected to a respective slide valve 32 of the other unit via line 113 and valve 32A whereby in the event of the signal exceeding a predetermined value, i.e. the pump requiring to operate at an excessive load with the pump failing to meet the required characteristic, the valve 32 is opened by the relays 52 to stop the pump. The control arrangement also provides for regulation for overspeed of the turbine, and the protection arrangement for overspeed control differs slightly from the above described protection systems for the other operating conditions.

When the throttle valve 4 is signalled to shut down, air will be released from the pneumatic actuator 12 of the valve through the positioner control 14 but due to resistance in the discharge through the positioner control 14 a considerable period can lapse, for example 5 to 10 seconds, before full closure of the throttle valve 4. This delay is unsatisfactory for overspeed control. To

overcome this disadvantage, the pneumatic actuator 12 is vented directly through a discharge valve 15 which is actuated through an overspeed sensing system. In the arrangement shown, the discharge valve 15 is connected by line 114 to by a spring biased roller operable multi-port relay slide-valve 53 the roller 115 of which when actuated by a speed trip governor, constituted for example by an unbalanced ring device on the pump drive shaft, opens the discharge valve 15 for rapid venting of the throttle actuator 12 and simultaneously opens via line 116 a respective safety valve 33 switching device in the circuit 7 of the other unit to vent the circuit. However, the discharge valve 15 could be connected directly to the speed governor or an air-reservoir could be provided as a back-up to protect against the collapse of the air supply system.

Additionally each of the slide valves 28-33 has an associated visual indicator 54; and when each of the valves 28-33 is moved to its "open" position, air is directed from pressure source 110 through line 117 and through the valve to the associated indicator 54 for operation of the indicator 54. The air supply lines include filter regulators.

To pressurize the pneumatic circuit, say 1A of one pump unit and so permit operation of the unit, the starter valve 36 of the unit is simply actuated; or alternatively, in the event of shut-down of the other unit with said one unit selected in automatic stand-by, a starting signal is automatically passed to the control valve 35 of the unit from the other unit via the selection switch 38 of the unit. When any one of the above stipulated operating conditions (a) to (f) falls outwith the desired limit, the appropriate slide valve 28-33 in the circuit 7 is "opened" and the circuit 7 is depressurised with the result that valve 9 opens to cut off the control signal to the positioner control 14 and the pump stops. In the event of turbine overspeed, the discharge valve 15 of the throttle valve actuator 12 is opened for rapid discharge (one-half second) of operating air from the actuator 12. In the event of the failure of the main motive power to the primary and secondary control system 6, 7, a short life back-up supply source can be manually selected to allow the feed water supply to the boiler to be maintained while the main supply is reestablished.

The controls have provision for remote/local selection. Since the control is particularly intended for an automated ship, the indicators 32-38, the start button 36, the function selection switch 38, the suction selection switch 49 and the remote/local selection switch 59 will be positioned in a remote control room.

Under remote control the pump is on automatic control while local control is through a manual pressure regulator item 57 (3-15 psi signal). This signal can be used to control the pump in the event of complete failure of the control loop.

The local control station consists of the start button 36 and the air regulator 57 and a pressure gauge (not shown). The control loop receives its air supply through the control selection switch item 59. When this switch is positioned in the local position air is fed to a start button 60 through line 119. The start button energizes relays 61 and 62. Relay 61 activates the protection loop 7 and relay 62 activates an isolation loop (line 120 including items 58 and 63), which isolate the auto control signal and pass the manual signal to the positioner control 14.

The pump can be run under local control for setting or other purposes. While this is being done, the action of the control loop can be observed and when manual tests have been completed the pump can be taken onto control by reversing the control selection switch 59 when the isolation loop (58, 63) will be vented and a "Pump Under Local Control" indicator 64 will cancel. Conversely if the pump is under auto control the pump can be changed onto local control with little disturbance if the manual signal is wound up to match the existing auto signal prior to selection changeover. Logging apparatus 65 registering the hours run and number of starts through times 66, 67 is connected to the secondary circuit 7 to bring in the stand-by pump at a pre-determined stage.

In a previous steam-turbine driven pump installation, a plurality of high pressure steam valves were used in the steam supply line to the turbine. For example, there could be provided in the supply line:

1. A "cut-in" isolation valve, which is activated by a signal from an alternate pump;
2. An emergency stop valve, which is a slave valve and is adapted for manual closure;
3. A throttle valve, which regulates the steam flow to the turbine; and
4. A high pressure spring operated vent valve, which is tripped by an overspeed linkage.

This previous arrangement had the disadvantage that the cut-in valve could fail to open to ensure a maintained feed water supply to the boiler at the expense of the pump; and that on failure of an operating signal from the pump discharge the throttle valve would be set in a full open condition. If a differential piston unit was used in the throttle valve seizure of the piston would also leave the valve in the full open position. Further, if the spring in the vent valve weakened, leakage of high pressure steam was possible with partial or total closure of the stop valve.

The above described steam turbine-pump installation according to the present invention enables a considerable reduction in the number of high pressure components required, and provided an inherently safe control system with more comprehensive protection.

Whereas the above described embodiment of the present invention concerned a pneumatic control arrangement, it will be understood that an analogous electrical or hydraulic arrangement could be used.

I claim:

1. In a machine installation comprising a rotodynamic pump, a steam prime mover having a drive shaft drivingly connected to the pump, a fluid inlet to the pump and a fluid discharge from the pump supplying pressurised fluid to a receiver, and a steam supply line to the prime mover; a control arrangement for the prime mover including a steam valve in said steam supply line controlling the steam flow to the prime mover; a controller including an actuator for regulating the opening of the steam valve; a power line supplying power to said actuator; a control relay in said power line settable to control the power supply to the actuator; primary control apparatus serving to ensure that fluid is supplied from the pump to the receiver at a required pressure, and including indicating means sensing any of the pressure and flow rate conditions of the fluid in said fluid discharge, the indicating means generating signals proportional to the sensed fluid conditions, and a comparator for comparing a sensed fluid

condition value with a desired value and connected to said control relay by a primary conduit whereby a control signal based on the comparison is delivered from the comparator to the control relay for setting of the relay to control the speed of the prime mover and consequently the fluid pressure in said fluid discharge; and secondary control apparatus including a circuit having switch devices arranged in series and connected to sensors sensing further operating conditions in the machine installation, a power source connected to said circuit for energisation of the circuit when the switch devices are in a closed position, an on-off switch in said primary conduit operatively connected to said circuit whereby if a switch device is moved to an open position due to one of said further operating conditions being unsatisfactory the circuit is automatically de-energised and the on-off switch in the primary conduit consequently actuated to interrupt the transmission of the control signal to the control relay and thereby cause stoppage of the prime mover.

2. In a machine installation comprising a rotodynamic pump, a steam prime mover having a drive shaft drivingly connected to the pump, a fluid inlet to the pump, and a fluid discharge from the pump supplying pressurised fluid to a receiver, and a steam supply to the prime mover: a control arrangement for the prime mover including a steam valve in said steam supply line controlling the steam flow to the prime mover; a controller including a pneumatic actuator for regulating the opening of the steam valve; a power line supplying compressed air to said pneumatic actuator; a control relay in said power line settable to control the air supply to the actuator; primary control apparatus serving to ensure that fluid is supplied from the pump to the receiver at a required pressure and including indicating means sensing any of the pressure and flow rate conditions of the fluid in said fluid discharge, the indicating means generating signals proportional to the sensed fluid conditions; a comparator for comparing a sensed fluid condition value with a desired value and producing a control signal based on the comparison; and a primary conduit for delivering the control signal from the comparator to the control relay to set the relay and to control the speed of the prime mover; secondary control apparatus including sensors sensing further operating conditions in the machine installation, an on-off switch in said primary conduit operatively connected to said sensors of the secondary control apparatus to interrupt the transmission of the control signal to the control relay when any of said further operating conditions are unsatisfactory, and a pneumatic discharge valve is provided in said power supply line and is operatively connected to a sensor sensing the speed of the prime mover drive shaft for rapid closure of the steam valve when the speed of said drive shaft increases above a predetermined value.

3. In a machine installation comprising a rotodynamic pump, a steam prime mover having a drive shaft drivingly connected to the pump, a fluid inlet to the pump and a fluid discharge from the pump supplying pressurised fluid to a receiver, and a steam supply line to the prime mover: a control arrangement for the prime mover including a steam valve in said steam supply line controlling the steam flow to the prime mover; a controller including an actuator for regulating the opening of the steam valve; a power line supplying power to said actuator; a control relay in said power

line settable to control the power supply to the actuator; primary control apparatus serving to ensure that fluid is supplied from the pump to the receiver at a required pressure, and including indicating means sensing any of the pressure and flow rate conditions of the fluid in said fluid discharge, the indicating means generating signals proportional to the sensed fluid conditions, and a comparator for comparing a sensed fluid condition value with a desired value and connected to said control relay by a primary conduit whereby a control signal based on the comparison is delivered from the comparator to the control relay for setting of the relay to control the speed of the prime mover and consequently the fluid pressure in said fluid discharge; and secondary control apparatus including switching devices operatively coupled to sensors sensing further operating conditions in the machine installation, an on-off switch in said primary conduit operatively connected to said switching devices whereby if any of said further operating conditions are unsatisfactory the on-off switch is actuated to interrupt the transmission of the control signal to the control relay and thereby cause closure of the steam valve and stoppage of the steam prime mover.

4. A control arrangement as claimed in claim 3, in which one of the sensors of the secondary control apparatus is additionally coupled to a further switch in the power supply line whereby in the event of the sensed condition rising above a predetermined value, said further switch is actuated to cut-off the power supply to the actuator and thereby effect prompt stopping of the prime mover.

5. A control arrangement as claimed in claim 4, in which said one sensor is a sensor sensing the shaft speed of the prime mover.

6. A control arrangement as claimed in claim 3, wherein the actuator of the steam valve controller is a pneumatic actuator and a source of pressurised operating air is connected by a conduit to said pneumatic actuator, the control relay regulating the flow of operating air to the actuator, and the primary control apparatus is comprised by pneumatic devices whereby the control signal is constituted by an air pressure signal, said on-off switch in the primary conduit being comprised by a fluid switch.

7. A control arrangement as claimed in claim 6, wherein the secondary control apparatus is comprised by a pneumatic circuit including a plurality of fluid switching devices arranged in series in the circuit, each sensor being operatively connected to a respective fluid switching device, said pneumatic circuit being connected to the fluid switch in the primary conduit, whereby on actuation of any of said fluid switching devices the air pressure signal to the control relay is interrupted.

8. In a machine installation comprising main and standby rotodynamic pumps, steam prime movers each having a drive shaft drivingly connected to a respective pump, a fluid inlet to each pump and a fluid discharge from each pump supplying pressurised fluid to a receiver, and steam supply lines to each prime mover: a control arrangement for each prime mover including a steam valve in said steam supply line controlling the steam flow to the prime mover; a controller including an actuator for regulating the opening of the steam valve; a power line supplying power to said actuator; a control relay in said power line settable to control the

power supply to the actuator; primary control apparatus serving to ensure that fluid is supplied from the pump to the receiver at a required pressure, and including indicating means sensing any of the pressure and flow rate conditions of the fluid in said fluid discharge, the indicating means generating signals proportional to the sensed fluid conditions, and a comparator for comparing a sensed fluid condition value with a desired value and connected to said control relay by a primary conduit whereby a control signal based on the comparison is delivered from the comparator to the control relay for setting of the relay to control the speed of the prime mover and consequently the fluid pressure in said fluid discharge, secondary control apparatus including a circuit having switch devices arranged in series and connected to sensors sensing further operating conditions in the machine installation, a power source connected to said circuit for energisation of the circuit when the switch devices are in a closed position, an on-off switch in said primary conduit operatively connected to said circuit whereby if a switch device is moved to an open position due to one of said further operating conditions being unsatisfactory the circuit is automatically deenergised and the on-off switch in the primary conduit consequently actuated to interrupt the transmission of the control signal to the control relay and thereby cause stoppage of the turbine; and control means in the circuit of the secondary control apparatus of each of the main and standby pumps operatively connected to the secondary control circuit of the other of the pumps, each control means being selectively settable to energise the secondary control circuit of the

standby pump on shut-down of the main pump, thereby permitting the standby pump to be started.

9. A control arrangement as claimed in claim 8, wherein the actuator of the steam valve controller is a pneumatic actuator and a source of pressurised operating air is connected by a conduit to said pneumatic actuator, the control relay regulating the flow of operating air to the actuator, and the primary control apparatus is comprised by pneumatic devices whereby the control signal is constituted by an air pressure signal, said on-off switch in the primary conduit being comprised by a fluid switch.

10. A control arrangement as claimed in claim 9, wherein the secondary control apparatus is comprised by a pneumatic circuit including a plurality of fluid switching devices arranged in series in the circuit, each sensor being operatively connected to a respective fluid switching device, said pneumatic circuit being connected to the fluid switch in the primary conduit whereby on actuation any of said fluid switching devices the air pressure signal to the control relay is interrupted.

11. A control arrangement as claimed in claim 10, wherein said control means is a pneumatic control selectively settable to pass a pneumatic signal from the secondary control apparatus of the main pump to the secondary control circuit of the standby pump for pressurisation of the circuit on shut-down of the main pump, whereby the prime mover of the standby pump may be started.

* * * * *

35

40

45

50

55

60

65