March 23, 1965 P. PROFOS 3,174,288

STEAM POWER PLANT

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Fig. 1

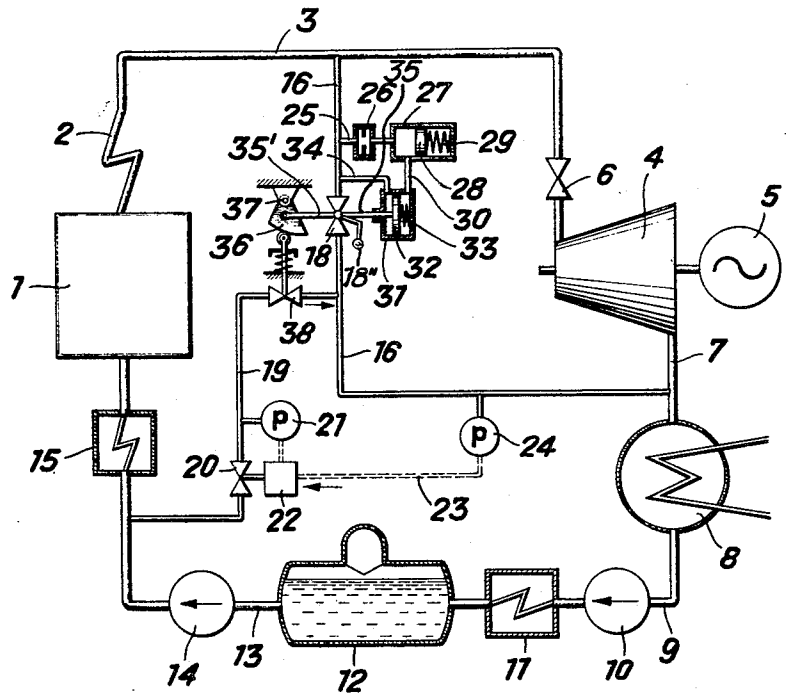

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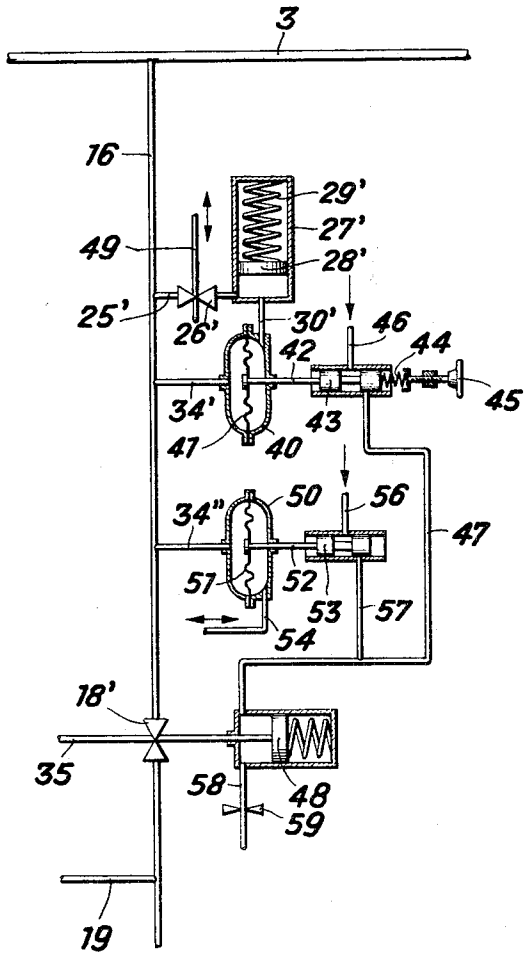
Fig. 2



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STEAM POWER PLANT

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9 Claims. (Cl. 60—105)

This invention relates to a steam power plant including a steam-operated prime mover or steam-consuming machine and a steam generator which comprises an evaporator and a superheater, the plant further including a bypass line which branches off between the superheater and the prime mover and which contains a valve operable in dependence on at least one operating condition of the working substance. The invention may be embodied in plants employing any desired vaporizable working substance. For brevity only the working substance will hereinafter be referred to as steam, and the word "steam" as hereinafter used is intended to refer to vaporizable working substances generally.

In known plants of this kind, the bypass valve is operated in dependence on the operating steam pressure, response pressure of the valve (i.e. to which it opens) being higher than the normal live steam pressure. If the steam flow control valve at the prime mover closes rapidly, a certain time elapses until the response pressure for the bypass valve is reached. During this time the flow of steam through the superheater is interrupted, so that there is a danger of the superheater's burning or suffering fire damage. To obviate this risk, the plant according to the invention is characterized in that the valve in the bypass line is controlled by an impulse which is derived from the time variation in pressure (dp/dt) of the steam between the evaporator and the prime mover. If the steam flow control valve at the prime mover closes suddenly, this arrangement ensures in a simple manner a more rapid response of the valve in the bypass line than with known plants and hence a steam flow sufficient to protect the superheater from burning.

According to one embodiment of the invention, the bypass valve is so constructed that it responds not only to the pressure variation per unit of time but also to pressures exceeding a limiting pressure upstream of the bypass valve. As a result of this construction of the bypass valve, the effect achieved is that said valve can open even when the rate of the pressure variation of the steam is lower than the rate to which the valve otherwise responds. The danger of fire damage to the superheater does not arise in these circumstances, since if the rate of change of the pressure is low a sufficient flow of steam is nonetheless maintained to cool the superheater. This construction gives the further advantage, known per se, that opening of the safety valve is avoided. Response of the safety valve is undesirable because after use the valve usually no longer closes steam-tight and then has to be overhauled or even replaced. Moreover, steam is lost when the safety valve opens.

According to a further advantageous embodiment of the invention, the values in response to which the bypass valve opens are made variable in dependence on the load on the steam generator, so that even in the case of less than full load operation it is always ensured that the valve in the bypass line opens at the correct time.

Further features of the invention will be apparent from the following description of exemplary embodiments taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a circuit diagram of a steam power plant according to the invention, and

FIGURE 2 is a diagram illustrating a modification of part of the plant shown in FIGURE 1.

According to FIGURE 1, reference character 1 denotes an evaporator and reference 2 a superheater connected thereto. From the superheater 2 a live steam line 3 leads to a turbine 4, which drives an electrical generator 5. At the inlet to the turbine 4 is a valve 6. The outlet of the turbine 4 is connected by a line 7 to a condenser 8, and from the latter a line 9 leads through a condensate pump 10 and a preheater 11 to a feed tank 12. The feed tank 12 is connected by a line 13 to the evaporator 1, the line 13 containing a feed pump 14 and a preheater 15. Downstream of the superheater 2 and upstream of the valve 6 a bypass line 16 branches off and leads into the connecting line 7 between the turbine 4 and the condenser 8. Line 16 contains a valve 18, which takes the form of a safety valve to protect the plant against excessive pressure. The weight which holds the valve closed against normal pressure is indicated at 18''.

A line 19 leads into the bypass line 16 downstream of the valve 18 and is connected to the line 13 downstream of the feed pump 14. Line 19 supplies feed water into line 16 for cooling purposes. The line 19 contains a flow-regulating valve 20, which is adjusted by a regulator 22 under control of a pressure measuring device 21 connected to the line 19 downstream of the valve 20. The regulator 22 receives a reference pressure signal via a signal channel 23 connected to a pressure signal transmitter 24, which is in turn connected to the bypass line 16. The pressure of cooling water supplied to the bypass line 16 therefore varies in dependence on the steam pressure in line 16 downstream of the valve 18.

The valve 18 in the bypass line 16 responds not only to excessive live steam pressure (by virtue of its construction as a safety valve) but also to pressure changes per unit of time in the steam between the evaporator 1 and the valve 6. To this end, a line 25 is provided, connecting to the bypass line 16. Line 25 contains a throttling element 26 and leads into a storage chamber 27. In the chamber 27 there is provided a piston 28, whose side away from line 25 bears against a spring 29. From the storage chamber 27 a line 30 leads into a cylinder 31 on one side of a piston 32 therein. Piston 32 is connected to the actuating member 35 of the valve 18. A spring 33 is disposed in the cylinder 31 on the side of the piston 32 into which line 30 opens, which side is remote from the member 35. On the other side of the piston 32 a line 34 leads from bypass line 16 into the cylinder 31. The member 35 of the valve 18 is connected by a linkage member 35' to a cam plate 36 adapted to pivot about a point 37. The actuating member of a valve 38 is spring-loaded to bear against the cam 36, and valve 38 is disposed in the line 19 between its point of entry into the bypass line 16 and the flow-regulating element 20.

In normal operation, the steam generated in the evaporator 1 and in the superheater 2 flows through the live steam line 3 to the turbine 4, where it is expanded and then condensed in the condenser 8. The condensate is then supplied through the preheater 11, the feed tank 12 and the preheater 15 to the evaporator 1 by means of the pumps 10 and 14. Under these conditions the valve 18 in the bypass line 16 is held closed by the spring 33, with members 35 and 35' shifted to the left in FIGURE 1, the pressures on both sides of the piston 32 being equal. With valve 18 closed, valve 38 in the line 19 is held closed by cam 36.

In the event of a sudden pressure rise such as may occur, for example, if the valve 6 is rapidly closed, the valve 18 opens and steam escapes through the bypass line 16 to the condenser 8. Opening of the valve 18 results from the fact that the rise in pressure in line 3

acts more rapidly on the left-hand side of the piston 32 than on the right-hand side in FIG. 1, due to the throttling action of element 26 and the storage action of chamber 27. Member 35 is thus shifted to the right in FIG. 1, opening valve 18. Simultaneously with the opening of valve 18, the cam 36 is rotated anticlockwise by way of the member 35 and the valve 38 is opened, so that the steam flowing through the bypass line 16 is cooled.

In the case of less sudden pressure rises, to which the piston 32 would not respond, the valve 18 opens in response to excess pressure, so that in this case too there is adequate security against damage to the superheater, since in the event of such a pressure rise a flow of steam sufficient to cool the superheater is maintained.

According to FIGURE 2, the plant is modified so that the response of the valve in the bypass line 16 varies with the load on the steam generator comprising evaporator 1 and superheater 2, and this applies both to response due to sudden pressure rises and to response due to excess pressure. In FIGURE 2, a line 25′ containing a throttling element 26′ branches off from line 16 and leads into a storage chamber 27′ having a piston 28′ which bears against a spring 29′. From the storage chamber 27′ a line 30′ leads to a pressure difference measurement device 40, which contains a diaphragm 41. A line 34′ leads from device 40 on the other side of the diaphragm 41 therein to the bypass line 16. The diaphragm 41 is coupled by a rod 42 with the actuating member of a valve 43, this actuating member being biased by a spring 44, whose force is adjustable by means of a hand wheel 45 and which tends to keep valve 43 closed. A fluid is supplied under pressure to valve 43 by way of a line 46, and valve 43 is also connected by a line 47 to the cylinder of a servo-piston 48. The latter is in turn coupled by member 35 to the valve 18′ in the bypass line 16. A discharge line 58 for fluid under pressure is connected to the cylinder of servo-piston 48 and contains a throttling element 59 so that pressure can be developed in the cylinder. Under the action of this pressure the servo-piston 48 moves to the right and opens the valve 18′.

The throttling element 26′ is coupled by an actuating member 49 to a load controller (not shown) which varies the cross-section of the throttling element 26′ in dependence on the load on the steam generator 1, 2, reducing the cross-section with decline in the load and vice-versa.

The control system of FIGURE 2 thus far described responds, in its action on valve 18′, to the rate of pressure variation of the steam. Control of valve 18′ to open it in response to steam pressure in line 3 exceeding a specified maximum pressure is also provided, and to this end a line 34″ branches off from the bypass line 16 and leads to one side of the diaphragm 51 of a pressure measuring device 50 similar to device 40. The diaphragm 51 of this device is coupled by a rod 52 to a control valve 53, similar to valve 43 but without the spring 44 of the latter. The cylinder of valve 53 is connected to a source 56 of fluid under pressure, and also by way of a line 57 to the line 47 which leads from the control valve 43 to the servo-piston 48. A line 54 leads into the chamber of the device 50 remote from the line 34″. A fluid medium is supplied to line 54 under a pressure which is varied by a load controller (not shown), so that the pressure of the medium in the line 54 and hence on the right-hand side of the diaphragm 51 varies as a function of the load.

In the event of sudden pressure variations, the diaphragm 41 of the pressure difference receiver 40 is moved to the right in FIGURE 2. Rod 42 thus shifts the body of the valve 43 to the right, so that fluid under pressure from source 46 passes through line 47 to the left-hand side of the servo-piston 48. This moves the latter to the right, and in so doing opens the valve 18′, so that steam can flow through the bypass line 16 into the condenser. If, on the other hand, in the event of a slower pressure rise the maximum pressure set at the diaphragm 51 of the pressure measuring device 50 is exceeded, the body of control valve 53 is moved to the right in FIGURE 2 and the source 56 of fluid under pressure is connected to servo-piston 48, moving it in the direction which opens the valve 18′.

Instead of making the reference value in regulator 22 in FIGURE 1 dependent on the steam pressure in the bypass line 16, it may according to another embodiment of the invention be made to depend on the load on the steam generator 1, 2, the reference value signal line 23 being connected to a load responsive device in the appropriate manner, as is the case of the throttling element 26′ and the pressure measuring device 50 in the example of FIGURE 2.

While the invention has been described herein in terms of a number of preferred embodiments, the invention is not limited to the details of construction thus illustrated and described, but is rather set forth in the appended claims.

I claim:

1. A steam power plant comprising an evaporator, a superheater, a steam consuming machine, conduit means to conduct steam from the evaporator through the superheater to said machine, a bypass line connected into said conduit means between the superheater and machine, a valve in said bypass line, and means to open said valve in response to time rate of change of pressure of the steam between the evaporator and the steam-consuming machine exceeding a limiting value.

2. A steam power plant comprising an evaporator, a superheater, a steam consuming machine, conduit means to conduct steam from the evaporator through the superheater to said machine, a bypass line connected into said conduit means between the superheater and machine, a valve in said bypass line, means to measure the time rate of change of pressure in the steam between the evaporator and steam-consuming machine, and means responsive to said measured time rate of change of pressure to open said valve upon increase of said rate of change beyond a limiting value.

3. A steam power plant comprising an evaporator, a superheater, a steam consuming machine, conduit means to conduct steam from the evaporator through the superheater to said machine, a bypass line connected into said conduit means between the superheater and machine, a valve in said bypass line, means to hold said valve closed in response to steam pressures below a specified value, and overriding means to open said valve in response to time rate of change of steam pressure exceeding a specified value.

4. A steam power plant comprising an evaporator, a superheater, a steam consuming machine, conduit means to conduct steam from the evaporator through the superheater to said machine, a bypass line connected into said conduit means between the superheater and machine, a valve in said bypass line, means to open said valve in response to time rate of change of steam pressure exceeding a limiting value, and means to vary said limiting value with changes in the load on the evaporator and superheater.

5. A steam power plant comprising an evaporator, a superheater, a steam consuming machine, conduit means to conduct steam from the evaporator through the superheater to said machine, a bypass line connected into said conduit means between the superheater and machine, a valve in said bypass line, means to measure the time rate of change of pressure in the steam between the evaporator and steam-consuming machine, means responsive to said measured time rate of change of pressure to open said valve upon increase of said rate of change beyond a limiting value, and means to vary said limiting value directly with the load on the evaporator and superheater.

6. A steam power plant comprising an evaporator, a superheater, a steam consuming machine, conduit means to conduct steam from the evaporator through the superheater to said machine, a bypass line connected into said conduit means between the superheater and machine, a valve in said bypass line, means to hold said valve closed in response to steam pressures below a specified value, overriding means to open said valve in response to time rate of change of steam pressure exceeding a limiting value, and means to vary said specified and limiting values directly with the load on the evaporator and superheater.

7. A steam power plant comprising an evaporator, a superheater, a steam consuming machine, conduit means to conduct steam from the evaporator through the superheater to said machine, a bypass line connected into said conduit means between the superheater and machine, a valve in said bypass line, resilient means stressing said valve to closed position, means responsive to change of steam pressure with time between said evaporator and machine to apply a force to said valve in opposition to said resilient means.

8. A steam power plant comprising an evaporator, a superheater, a steam consuming machine, a first conduit means to conduct steam from the evaporator through the superheater to said machine, a bypass line connected into said first conduit means between the superheater and machine, a valve in said bypass line, said valve having a movable actuating member, a chamber having a movable diaphragm dividing the interior thereof into two parts, second and third conduit means connecting said parts with said first conduit means, said second and third conduit means having unlike resistance to steam flow, and means responsive to motion of said diaphragm to shift said actuating member.

9. A steam power plant comprising an evaporator, a superheater, a steam consuming machine, a first conduit means to conduct steam from the evaporator through the superheater to said machine, a bypass line connected into said first conduit means between the superheater and machine, a valve in said bypass line, said valve having a movable actuating member, resilient means stressing said member to valve-closing position, a piston coupled to said member, second conduit means to apply to one side of said piston in opposition to said resilient means the pressure in said first conduit means, and third conduit means to apply to the opposite side of said piston the pressure in said first conduit means, said third conduit means having greater resistance to steam flow than said second conduit means.

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