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PRESSURE BOOSTER REGULATOR

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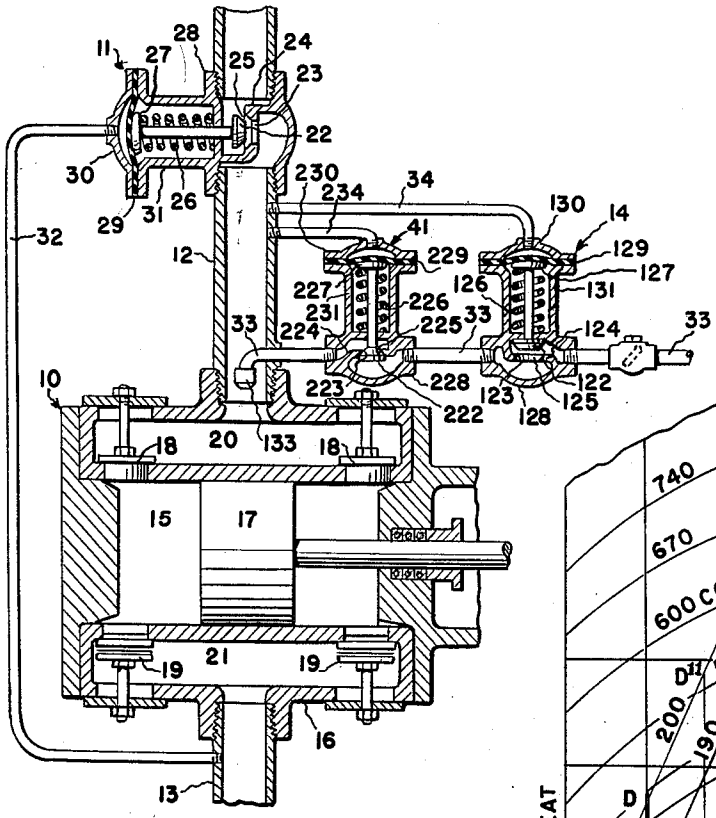


FIG.-1.

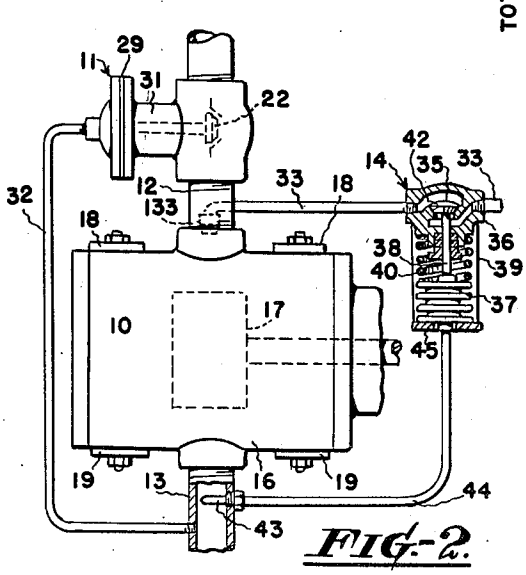


FIG.-2.

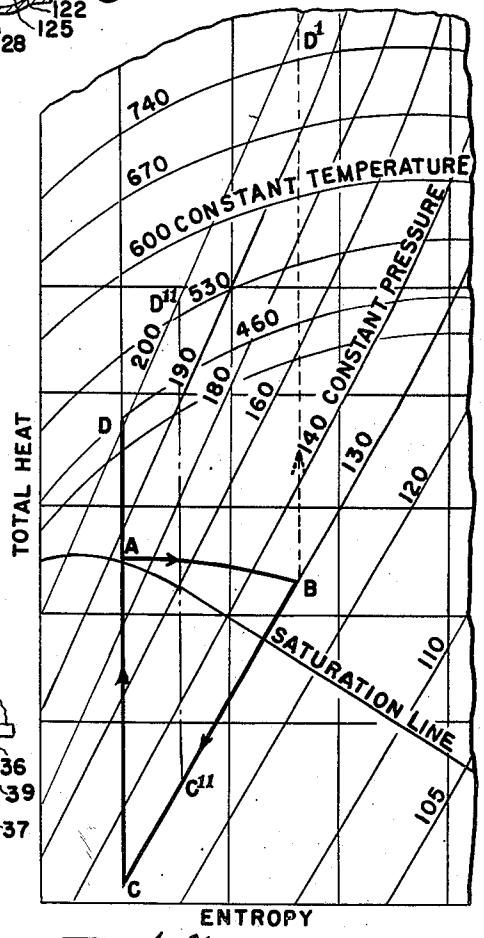


FIG.-3.

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PRESSURE BOOSTER REGULATOR

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6 Claims. (Cl. 230—19)

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This invention relates to pressure booster regulators, and more particularly to a regulating device for controlling the outlet temperature of a steam pressure booster.

One difficulty encountered in the operation of steam pressure boosters arises when the demand for high pressure steam falls below the operating capacity of the booster. In order to reduce the output of the booster in accordance with the demand, several well known methods have been used but, in general, these methods have several inherent disadvantages. For example, one method of reducing the output of the booster is the use of clearance valves in the booster. It is a recognized fact that to decrease the output of a booster by increasing the clearance leads to lower efficiency of the booster.

Another method used in the past has been to throttle the steam before compression. This mode of reducing the output of the booster leads to excessively high outlet, or exhaust, temperatures on the steam which, of course, leads to rapid deterioration of those members of the booster exposed to such high temperatures; or if the booster is adequately cool by means of a water jacket or some similar device, then an appreciable quantity of the energy of the steam is carried off in the cooling water.

It is, accordingly, one object of this invention to control the outlet temperature of steam being compressed in a pressure booster operating at less than full capacity.

Another object of this invention is to introduce a cooling medium into the steam before the steam enters the booster.

A further object is to automatically control the flow rate of such cooling medium introduced into the steam in accordance with the flow rate of steam through the outlet of the booster.

Further objects will become obvious in the following specification and accompanying drawings in which,

Figure 1 is a longitudinal elevation, partly in section, of a booster provided with a preferred form of the regulator,

Fig. 2 is a similar view of the booster provided with a modified form of the regulator, and

Fig. 3 is an enthalpy-entropy (Mollier) diagram on which the states of the steam is traced as it passes through the booster system.

Referring to the drawings and more particularly to Figure 1, 10 indicates a steam pressure booster to which is adapted one form of the regulator for controlling the outlet temperature of the steam. The regulator comprises a valve

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unit, designated in its entirety by 11, for controlling the rate of flow of steam through the booster inlet 12 in response to the rate of flow of steam through the outlet 13; and a second valve unit, designated in its entirety by 14, for automatically controlling the flow of a cooling medium, such as water, into the steam prior to its entry into the compression chamber 15 of the booster. In the form of the invention illustrated in Figure 1, the unit 14 is similar in construction to the unit 11 and is actuated in response to changes in pressure or the flow rate of steam through the inlet 12.

The unit 11 is actuated in response to a decrease in demand on the booster to decrease the flow of steam into the booster 10, thereby decreasing the pressure or flow of the steam in the inlet 12. In response to this decrease in pressure, the unit 14 permits an increase in flow of cooling water into the inlet 12. The converse function also occurs—that is, in response to an increase in demand, the unit 11 permits a corresponding increase in the supply of steam to the booster, and the unit 14 decreases the supply of cooling water. In other words, the unit 14 controls the flow of cooling medium in inverse proportion to the rate of flow of steam through the unit 11.

With this particular arrangement, the danger of encountering excessively high outlet temperatures of the steam when the booster is operating at less than full capacity, is obviated and, further, the need of surface cooling of the booster is eliminated thereby conserving the heat energy loss normally associated with that type of cooling. The advantages associated with this method of controlling the outlet temperature of the steam is more readily appreciated from a study of the steam cycle traced on the Mollier diagram shown in Fig. 3.

Referring to Fig. 3, the point A shows the state of the steam prior to passing through the valve unit 11. Assuming the demand on the booster has fallen below its full capacity, the valve unit 11 will throttle the steam in accordance with this demand and, accordingly, the steam in passing through the valve unit 11 will undergo the change as indicated by the line AB, B being the state of the steam after passing through the valve unit 11.

If the steam were now compressed to an outlet pressure of say, for the sake of example, 200 p. s. i., the state of the steam would be as shown at D^1 and the outlet temperature of the steam would be approximately 750° F. This excessive

temperature is avoided, however, by the introduction of cooling water into the steam at the point B which reduces the temperature of the steam at substantially constant pressure along the line B—C and the state of the steam entering the compression chamber 15 is that of steam at the point C on the Mollier diagram.

The position of the point C is, of course, determined by the amount of water introduced into the steam in the inlet 12. For example, in order to reduce the temperature of a pound of stream at the point B to the temperature and quality at point C, a fixed number, X, of British thermal units must be absorbed, or removed, from the steam. Also X B. t. u. are required to raise some fraction of a pound of water of a given temperature to the state indicated at point C. Thus, the addition of this quantity of water to one pound of steam at the point B will change the state of the steam to that indicated at C. The exact amount of water introduced into each pound of steam depends, of course, on the state of the steam desired (at C) and the steam pressure. The manner in which this amount of water is computed for any given condition is too well known to those familiar with the art to warrant a detailed discussion herein.

The amount of water introduced into the steam is regulated automatically in accordance with the degree of throttling of the booster or, in other words, in accordance with the rate of flow of steam through the outlet 13. The steam is then compressed adiabatically from point C to 200 p. s. i., the point D, at which point the steam is discharged into the outlet 13 at a relatively moderate temperature of approximately 460° F. The cooling water introduced into the system will, of course, increase somewhat the output, or rate of flow, in pounds per hour, of steam but this increase is not substantial.

The booster 10 to which the regulating device for controlling the outlet temperature of the steam is adapted, comprises a housing 16 enclosing the compression chamber 15 for a reciprocating piston 17 of the double acting type. The booster 10 is of any conventional design and is, accordingly, provided with the usual inlet and exhaust valves 18 and 19, respectively. The structure and function of the valves 18 and 19 is fully disclosed in U. S. Patent No. 2,040,542. Their function, in general, is to control, respectively, the flow of pressure fluid into the chamber 15 from an inlet chamber 20 within the housing 16 and out of the chamber 15 into the outlet chamber 21. The outlet 13 is threadedly connected to the housing 16 and communicates with the chamber 21; and the inlet 12 is connected in a similar fashion to the housing 16, in communication with the inlet chamber 20.

Interposed in the inlet 12 at a point adjacent to the booster 10 is the valve unit 11 which comprises a fluid pressure operated valve acting responsively to the rate of flow of fluid through the outlet 13 for controlling the rate of flow of fluid through the inlet 12. In furtherance to this end, the unit 11 includes a reciprocating valve 22 in a valve housing 28 inserted in and forming a section of the inlet 12. Movement of the valve 22 controls the flow of fluid through a port 23 in a partition 24 integral with the housing 28 and lying across the passage therethrough.

The valve 22 is urged off its seat 25 encircling the port 23, by means of a spring 26 biased between the inner surface of a flange 27 on the end of the stem of the valve 22 and the outer surface of the valve housing 28. The valve 22 is actuated onto its seat 25 by means of a diaphragm 29, or similar reciprocating element, in contact on one side with the outer surface of the flange 27 and exposed on the other side to fluid pressure in the outlet 13. The marginal portions of the diaphragm 29 are clamped between a cap 30 and the free end of a tubular member 31 integral with and extending radially from the housing 28 to encircle the stem of the valve 22.

Threaded in the cap 30 is one end of a conduit 32 which is connected at its other end in the outlet 13, thus the diaphragm 29 is at all times exposed to pressure in the outlet 13 and is actuated by steam conducted therefrom. Accordingly, the movement of the valve 22 controlling the rate of flow of steam through the inlet 12, is directly dependent upon the pressure of the fluid in the outlet 13 or, in other words, the rate of flow of fluid in the outlet 13.

The unit 14, shown in Figure 1, for supplying cooling water to the inlet 12 in response to changes in pressure, or the rate of flow of fluid through the outlet 13, comprises a fluid pressure operated valve 122 inserted in a conduit 33 terminating, at one end, in the inlet 12 downstream of the valve 22 and connected at its other end with a source of cooling water (not shown). The discharge end of the conduit 33 is turned, or directed, downstream with respect to the flow of steam in the inlet 12, and a nozzle 133 is adapted thereon so that the cooling water is sprayed into the steam to obtain effective and rapid heat transfer therebetween.

The construction of the valve unit 14 is similar to the unit 11 inserted in the inlet 12 and, accordingly, includes a valve housing 131 encasing a reciprocating valve 122 for controlling the flow of fluid through a port 123 in a partition 124. The valve 122 is actuated off its seat 125 by a spring 126 and is urged onto its seat by a diaphragm 129 overlying the end of the stem of the valve 122 and clamped at its marginal portions between a cap 130 and the end of the housing 131. Pressure fluid for actuating the diaphragm 129 is conducted to the cap 130 by means of a conduit 34 connected between the cap 130 and the inlet 12 at a point adjacent to and downstream of the valve 22. Thus, the rate of flow of cooling water introduced into the steam prior to its entry into the compression chamber 15 is controlled automatically in response to the rate of flow of fluid through the inlet 12 and, accordingly, the rate of flow of fluid through the outlet 13.

The actual rate of flow of cooling water for any given rate of flow of fluid through the inlet 12 is, of course, dependent on the strength of the spring 126 and the area of the diaphragm 129 exposed to pressure fluid conducted from the inlet 12. By the proper choice these elements 126 and 129, the temperature of the stream in the outlet 13 may be controlled over a wide range. For example, referring to the Mollier diagram (Figure 3) and assuming a weaker spring 126 is used in the regulating device than was used under the conditions of the previously traced example, the rate of flow of cooling water would be somewhat less for the same rate of flow of steam through the outlet 13 and, accordingly, the point corresponding to C would lie on the line C—B between the points C and B, say at C^{11}. In other words, the steam would enter the compression chamber 15 at a somewhat higher temperature and, accordingly, the discharge point corresponding to D on the dia-

gram would lie on the 200 pound pressure line between the points D and D^1, say at D^{11}, and, accordingly, the outlet temperature of the steam (540° F.) would be higher than in the previously traced example. Accordingly, if a stronger spring were used, a greater amount of water would be introduced into the inlet 12 than in the first said example and the temperature of the steam entering the booster 10 and discharged therefrom would be at a somewhat lower temperature than in the first said example.

It is to be noted in connection with this method of preventing excessive temperatures of steam discharged from a booster, that in theory, the amount of water that should be injected into each pound of steam should increase with an increase in throttling, or decrease in pressure, of the steam. In accordance with this theory, as the unit 11 progressively throttles the flow of steam, the unit 14 (Fig. 1) permits a corresponding increase in the flow of water through the conduit 33; however, if this inverse relationship is continued, a point is reached whereat the quantity of steam available to heat the cooling water is not sufficient to vaporize the water.

In order to obviate this situation, the valve 122 is designed to be actuated into the full open position when the load is, for example, one half the rated capacity of the booster, and a second valve unit 41 is inserted in the conduit 33 downstream of the unit 14. The unit 41 is similar in construction to the unit 14 and is communicated with the inlet 12 and actuated by fluid conveyed therefrom in a manner similar to the unit 14. The valve unit 41 differs, however, from the unit 14 in that it is reverse acting and comes into action at a somewhat lower pressure value in the inlet 12 than does the unit 14. In other words, the valve unit 41 is actuated to decrease the rate of flow of water through the conduit 33 in response to a decrease in flow, or pressure, in the inlet 12.

In furtherance to this end, the valve unit 41 comprises a valve housing 228 inserted in and forming a section of the conduit 33. Located within the housing 228 is a partition 224 having a port 223 therein through which one end of the stem of a reciprocating valve 222 extends. Secured to this end of the stem is the head of the valve 222 which bears against the valve seat 225 formed on the surface bounding the port 223. The opposite end portion of said stem protrudes from the housing 228 and is encased by a tubular member extending radially from the housing 228 and integral therewith.

The valve 222, as counterdistinguished from the movement of the valve 122, is actuated into the open position by fluid pressure acting against a diaphragm 229, and is urged into the closed position by a spring 226. In furtherance to this end, located within the member 231 and encircling the stem of the valve 222 is the spring 226 biased between a flange 227 on the back end of the valve stem and the outer surface of the housing 228. The diaphragm 229 overlies the flange 227 and is clamped at its marginal portions between the free end of the tubular member 231 and a cap 230 adapted to the end of said member 231. A pipe 234 connected between the cap 230 and the inlet 12 conveys steam or other pressure fluid from the inlet 12 to the diaphragm 229. With this arrangement then, the spring 226 tends to urge the valve 222 onto its seat 225, and pressure fluid conducted from the inlet 12 acts on the diaphragm 229 which in

turn bears on the flange 227 thereby urging the valve 222 off its seat 225 whenever the force of the fluid pressure acting on the diaphragm is sufficient to overcome the force exerted in the opposite direction by the spring 226.

As was previously mentioned, the valve unit 41 comes into action at a somewhat lower pressure than is required for movement of the valve 122 in the unit 14. This function may be accomplished by having either a larger area of the diaphragm 229 exposed to pressure fluid from the inlet 12 than the area of the diaphragm 129 exposed to the same fluid pressure, or the same result may be attained by providing a weaker spring, such as the spring 226, for the unit 41 than is provided for the unit 14.

Reviewing the operation of the form of the invention illustrated in Figure 1, it will be assumed that the booster is operating at full capacity and the demand on the booster is equal to its capacity. It will be further assumed that at this demand the pressure in the outlet 13 is 200 p. s. i. Under these conditions the spring 26 will hold the valve 22 fully open against the force exerted by the diaphragm 29, and fluid pressure acting on the diaphragm 229 will overcome the force of the spring 226 to hold the valve 222 fully open, whereas fluid pressure acting on the diaphragm 129 will hold the valve 122 closed inasmuch as this valve is reverse acting with respect to the valve 222.

If the demand on the booster drops, to say three quarters of full capacity, this decrease in demand will result in a decrease in flow of fluid and a pressure rise, say to 202 p. s. i., in the outlet 13. This increase in pressure acting on the diaphragm 29 will overcome the force exerted by the spring 26 to partially close the valve 22 thereby throttling the steam that passes through the valve unit 11 and causing a decrease in pressure in the inlet 12. As a result of this decrease in pressure in the inlet 12, the spring 126 will move the valve 122 into the partially open position thereby permitting cooling water to flow into the throttled steam within the inlet 12. The valve unit 41 will not, at this demand, come into operation inasmuch as the spring 226 is somewhat weaker than the spring 126.

In the event of a further decrease in demand, the pressure will again increase and the flow rate decrease in the outlet 13 and the valve 22 will, in accordance with this change, move towards its closed position to throttle further the steam in the inlet 12. In accordance with the decrease in pressure in the inlet 12, due to the throttling action of the unit 11, the valve 22 will move towards its full open position to permit a further increase in flow of cooling water in inverse proportion to the decrease in flow of steam through the inlet 12.

If the demand on the booster continues to decrease, the pressure of the steam in the inlet 12 will be decreased accordingly and the unit 14 will continue to valve cooling water into the inlet 12 at a rate in inverse proportion to the demand on the booster until the pressure within the inlet 12 falls to a value whereat the valve 122 is moved into its full open position, say at demand of one half the rated capacity of the booster. When the demand on the booster falls to say, for the sake of example, one quarter of the rated capacity of the booster, the pressure in the inlet 12 will have fallen to a value whereat the force of the spring 226 in the unit 41 will overcome the force exerted on the diaphragm 229 by fluid con-

veyed from the inlet 12, so that the valve 222 is moved towards its closed position thereby decreasing the flow of cooling water through the conduit 33.

The exact values of the flow rate of steam through the inlet 12 or the percentages of demand on the booster at which the valve unit 41 comes into operation and the valve 122 moves into the full open position is, of course, dependent on the pressure of the steam in the inlet 12 and the discharge pressure and temperature desired for the steam and will vary somewhat with different installations. It is to be noted, however, that these values may vary considerably without exposing the booster to the danger of excess discharge pressures. When there is no demand on the booster, the valve unit 11 will cut-off the flow of steam through the inlet 12 and the valve unit 41 will cut-off the flow of cooling water into the inlet 12.

Referring to Figure 2, a modified form of the unit 14 is shown and comprises, in this instance, a spring-pressed valve 35 mounted in the valve housing 36 connected in the conduit 33. The valve 35 is moved into the opening position by means of a conventional thermal actuated device responsive to changes in temperature of the steam in the outlet 13. This device in its simplest form, as shown in Fig. 2 by way of example, comprises a bellows 37, or similar reciprocating element, adapted to the end of the valve stem 38 and encased by a tubular member 39 extending radially from the housing 36. A spring 40, also within the member 39, is biased between the inner end of the bellows 37 and the surface of the housing 36. The opposite end of the bellows rests on a cover 45 enclosing the free end of the member 39, thus the spring 40 tends to collapse, or compress, the bellows 37 and urge the valve 35 onto its seat 42 formed within the housing 36.

The valve 35 is actuated into its open position by the extension of the bellows due to the thermal expansion of the fluid in a bulb 43 positioned in the outlet 13 at a point adjacent the booster 10. The force resulting from the expansion of this fluid is transmitted to the bellows 37 through a conduit 44 connected between the thermometer, or bulb 43, and the outer end of the bellows 37.

The operation of this form of the regulator is quite similar to the previously described regulator with the exception that the operation of the valve 35 for controlling the flow of cooling water is dependent upon the temperature of the steam in the outlet 13 rather than the steam pressure in the inlet 12. It is to be noted, however, that the temperature of the steam in the outlet 13 is directly related to the rate of flow of fluid therethrough inasmuch as whenever this rate of flow drops below some predetermined value, the valve 22 is actuated to throttle the flow of steam into the booster 10 and, accordingly, the outlet temperature of the steam increases, as shown on the Mollier diagram (see point D^1), and the valve 35 is thereby actuated to introduce cooling water into the inlet 12 in accordance with this increase in temperature or, as aforesaid, in accordance with the decrease in the rate of flow through the outlet 13.

With this form of the invention, the exact amount of water necessary to maintain a relatively constant temperature of the discharge steam will be controlled in a completely automatic manner in response to changes in the rate of flow of fluid through the outlet 13. In the event the demand on the booster falls to zero, the temperature in the outlet 13 will fall accordingly to a value whereat the valve 35 will close to prevent to flow of water into the inlet 12.

Briefly reviewing the operation of the regulating device, in both forms of the invention whenever the rate of flow through the outlet 13 decreases, due, for example to a decrease in demand for high pressure steam, the accompanying increase in pressure therein actuates the valve 22 to throttle the steam in the inlet 12 in accordance with the change in the rate of flow through the outlet 13. Immediately thereafter in response to this decrease in rate of flow through the outlet 13, the unit 14 for controlling the flow of cooling water into the inlet 12 comes into operation to maintain the outlet temperature of the steam at a relatively low and constant value.

In the first form of the invention (Figure 1), the valve unit 14 is actuated in response to changes in pressure in the inlet 12 at a point downstream of the valve 22, and a second reverse acting valve unit 41 responsive to the same pressure changes is provided to prevent flooding of the booster at a relatively low load demand thereon. In the second form of the invention (Figure 2), the unit 14 is actuated in response to changes in temperature in the outlet 13. It is to be noted, however, in both forms of the regulating device that whenever the booster is operating under normal conditions—a condition wherein the demand varies between one half to the rated capacity of the booster—the rate of flow of cooling water is inversely proportional to the rate of flow of steam through the outlet 13.

It is apparent from the foregoing discussion that a regulating device for steam pressure boosters constructed in accordance with the practice of the invention, accomplishes, among others, the objects hereinbefore stated.

While I have shown and described specific forms of my invention, it is to be understood that various changes and modifications may be made without departing from the spirit of the invention as set forth in the appended claims.

I claim:

1. A regulating device for a steam pressure booster having an inlet and an outlet, comprising a valve in said inlet for controlling the flow of steam through said inlet, means connected to said valve for actuating said valve in response to changes in pressure in the outlet, a conduit for supplying cooling water to steam in the inlet and connected to the inlet at a point downstream of the said valve, a valve in said conduit for controlling the rate of flow of cooling water through said conduit, and means operatively connected to the last valve responsive to variations in the rate of flow through said booster for actuating the last said valve.

2. A regulating device for a fluid pressure booster having an inlet and an outlet, comprising a valve in said inlet for controlling the rate of flow of fluid therethrough, a conduit connected between the outlet and said valve for conducting pressure fluid from the outlet to said valve, a reciprocating element overlying an end of the valve and having a pressure surface exposed to pressure fluid conducted thereto by said conduit for actuating said valve, a conduit for conducting cooling medium into the inlet downstream of said valve, a valve in said conduit, a reciprocating element operatively connected to the last said valve, and means connected to said element and responsive to changes in demand on the booster for actuating said element to control the rate of flow of cooling medium through the last said

conduit in inverse proportion to the rate of flow of fluid through the first said valve.

3. A regulating device for a steam pressure booster having an inlet and an outlet, comprising a valve in said inlet, a diaphragm overlying an end of said valve for urging said valve toward the closed position in response to a decrease in demand on the booster, a conduit connected between the outlet and said diaphragm for conveying steam from the outlet to actuate the diaphragm, a conduit for supplying cooling water in the inlet and connected to the inlet at a point downstream of said valve, a valve in the last said conduit for controlling the flow of cooling water therethrough, a reciprocating element operatively connected to the last said valve for actuating it into the closed position, and a conduit connected between said element and the inlet for supplying steam to actuate said element in response to an increase in demand on the booster to close progressively the last said valve in accordance with such increase.

4. A regulating device for a fluid pressure booster having an inlet and an outlet, a valve unit in said inlet and connected to said outlet and acting responsively to the rate of flow of fluid through the outlet for controlling the rate of flow of fluid through the inlet, a conduit connected to the inlet for supplying cooling medium to said inlet, a valve in said conduit for controlling the rate of flow of cooling medium, and a device operatively connected to the last said valve and responsive to changes in temperature of fluid in said outlet for actuating the last said valve.

5. A regulating device for a steam pressure booster having an inlet and an outlet, a valve unit in the inlet for controlling the rate of flow of steam through the inlet, a conduit connected between said valve unit and the outlet for supplying steam to actuate said unit in response to the rate of flow of fluid through the outlet, a conduit connected to the inlet for supplying cooling water to said inlet, a cooling water valve unit in the second said conduit actuated by steam

pressure from the inlet for controlling the rate of flow of cooling water in inverse proportion to the rate of flow of steam through the booster, a conduit connected to said cooling water valve and to the inlet at a point downstream of the first said valve for supplying actuating steam to said cooling water valve, a second cooling water valve unit in the second said conduit exposed to and actuated by steam from the inlet for decreasing the supply of cooling water to the inlet whenever the demand on the booster falls below some predetermined value, and a conduit connected to said inlet at a point downstream of the first said valve unit and to the second said cooling water valve for supplying actuating steam thereto.

6. A regulating device for a fluid pressure booster having an inlet and an outlet, comprising a valve in the inlet for controlling the flow of fluid into the booster, means operatively connected to said valve and connected to the outlet for actuating the valve, such means being actuated in response to variations in pressure in the outlet for actuating said valve to vary the flow of fluid into the booster in accordance with the load demand thereon, a conduit connected to said inlet for supplying cooling fluid thereto at a point downstream of said valve, a valve in said conduit, means operatively connected to the last said valve for actuating the last said valve in response to variations in temperature of fluid in the outlet, and a thermo-responsive element connected in said outlet and to the last said means for actuating the last said means.

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