

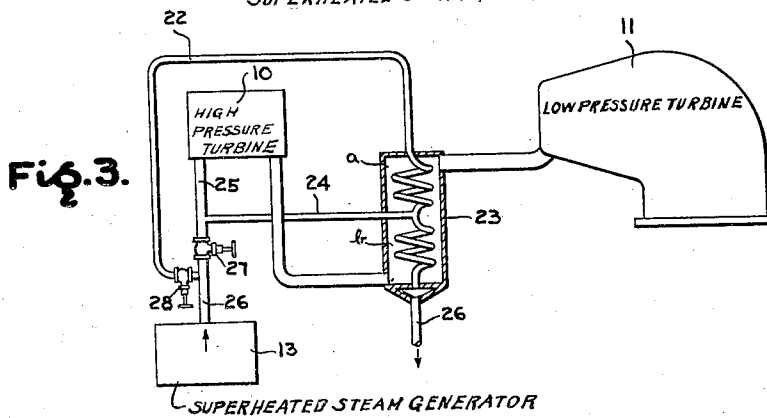
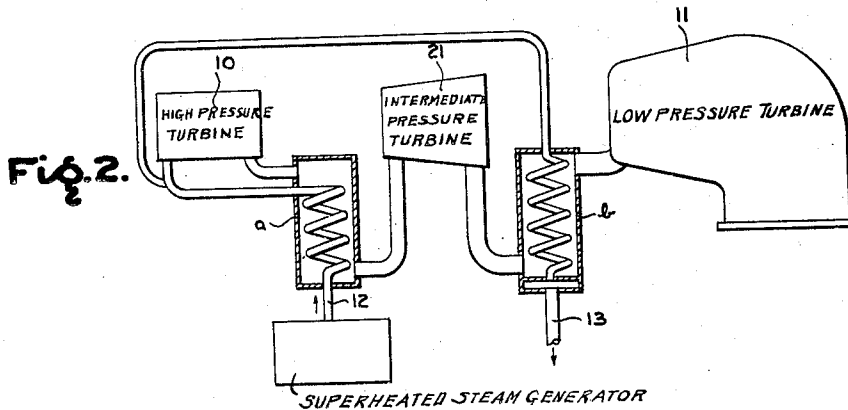
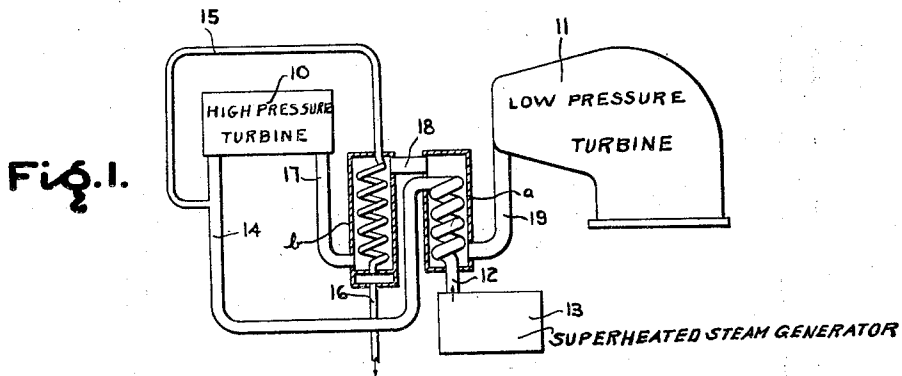
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K. BAUMANN

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SYSTEM OF REHEATING IN A POWER PLANT

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WITNESSES:

E. Luty.

INVENTOR

K. Baumann

BY

A. B. Reavis

ATTORNEY

UNITED STATES PATENT OFFICE

KARL BAUMANN, OF URMSTON, ENGLAND, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA

SYSTEM OF REHEATING IN A POWER PLANT

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The invention relates to a power plant of the kind wherein an elastic motive fluid such as steam is employed expansively, for example, in one or more turbines, for the purpose of performing mechanical work, and wherein the motive fluid is re-heated between two or more operative stages of its expansion; and it has for an object to provide an improved system of reheating in a power plant.

In a power plant of this kind, several different reheating systems have already been proposed with the two-fold object of increasing the overall efficiency of the plant and obtaining drier steam in the later stages of expansion. One such system employs live steam at relatively high pressure and temperature to re-heat motive steam passing between two expansion stages, for example, between a high pressure and a low pressure turbine, the high pressure steam being thereby condensed and returned to the boiler. Another system employs superheated steam at relatively high pressure to re-heat the motive steam passing between two expansion stages; the heating steam, still at a relatively high pressure but with less degrees of superheat, being then admitted to the turbine and employed for motive purposes.

In the former of these two systems, the temperature of the steam re-heated can only attain approximately the temperature of saturation of the high pressure steam, whilst in the latter system referred to the temperature rise of the steam reheated is dependent upon the degree of superheat of the high pressure steam, which again is limited by problems arising in the construction of superheaters.

The improvement in overall efficiency obtainable by either of the re-heating systems aforesaid is thus strictly limited, and can be ascertained theoretically for any given set of conditions in either case.

With the object of enabling a greater improvement in efficiency to be attained than by either of the two systems above referred to, it has been proposed to employ a modified system, in which a portion of the superheated steam supplied for a turbine plant is

tapped off and utilized to re-heat motive steam between certain expansion stages, by passing said tapped steam through two heating circuits in series, in the first of which it gives up its superheat in re-heating the motive steam and in the second of which it gives up its latent heat of vaporization in reheating the motive steam.

According to the present invention a reheating system is provided having two stages of re-heating, in one (a) of which motive fluid in a superheated condition is caused to give up a portion of its superheat in reheating cooler motive fluid between two operative expansion stages, while in the other reheating stage (b) a portion only of the motive fluid employed for reheating in the first mentioned reheating stage (a) is again utilized for reheating cooler motive fluid between two expansion stages and is thereby condensed. All of the motive fluid supplied or available for supply to a prime mover may be employed to re-heat the motive fluid in the first mentioned reheating stage (a) or only a portion of such motive fluid may be employed for this purpose.

Motive fluid may be re-heated between two expansion stages by passing it first through reheating stage (b) and then through reheating stage (a), or the motive fluid may be re-heated between two expansion stages by passing it through reheating stage (a) and may be again re-heated between two subsequent expansion stages by passing it through reheating stage (b).

In some cases it may be desirable to divide the supply of superheated motive fluid available for delivery to a prime mover, a portion only being employed in reheating stage (a), a fraction of said portion being subsequently used directly as motive fluid in the prime mover while another fraction is passed to reheating stage (b) where it is further cooled and condensed.

The above and other objects are effected by my invention, as will be apparent from the following description and claim taken in connection with the accompanying drawing, forming a part of this application, in which:

Fig. 1 is a diagrammatic view of one embodiment of my invention; and,

Figs. 2 and 3 are diagrammatic views of modified embodiments.

In the arrangement shown in Fig. 1 the steam exhausted from a high pressure turbine 10 is passed in series through two reheaters *b*, *a* before being delivered to a low pressure turbine 11. The re-heater *a* is adapted to be heated by the main steam supply of the turbine plane which is delivered through pipe 12 in a highly superheated condition from a suitable source, such as a steam generator indicated diagrammatically at 13. After passing through the heating unit of re-heater *a*, the steam proceeds to the turbine 10 by way of pipe 14, from which a tapping pipe 15 conducts a portion of the steam to the re-heater *b*. This steam is condensed and drawn off and preferably returned as feed water to the generator by a pipe 16.

The steam to be re-heated passes from the turbine 10 to re-heater *b* through conduit 17, from re-heater *b*, to re-heater *a* through connection 18 and from re-heater *a* to the turbine 11 through conduit 19. In re-heater *b* the motive steam takes up the latent heat of vaporization of the tapped steam supplied through pipe 15 and is heated approximately to the saturation temperature of steam at the pressure prevailing in pipe 14 (i. e. at the inlet to the turbine 10), while in re-heater *a* it is further heated by the superheated steam supplied from the generator through 12.

The re-heater stage *a* may be termed the high temperature re-heater stage, and the stage *b* the lower temperature re-heater stage.

In a practical example, steam supplied from the generator 13 at a temperature of 850° F. and an absolute pressure of 565 lbs. per square inch may be cooled to 750° F. in passing through the heater *a* the pressure of the steam thereby falling to 537 lbs. per square inch absolute, in which condition it is supplied to the turbine 10. The tapped portion of steam drawn off and supplied to re-heater *b* also has this condition initially, but leaves said re-heater at a temperature of 476° F. The temperature of the motive steam passing through the connection 18 may be about 480° F., this temperature being approximately the mean of the temperatures of the steam in the pipes 17 and 19.

Assuming a condenser vacuum pressure of 29 in. (mercury gauge) for the exhaust of the low pressure turbine, a dry stage efficiency of 80% and 10% fall in pressure of the motive steam in the double re-heating process, it is calculated that the theoretical efficiency may be increased to approximately 1.035 times the efficiency obtainable by direct expansion from an initial pressure of 565 lbs. per square inch absolute and a temperature of 750° F.

It is found that the gain in efficiency varies with the pressure at which re-heating occurs and in the example given attains a maximum at approximately 50 lbs. per square inch absolute.

In some cases it may be advantageous to employ somewhat modified arrangements. Fig. 2 shows a scheme for use, for example, where it is desired to effect re-heating of the motive steam between a high pressure turbine 10 and an intermediate pressure turbine 21 and between the intermediate pressure turbine 21 and a low pressure turbine 11. In this case the re-heater *a* is arranged between turbines 10 and 21 and re-heater *b* between turbines 21 and 11. As before, the main supply of superheated steam passes through the heating unit of re-heater *a* where it is partially de-superheated, and a portion is tapped off and supplied to the heating unit of re-heater *b* where it condensed and preferably returned to the generator.

A further modified arrangement is illustrated in Fig. 3, wherein the steam supply pipe 26 from the generator 13 is tapped by a pipe 22 whereby a portion of the available steam supply is passed in a superheated condition through the heating unit *a* of a re-heater 23. A part of the steam leaving the heating unit *a* is returned by a pipe 24 to the inlet pipe 25 of turbine 10 while the remainder passes through the second heating unit *b* where it is further cooled and finally leaves by pipe 26 as condensate water. The motive steam leaving the turbine 10 passes in succession the heating units *b*, *a* of re-heater 23 and in so doing takes up first the latent heat of the steam condensed in unit *b* and secondly the heat given up in the de-superheating of the tapped steam which takes place in unit *a*. The portion of the tapped steam returned to the inlet pipe 25 mixes with the remainder of the steam supplied thereto from pipe 26 and thereby renders the temperature of the motive steam on admission to the turbine 10 somewhat less than the temperature at which it is supplied through pipe 26 upon the generator. It will be evident that with this arrangement an economy in steam piping may be effected, for example, in comparison with the example shown in Fig. 1.

Regulating valves 27, 28 serve to control the proportion of steam which is tapped off and employed for re-heating purposes, so that the re-heating effect and the temperatures may be properly adjusted. It will be evident that regulating valves may also be employed where desired for similar purposes in the examples previously described above.

As a general rule it is convenient to operate the plant so that the increase of temperature of the motive steam effected in each of the two re-heating stages (*a*) and (*b*) is approximately equal. While it is generally preferred in arrangements such as shown in Fig. 1

2 to employ re-heating stage (a) to re-heat the motive steam at higher pressure stages than the re-heater b, the arrangement may in some cases be reversed. Furthermore the arrangements may be otherwise modified or may be duplicated, for example, re-heating stages (a) and (b) arranged as shown in Fig. 1 or Fig. 3 may be employed to re-heat the motive steam at more than one stage of its expansion, for instance as a modification of the example shown in Fig. 2.

Whereas in the arrangements shown in the drawing it has been convenient to indicate means for re-heating the motive steam while passing between two turbine units it is to be understood that similar arrangements may be employed for re-heating motive steam between any appropriate expansion stages of one or more turbines or the like for the purpose of decreasing the wetness of the steam in the later stages of expansion and improving the economy of the plant generally.

While in the above description the action of steam in a turbine or turbines has been mainly referred to, it is evident that the re-heating system may be employed with advantage if other motive fluid which behaves in a similar manner to steam is employed.

While I have shown my invention in several forms, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be imposed thereupon as are imposed by the prior art or as are specifically set forth in the appended claim.

What I claim is:—

In an elastic fluid power plant, the combination of a source of superheated elastic motive fluid, a prime mover comprising a high pressure portion and a low pressure portion, a conduit providing communication between said source and the inlet of the high pressure portion of the prime mover, a valve in said conduit, means for reheating the motive fluid flowing from the high pressure portion of the prime mover to the low pressure portion comprising a lower temperature reheater stage having a heating unit and a higher temperature reheater stage having a heating unit through which said motive fluid flows successively, a second conduit communicating with the first conduit intermediate said source of motive fluid and said valve and with the heating unit of the higher temperature reheater stage for supplying superheated motive fluid to the latter, a third conduit communicating with the discharge end of said heating unit and the first conduit intermediate the valve therein and the inlet of the prime mover for returning a portion of the motive fluid flowing through said heating unit to the motive fluid supply of the prime mover, the heating unit of the lower temperature re-

heater stage communicating with the heating unit of the higher temperature reheater stage and receiving the remaining portion of the fluid discharged therefrom, the fluid flowing through the heating unit of the lower temperature reheater stage being condensed therein.

In testimony whereof, I have hereunto subscribed my name this ninth day of October, 1928.

KARL BAUMANN.