

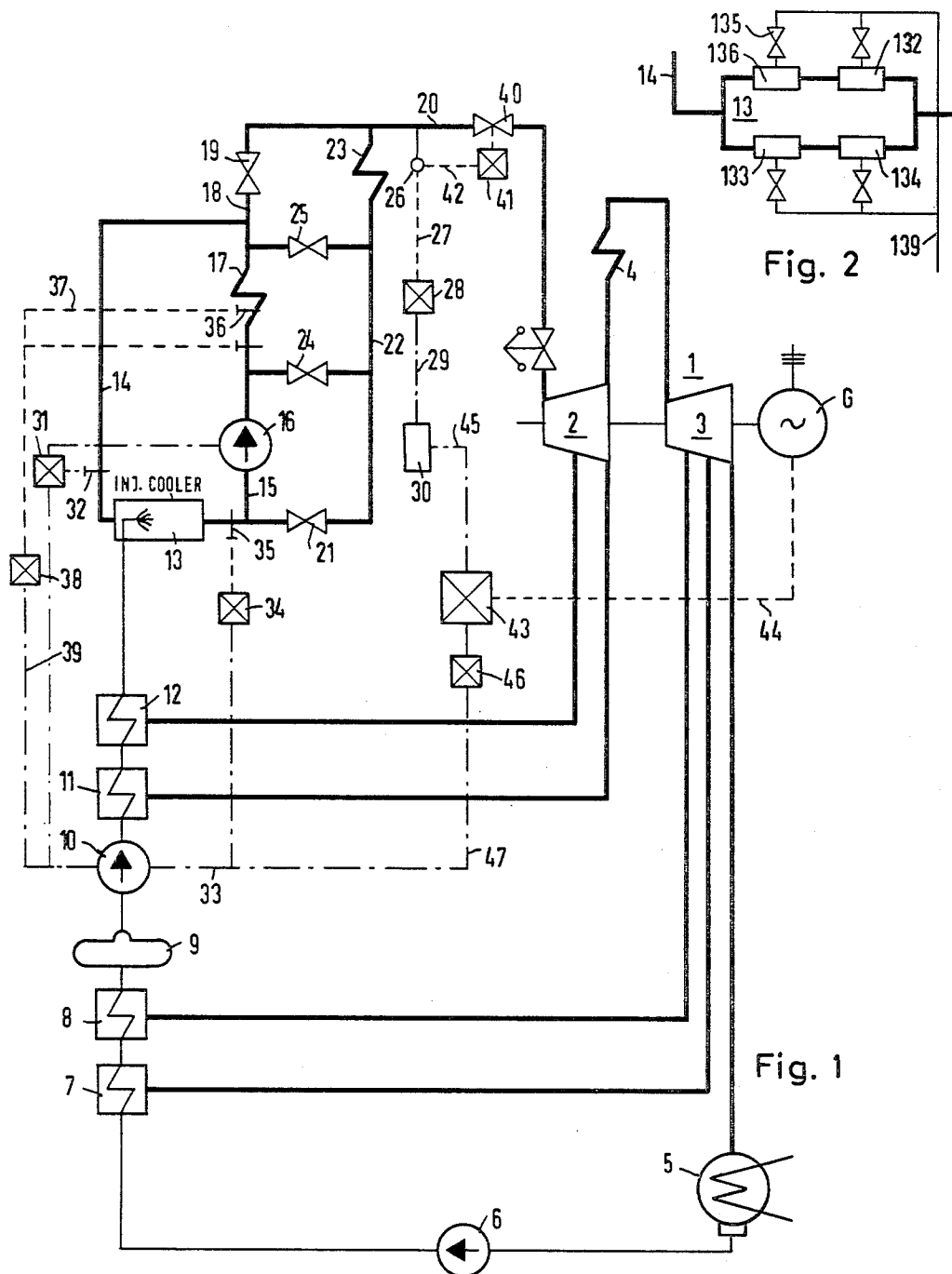
Dec. 3, 1968

W. BREDTSCHNEIDER ET AL

3,413,809

STEAM POWER PLANTS

Filed Sept. 27, 1966



1

3,413,809

STEAM POWER PLANTS

Walter Bredtschneider and Elmar Kefer, Erlangen, Germany, assignors to Siemens Aktiengesellschaft, Munich, Germany

Filed Sept. 27, 1966, Ser. No. 582,411
Claims priority, application Germany, Sept. 30, 1965,
S 99,851

9 Claims. (Cl. 60—104)

ABSTRACT OF THE DISCLOSURE

Steam power plant has a boiler circulating system including a live steam conduit, a return conduit, at least one injection cooler, and a heater for producing superheated live steam in the system which is fed in part to a prime mover through the live steam conduit and is returnable in part through the return conduit to the injection cooler before it is fed to the prime mover. Regulation of the system is afforded by a pressure sensor for measuring live steam pressure in the live steam conduit, the pressure sensor being operatively connected to the heater for regulating the same in accordance with the pressure of the live steam in the live steam conduit. Regulation of the system is also provided by two temperature sensors, one of which is disposed in the return conduit at a location thereof upstream from the injection cooler and operatively connected to the return conduit for regulating the flow of superheated steam through the return conduit in accordance with the temperature sensed thereby. The other temperature sensor is located downstream of the injection cooler and operatively connected to a feedwater supply system for the injection cooler for regulating the supply of feedwater to the injection cooler in accordance with the temperature sensed thereby.

Our invention relates to steam power plants.

In particular, our invention relates to a steam power plant which has a boiler which does not include an evaporator drum. The evaporation of the liquid operating fluid into steam is achieved in the system of our invention by way of the transfer of superheat from part of the hot steam which is returned into the system instead of being directed to the prime mover.

It is already known to evaporate the operating fluid into steam by returning a part of the superheated steam into the system. For example, the Loeffler boiler operates in this way. With this type of boiler, however, it is necessary to include in the boiler system an evaporator drum in which the feedwater is converted into steam. According to this known principle, a circulating pump draws saturated steam out of the steam chamber situated over the liquid in the unheated evaporator drum, this evaporator drum containing a body of liquid beneath the saturated steam therein. The circulating pump delivers the saturated steam to a superheater and the hot steam derived from the superheater is returned to the evaporator drum where the hot steam is blown into the water chamber to give up its superheat to the water and thus provide a supply of saturated steam. A part of the steam which is derived from the superheater is taken out of the circulating system downstream of the superheater and delivered to the prime mover. The water which is evaporated into steam in the evaporator drum is replaced by feedwater which before reaching the evaporator drum is preheated as much as possible.

Boilers which operate according to the latter principle require a relatively large evaporator drum and in many cases a plurality of these drums are required so as to guarantee that all of the superheat is taken from the hot

2

steam which is blown into the evaporator drums and so as to guarantee that no water is drawn out of the evaporator drums together with the saturated steam, so that the circulating pump will operate properly and will not be damaged.

It is a primary object of our invention to provide a steam power plant which operates according to a similar principle but which is capable of eliminating the above disadvantages of the Loeffler boiler.

In particular, it is an object of our invention to provide a steam power plant which does not require any evaporator drums.

Furthermore, it is an object of our invention to provide a steam power plant which is capable of operating at pressures greater than the critical pressure.

In accordance with our invention, the evaporating of the operating liquid into steam is also brought about by utilizing the superheat of a part of the steam taken from the superheater and returned back into the circulating system of the boiler. However, instead of using an evaporator drum, the steam which is returned into the system from the superheater is directed into one or more injection cooling units where in the case of a plurality of injection cooling units the latter are connected either in parallel or in series or in parallel and in series. This latter structure provides for the system of our invention an injection cooling means into which feedwater is injected in the form of a spray, and the injection cooling means of our boiler receives the superheated steam which is returned into the system from the superheater so as to transfer the superheat from the latter to the injected feedwater spray so as to convert the latter into steam. The amount of feedwater which is injected into the injection cooling means of our invention is controlled in such a way that there is in the steam circulating system at the inlet of the circulating pump steam which is approximately at the temperature of saturated steam. By providing an injection cooling means made up of a plurality of injection cooling units which are connected in series, the evaporation of the operating fluid into steam can take place in a plurality of stages so that increasing temperature values permit relatively low saturated steam conditions to be provided at the lowest temperature stage while at the upper stages the presence of dry steam is assured.

The steam which is delivered to the prime mover can be taken from the system either upstream or downstream of the circulating pump and in some cases can be brought to the desired temperature in an isolated superheater. In this way the amount of steam which is circulated in the system can be limited to the required minimum. Of course, it is also possible to direct the steam to the prime mover through a second superheater which is situated downstream of a first superheater so as to provide separate additional superheating of the steam which is delivered to the prime mover.

Our invention is illustrated by way of example in the accompanying drawings in which the essential components of the system of our invention are illustrated in a highly simplified and schematic manner and in which:

FIG. 1 illustrates the entire system; and

FIG. 2 shows in a schematic manner an injection cooling means of our invention composed of a plurality of injection cooling units connected in parallel and in series.

Referring now to FIG. 1, there is shown therein a prime mover 1 operatively connected with a generator G for driving the latter. The prime mover 1 in the illustrated example is a turbine having a high pressure section 2 and a low pressure section 3. An intermediate superheater 4 is connected between the turbine sections 2 and 3.

From a turbine condenser 5 condensate is pumped by a condensate pump 6 to the low pressure preheating units 7 and 8 in which the operating fluid in the form of a liquid is preheated before reaching the feedwater container 9. A feedwater supply means of the boiler circulating system shown in FIG. 1 is formed by the feedwater pump 10 which pumps the operating fluid from the container 9 through the high pressure preheating units 11 and 12 to an evaporator which in accordance with our invention is formed by an injection cooling means 13.

The injection cooling means 13 of our invention may be formed by a single unit as shown schematically in FIG. 1, or, as indicated in FIG. 2, a plurality of injection cooling units may be connected together either in parallel or in series or in parallel and in series. Thus, FIG. 2 shows one pair of injection cooling units 133 and 134 connected in series with respect to each other and a second pair of units 132 and 136 also connected in series with respect to each other, while these two pairs of units are connected in parallel with each other as indicated in FIG. 2. The feedwater is supplied to the interior of the injection cooling units in the form of a liquid spray, as shown schematically in FIG. 1, and in FIG. 2 the feedwater is delivered through the conduit 139 and through the series of the valves 135 into the several units, respectively, to be received therein in the form of liquid sprays.

The operating fluid of the circulating system shown in FIG. 1 has different conditions at different parts of the system, these different conditions ranging all the way from the water which is preheated to superheated steam, and the system includes a return conduit means 14 which serves to return into the system some of the superheated steam which otherwise would be delivered to the prime mover 1. The return conduit means 14 communicates with the interior of the injection cooling means 13 so as to deliver into the latter superheated live steam which thus gives up its superheat to the feedwater spray in the injection cooling means of our invention. The circulating system includes downstream of the injection cooling means 13 a conduit 15 which takes the fluid from the injection cooling means 13 and delivers it to a circulating pump 16 which forms a circulating means for circulating the operating fluid through the system. The fluid which the pump 16 draws from the injection cooling means 13 is in the form of saturated steam, and this saturated steam is pumped by the pump 16 into a superheater 17. The fluid which flows out of the superheater 17 downstream of the latter is divided into a pair of branches one of which is formed by the return conduit means 14 and the other of which is formed by a live steam conduit means 20 which delivers the superheated live steam from the superheater 17 to the turbine 1. The live steam conduit means 20 has a section 18 adjacent the superheater 17 and to which the return conduit means 14 is connected, and downstream of its connection with the conduit 14 the section 18 of the conduit 20 is provided with a valve 19 which is open so that the steam will flow from the superheater 17 through the live steam conduit 20 to the turbine.

It is also possible to provide, as pointed out above, an isolated superheater 23 through which the operating fluid is directed so as to provide live steam through the conduit 20 for the turbine 1. For this purpose the valve 19 is closed and instead a valve 21 is opened so as to direct the saturated steam which flows out of the injection cooling means 13 along a conduit 22 and through the isolated superheater 23 into the live steam conduit 20 for delivery to the turbine 1. The operating fluid can also be directed through the superheater 23 by opening a valve 24 which thus enables the operating fluid to be delivered to the isolated superheater 23 after it has been pumped by the circulating pump 16. Finally, it is also possible to use the superheater 23 as a second superheater connected in series with the superheater 17 and receiving the operating

fluid therefrom. For this purpose the valve 25 may be opened, so that in this way the operating fluid will flow first through the superheater 17 and then through the superheater 23 before reaching the live steam conduit 20.

In order to control the boiler, the boiler heating means 30 which is referred to below is controlled in accordance with the pressure of the live steam while the amount of operating fluid circulated by the circulating means 16 is controlled in accordance with the temperature of the steam in the return conduit 14 just before this steam is introduced into the injection cooling means 13, and the amount of feedwater which is supplied by the feedwater supply means 10 is controlled in accordance with the temperature in the circulating system just downstream of the injection cooling means 13. For this purpose, a pressure measuring station 26 has pressure measuring structure operatively connected with the live steam conduit 20 for determining the pressure of the live steam, and in accordance with the pressure sensed by the pressure-sensing means a signal is transmitted through a signal line 27, as shown schematically in FIG. 1, to provide an impulse at a heating means regulator 28. This regulator 28 is operatively connected with a boiler heater means 30 as schematically indicated by the operative connection line 29, and in accordance with the information received by the regulator 28 from the pressure-sensing means 26 the flow of fuel and combustion air to the heater 30 will be regulated.

The circulating means 16 is controlled by a regulator 31 which is operatively connected therewith as schematically indicated in FIG. 1. A temperature-sensing means 32 communicates with the return conduit means 14 just upstream of the injection cooling means 13 to sense the temperature of the hot steam just before it enters into the injection cooling means 13, and in accordance with the temperature sensed by the temperature sensing means 32, a signal will be transmitted to the regulator 31 so that the latter will regulate the pump 16 according to the temperature of the steam entering the injection cooling means 13.

The feedwater supply means 10 is controlled by the control connections 33 schematically indicated in FIG. 1, and among the different controls for the feedwater supply means 10 is a regulator 34 which is connected through the operative connection 33 with the pump 10 and which is in turn connected with a temperature-sensing means 35 which delivers to the regulator 34 a signal by means of which the regulator 34 controls the feedwater supply means 10. This temperature-sensing means 35 communicates with the boiler circulating system just downstream of the injection cooling means 13 so as to sense the temperature of the saturated steam drawn out of the latter by the pump 16.

Inasmuch as it becomes increasingly difficult at high operating pressures, particularly at pressures which are higher than the critical pressure, to provide a temperature control in the region of the saturated steam conditions, it is possible to control the amount of feedwater sprayed into the injection cooling means in such a way that at a predetermined part of the circulating system, particularly at the inlet region of the superheater 17, a predetermined temperature is maintained so that with this type of control the inlet region of the superheater 17 has a constant temperature. In the illustrated example there is at the inlet region of the superheater 17 a temperature sensing means 36 which delivers a signal through the line 37 to a regulator 38. This regulator 38 acts through the operative connecting line 39 on the feedwater pump 10 or on a control valve which controls the amount of feedwater so as to derive from the pump 10 an operation which will maintain a constant temperature at the inlet region of the superheater 17.

A particularly simple control for the boiler can be achieved if the circulating pump 16 runs at only a single speed of rotation so that the amount of fluid which is

circulated through the system is not controlled by changing the speed of rotation of the pump, so that in this case there is no adjustable transmission gearing or the like for regulating the speed of operation of the circulating means 16. Where the circulating means 16 thus operates at a constant speed, it is sufficient in most cases simply to regulate the supply of feedwater in such a way that the amount of feedwater injected into the injection cooling means becomes greater in the case where the steam temperature in the circulating system at the entrance into the injection cooler increases, while if the steam temperature at the entrance to the injection cooling means decreases the amount of feedwater injected into the injection cooler is correspondingly reduced. In this way it is possible to provide at the inlet of the injection cooling means which receives the steam from the return conduit 14 a constant temperature. The regulator 31 can also be used in this case and it will operate in accordance with the constant temperature which is sensed by the temperature-sensing means 32. With this type of control the temperature at the outlet of the injection cooling means 13, where the temperature-sensing means 35 is shown in FIG. 1, will then be automatically determined so as to be at different elevations in accordance with the particular loading conditions.

Under special operating circumstances it may be of advantage to provide in the live steam conduit means 20 a pressure valve 40 capable of maintaining a predetermined pressure in the live steam conduit means 20 and capable of being actuated through a regulator 41 which receives a signal through the connection 42 from the pressure-sensing means 26 so that in response to the signal received therefrom the valve 40 can be automatically regulated to maintain a predetermined constant pressure in the conduit 20. In this case the heating of the boiler can be regulated in accordance with the steam requirements. For this purpose the control includes a signal transmitter 43 which transmits a signal indicative of the magnitude of the load, and this load-signal transmitter 43 can either be regulated by hand or according to a predetermined program either through remote control signals or in correspondence with the electrical power 44 delivered by the generator G. The load-signal transmitter 43 is operatively connected by a control connection 45, schematically indicated in FIG. 1, to the boiler heater means 30 while a feedwater regulator 46 also receives a signal from the transmitter 43 and is operatively connected by way of the schematically indicated connection 47 with the control 33 for the feedwater supply means 10, so that in this way the feedwater supply is also controlled in accordance with a signal transmitted by the load-signal transmitter 43.

We claim:

1. In a steam power plant, a prime mover, live steam conduit means, heater means for producing superheated live steam in the plant traversible through said live steam conduit means, said live steam conduit means communicating with said prime mover for feeding superheated live steam to said prime mover for driving the latter, injection cooling means for receiving feedwater in the form of a spray which is injected into said injection cooling means, return conduit means communicating with said live steam conduit means and with said injection cooling means for returning a portion of the superheated live steam to said injection cooling means before the latter portion of the superheated live steam reaches said prime mover so that the superheated live steam received in said injection cooling means from said return conduit means gives up its heat to said feedwater spray injected into said injection cooling means to convert the spray in said injection cooling means to hot steam, and regulating means comprising pressure-sensing means for measuring live steam pressure in said live steam conduit means, said pressure-sensing means being operatively connected to said heating means for regulating the same in accordance with the pressure of the live

steam in said live steam conduit means, first temperature sensing means disposed in said return conduit means at a location thereof upstream from said injection cooling means and operatively connected to said return conduit means for regulating the flow of superheated live steam through said return conduit means in accordance with the temperature sensed thereby, and second temperature sensing means located downstream of said injection cooling means and operatively connected to a feedwater supply system for said injection cooling means for regulating the supply of feedwater to said injection cooling means in accordance with the temperature sensed thereby.

2. The combination of claim 1 and wherein said injection cooling means includes a single injection cooling unit.

3. The combination of claim 1 and wherein said injection cooling means comprises a plurality of injection cooling units connected in parallel.

4. The combination of claim 1 and wherein said injection cooling means comprises a plurality of injection cooling units connected in series.

5. The combination of claim 1 and wherein said injection cooling means comprises a plurality of injection cooling units connected in parallel and in series.

6. The combination of claim 1 and wherein a superheater means communicates with said live steam conduit means for supplying live superheated steam thereto, said superheater means having an inlet region, feedwater supply means communicating with said injection cooling means for supplying feedwater thereto, and control means connected on the one hand with said injection cooling means downstream thereof and on the other hand with said inlet region of said superheater means for controlling said feedwater supply means to maintain the temperature of the fluid at said inlet region of said superheater means constant.

7. In a steam power plant, a prime mover, live steam conduit means communicating with said prime mover for feeding superheated live steam to said prime mover for driving the latter, injection cooling means for receiving feedwater in the form of a spray which is injected into said injection cooling means, return conduit means communicating with said live steam conduit means and with said injection cooling means for returning a portion of the superheated live steam to said injection cooling means before the latter portion of the superheated live steam reaches said prime mover so that the superheated live steam received in said injection cooling means from said return conduit means gives up its heat to said feedwater spray injected into said injection cooling means to convert the spray in said injection cooling means to hot steam, said live steam conduit means, said return conduit means, and said injection cooling means being included in a boiler circulating system, said boiler circulating system circulating an operating fluid composed in part of feedwater and in part of steam, heater means for heating a part of said system so as to produce the superheated live steam returnable in part to said injection cooling means through said return conduit means, pressure-sensing means communicating with said system for sensing the fluid pressure thereof, said pressure-sensing means being operatively connected with said heater means for controlling the latter according to the fluid pressure of the system, circulating means operatively connected with said system for circulating a given amount of fluid therethrough, feedwater supply means communicating with said system for supplying a given amount of feedwater thereto, and a pair of temperature-sensing means operatively connected with said circulating means and said feedwater supply means, respectively, for controlling them according to the temperatures sensed by said pair of temperature-sensing means, respectively, the temperature-sensing means which is operatively connected to said circulating means for controlling the latter being operatively connected with said return conduit means upstream of said injection cooling means for sensing the temperature in said return conduit

7

means to control said circulating means according to the latter temperature, and the temperature-sensing means which is operatively connected with said feedwater supply means communicating with said circulating system downstream of and adjacent to said injection cooling means for sensing the temperature in the system downstream of and adjacent to said injection cooling means to control said feedwater supply means according to the latter temperature.

8. The combination of claim 7 and wherein a superheater means forms part of said system and is situated downstream of said injection cooling means for receiving steam therefrom and upstream of said live steam conduit means for delivering superheated live steam thereto, said superheater means having an inlet region, and third temperature-sensing means communicating with said inlet region of said superheater means for sensing the temperature of the fluid at said inlet region, said third temperature-sensing means being operatively connected with said feedwater supply means and said temperature-sensing means which senses the temperature of the fluid in the system downstream of and adjacent to said injection cooling means controlling said feedwater supply means to maintain constant the temperature sensed by said third temperature-sensing means.

9. In a steam power plant, a prime mover, live steam conduit means communicating with said prime mover for feeding superheated live steam to said prime mover for driving the latter, injection cooling means for receiving feedwater in the form of a spray which is injected into said injection cooling means, return conduit means communicating with said live steam conduit means and with said injection cooling means for returning a portion of the superheated live steam to said injection cooling means before the latter portion of the superheated live steam reaches said prime mover so that the superheated live

8

steam received in said injection cooling means from said return conduit means gives up its heat to said feedwater spray injected into said injection cooling means to convert the spray in said injection cooling means to hot steam, said live steam conduit means, said return conduit means, and said injection cooling means being included in a boiler circulating system, circulating means operatively connected with said system for circulating a constant amount of fluid therethrough so that said circulating means need not be regulated, feedwater supply means communicating with said system for supplying feedwater thereto, means for producing the superheated live steam in said system returnable in part through said return conduit means to said injection cooling means, and temperature-sensing means communicating with said return conduit means adjacent to said injection cooling means for sensing the temperature of the fluid entering said injection cooling means through said return conduit means, said temperature-sensing means being operatively connected with said feedwater supply means for controlling the amount of feedwater supplied thereby according to the temperature sensed by said temperature-sensing means.

References Cited

UNITED STATES PATENTS

2,702,531	2/1955	Epley	122—479
3,139,869	7/1964	Koch	122—479

FOREIGN PATENTS

395,189	7/1933	Great Britain.
399,937	10/1933	Great Britain.

MARTIN P. SCHWADRON, *Primary Examiner.*

CARROLL B. DORITY, *Assistant Examiner.*