Jan. 19, 1960 A. BURI 2,921,441

FEED WATER PREHEATING SYSTEM FOR STEAM POWER PLANTS

Filed Dec. 13, 1954 2 Sheets-Sheet 1

Fig. 1.

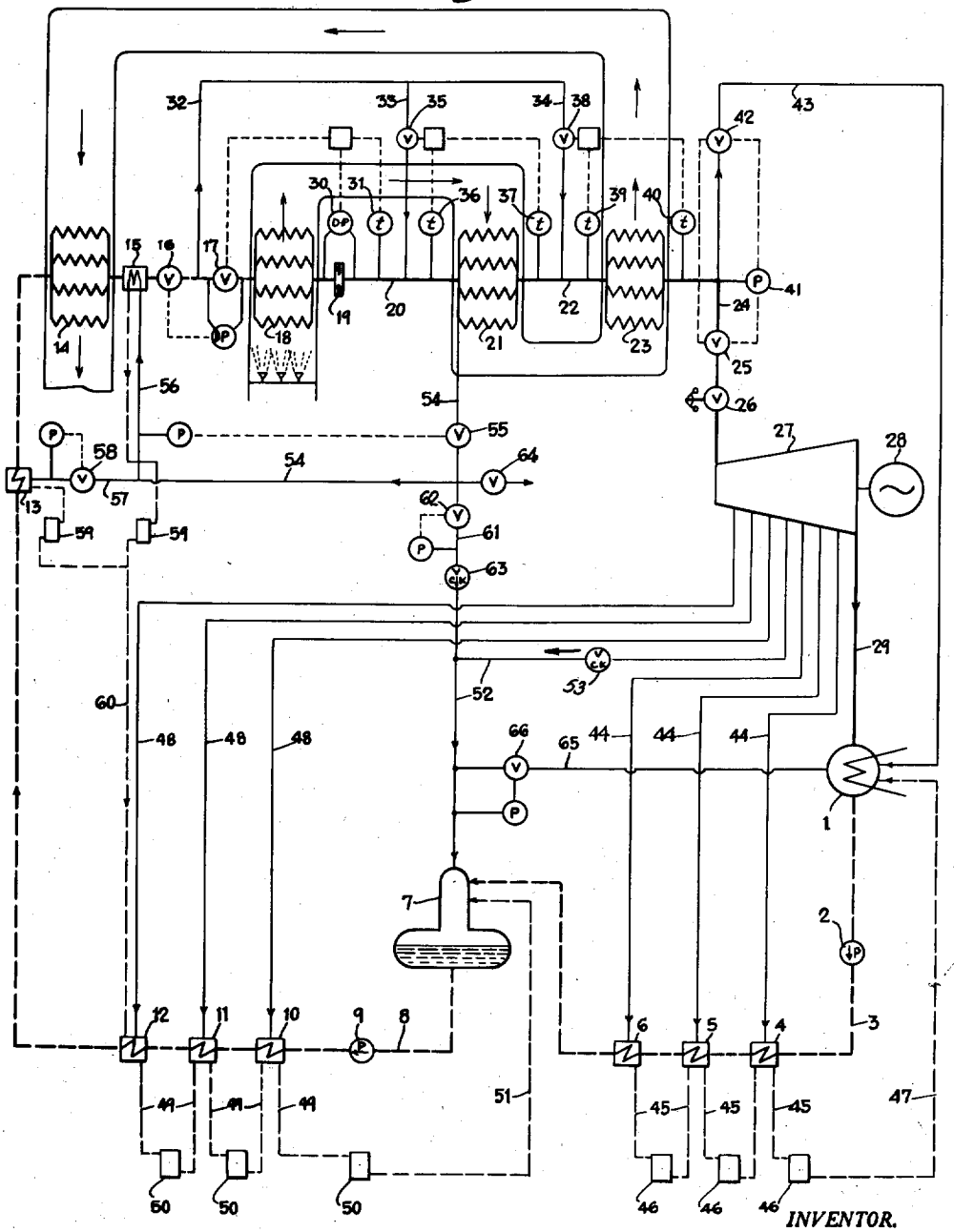

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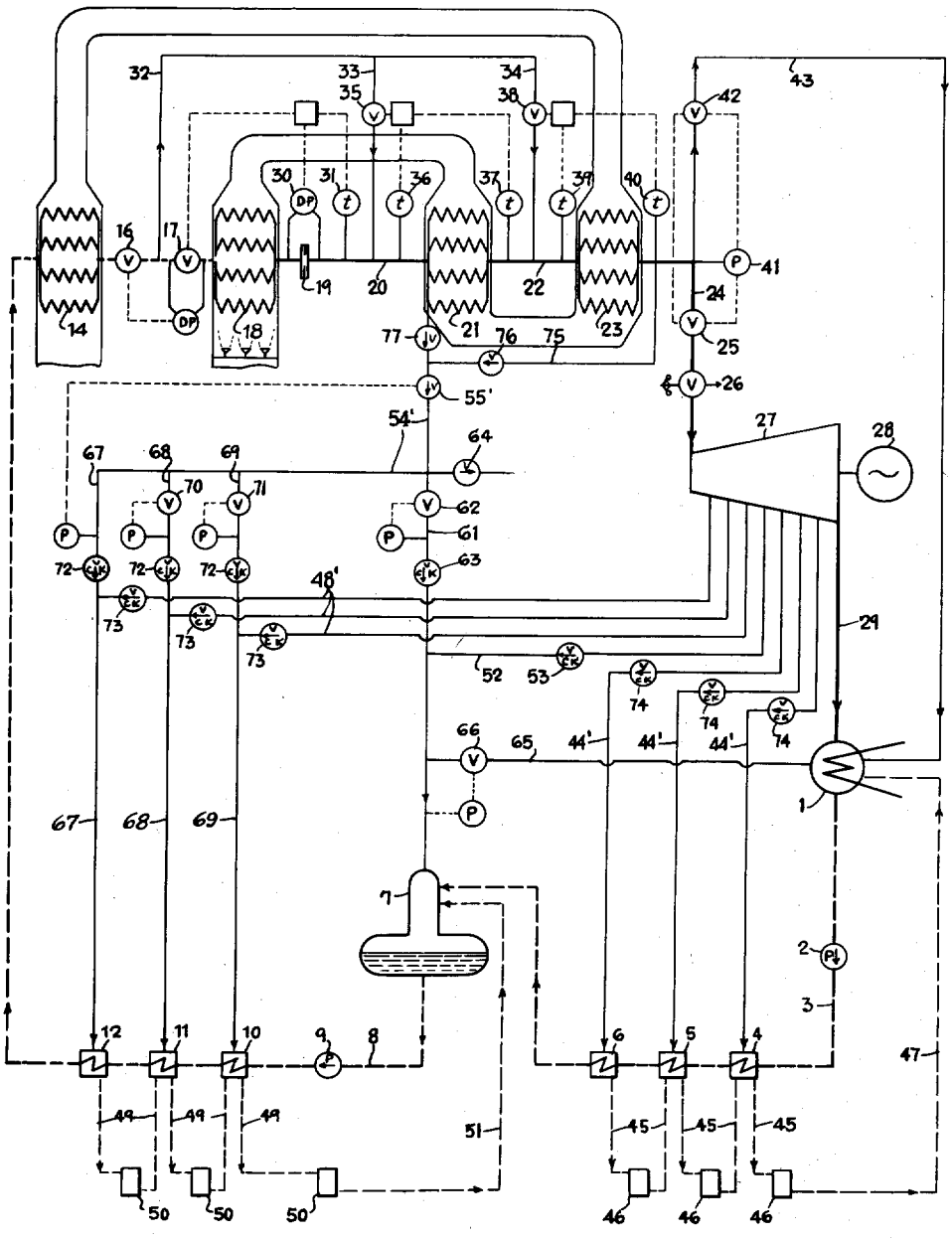
Fig. 2.



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FEED WATER PREHEATING SYSTEM FOR STEAM POWER PLANTS

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4 Claims. (Cl. 60—67)

The present invention relates to a method for operating a steam power plant including a forced flow steam generator supplying a turbine plant, and feed water preheaters heated by the operating medium of the plant, and to a steam power plant for performing the method.

A main feature of the present invention is the selective heating of the feed water by operating medium which is bled from the turbine plant during normal operation, and the heating of the feed water by operating medium which is taken from the tube system of the forced flow steam generator during starting of the plant and between the inlet and the outlet of the tube system during periods of low loads on the turbine plant.

In the following description of the invention, the terms "water" and "steam" are used for designating the operating medium. The invention, however, is not limited to water and steam as operating medium, but applies to methods and plants which use any suitable operating medium in liquid and vapor state.

It is a well-known fact that preheating of the feed water considerably increases the thermal efficiency of a steam power plant. It has been proposed to bleed steam from individual turbine stages and to use this steam for preheating the feed water on its way to the steam boiler. The conventional methods are of advantage during normal operation of the steam power plant, but are of little advantage at partial loads. The pressure in the individual turbine stages is approximately proportionally reduced if the amount of steam flowing through the turbine is reduced. This causes lowering of the temperature at which the operating medium condenses in the feed water preheaters where it transfers its heat to the feed water. For this reason, the effect of preheating the feed water is reduced during periods of reduced load on the turbine. It is an object of the present invention to overcome this disadvantage of conventional systems by using steam diverted from the tube system of the steam generator for heating the feed water preheaters during periods of low load on the turbine.

The operating medium which is diverted from the tube system of the steam generator must be taken at a point where it has already reached a suitable temperature. The point where the medium for heating the feed water preheaters is taken from the steam generator is preferably downstream of an intensely heated section of the tube system, i.e. of a section which is located within or close to the combustion chamber. This section of the heating surface of the steam generator must be well cooled, so that it is not damaged by overheating during periods of low load, when the amount of operating medium required by the turbine is insufficient to properly cool the sections which are exposed to radiant heat and very hot combustion gases. If, however, during periods of low load, operating medium is taken downstream of the endangered heating surface sections of the steam generator for heating the feed water preheaters, as proposed by the present invention, these sections are always

provided with an amount of operating medium which is ample for cooling the sections.

The method according to the invention is also of advantage during starting of the steam power plant, so long as the turbine is at a standstill and does not receive steam or vapor. During starting, the method according to the invention affords quick heating of the operating medium without wasting the heat absorbed by the operating medium, which is conducted through the tube system of a forced circulation steam generator, because a portion of the heated operating medium transfers its heat in the feed water preheaters to the liquid flowing into the steam generator before the operating medium is conducted into a condenser, as is the conventional operation when starting forced flow steam generators.

The amount of operating medium diverted from the tube system of the steam generator may be controlled in accordance with the pressure prevailing in the feed water preheaters which are heated by the diverted operating medium. This control is preferably operated in such manner that, during low load operation and during starting of the plant, a predetermined adjustable pressure is maintained in each of the feed water preheaters through which flows the heating medium taken from the steam generator. If, for example, a greater amount of heating steam is supplied to a feed water heater than can be condensed, considering the temperature of the feed water to be heated and the pressure in the preheater, the pressure in the latter rises and the amount of heating steam taken from the steam generator is throttled. During starting of the plant, the pressure to be maintained in the feed water heaters is preferably adjusted to the maximum pressure for which the feed water heaters are designed. Thereby, an optimum amount of medium can be taken from the tube system of the steam generator, the heat content of the operating medium being transferred to the water fed into the steam generator.

It is within the scope of the present invention to heat different feed water preheaters by simultaneously bleeding operating medium from the turbine plant and by bleeding operating medium from the tube system of the steam generator, so that the operation for normal operation overlaps the operation for low load operation.

The possibility provided by the present invention of conducting operating medium into the same feed water preheaters from the turbine plant during normal operation, and from the tube system of the steam generator during starting and low load operation is of particular advantage. Since bleeder steam heated feed water preheaters are usually present in steam power plants, the method according to the invention calls only for additional conduits and control apparatus.

A steam power plant for performing the method according to the invention includes bleeder steam conduits connecting the turbine plant with the primary side of the feed water preheaters and a conduit connected with the tube system of the steam generator at a point downstream of the tube sections which are arranged within or close to the combustion chambers and upstream of the tube sections which are heated by connection, the last mentioned conduit being also connected with the primary side of the feed water preheaters, and control devices in the aforesaid conduits for effecting switching of the heating steam supply to the feed water preheaters from the turbine plant to the tube system of the steam generator, whenever preheating is reduced due to insufficient supply of heating steam from the turbine plant.

A valve may be inserted in the conduit connected with the tube system of the steam generator, which valve is actuated according to the pressure in the feed water heater which is next to the steam generator with respect to the

flow of the feed water. It is recommended to branch off conduits from the conduit connected to the tube system of the steam generator downstream of the aforementioned valve and to connect the branch conduits with the other feed water preheaters, a valve being provided in each of the branch conduits, the valve being controlled in accordance with the pressure in the respective feed water preheater. Effective preheating of the feed water by the operating medium of the plant may render the conventional flue gas heated feed water preheater or economizer ineffective, because it can no longer cool the flue gases. It will therefore be preferable in many cases to arrange the flue gas heated feed water heater or economizer not as the last feed water preheater, but to interpose the economizer between two feed water preheaters which are heated by the operating medium of the plant.

The number of the feed water preheaters can be reduced by individually connecting the conduit connected with the tube system of the steam generator and the branch conduits of this conduit with the bleeder conduits and by providing a valve in the conduit which is connected with the steam generator and in each branch conduit for controlling the amount of operating medium taken from the steam generator, so that a constant adjustable pressure is maintained in the feed water preheaters, a flow control means being provided in each bleeder conduit, which control means is adapted to open, if the steam pressure in the respective bleeder conduit exceeds the pressure which is maintained in the respective feed water prehater, in which case the valves in the conduit connected to the steam generator and in the branch conduits are closed.

The term "feed water preheater" used in the present description of the invention covers any arrangement in which feed water can be preheated. This includes surface or indirect preheaters as well as mixing or direct preheaters. The latter include a feed water reservoir which can also be used for preheating feed water by conducting operating medium from the tube system of the steam generator or from the turbine plant directly into the reservoir. It is immaterial whether or not the feed water reservoir is provided with a degasifier.

The invention is of particular advantage with respect to the feed water reservoir. Since the steam pressure in the dome of the reservoir receptacle is maintained above a predetermined adjustable minimum value, all devices which are used in conventional plants for preventing undesirable lowering of the steam pressure can be omitted.

The novel features which are considered characteristic of the invention are set forth with particularity in the appended claims. The invention itself however and additional objects and advantages thereof will best be understood from the following description of embodiments thereof when read in conjunction with the accompanying drawing, in which:

Fig. 1 is a diagram of a steam power plant in which a group of feed water preheaters can be heated by means of bleeder steam from the turbine plant and a second group of feed water preheaters can be heated by means of operating medium taken from the tube system of the steam generator;

Fig. 2 is a diagrammatic illustration of a steam power plant in which a group of feed water preheaters can be heated by means of bleeder steam as well as by means of operating medium from the tube system of the steam generator.

The same numerals designate the same parts in both figures.

Referring more particularly to Fig. 1 of the drawing, feed water is conducted from a condenser **1** through a condensate pump **2** in a conduit **3**, and through feed water preheaters **4**, **5**, and **6** into a feed water reservoir **7**. A feed pump **9** pumps feed water from the reservoir **7** through a conduit **8** into feed water preheaters **10**, **11**, **12**, and **13**, and from the latter into a feed water heater **14** which is heated by flue gas from the steam generator.

From the flue gas heated heater or economizer **14**, the operating medium flows through an additional feed water preheater **15**, through a differential pressure controlled valve **16** and through a feed valve **17** into a tubular heating section **18** of the steam generator in which section the liquid is further heated and converted into vapor or steam and which section may be used for lining the combustion chamber of the steam generator. The operating medium flows from the tubular heating section **18** through a conduit **20**, in which a measuring orifice plate **19** is inserted, to a tubular heating section **21**, which constitutes a first superheater, and subsequently through a conduit **22** into a tubular heating section **23**, which forms a final superheater. The superheated steam from the superheater **23** is conducted through a conduit **24**, a valve **25**, and a turbine speed controlled valve **26** into a turbine **27** which drives an electric generator **28**. The turbine **27** may consist of several parts, the steam being resuperheated in the conventional manner between the individual parts. The operating medium exhausting from the turbine **27** is conducted through a conduit **29** into the condenser **1**.

The amount of steam produced in the steam generator and the steam temperature are controlled in the conventional manner. The feed valve **17** is controlled by a device **30** which is responsive to the pressure difference upstream and downstream of the orifice plate **19**, and by a device **31** which is responsive to the temperature of the operating medium leaving the heating section **18**. The pressure differential valve **16** is controlled according to the differenec between the pressure of the liquid at the inlet and at the outlet of the feed valve **17**, the valve **16** maintaining a desired pressure difference. A conduit **32** is branched off between the valves **16** and **17**, so that operating medium may be conducted through a conduit **33** into the operating medium leaving the heating section **18** and through a conduit **34** into the operating medium leaving the heating section **21**, by-passing the sections **18** and **21**. The operating medium flowing through the conduit **33** is controlled by a valve **35** which is actuated by conventional devices **36** and **37** which are responsive to the temperature of the operating medium upstream and downstream of the heating section **21**. The amount of operating medium flowing through the conduit **34** is controlled by means of a valve **38** which is actuated by conventional devices **39** and **40**, which are responsive to the temperature of the operating medium upstream and downstream of the heating section **23**. The steam valve **25** is controlled by a conventional device **41** which is responsive to the pressure in the steam main **24** and which closes the steam valve **25** when the steam pressure at the outlet of the steam generator is too low for operating the turbine. In that case, the device **41** opens a by-pass valve **42** in a by-pass conduit **43** for flowing the operating medium from the steam generator directly into the condenser **1**. This operation is applied when the steam generator is started.

During normal operation, bleeder steam from the turbine **27** flows through conduits **44** into the feed water preheaters **4**, **5**, and **6**, and condenses therein, while transferring its heat to the feed water. The condensate is conducted through conduits **45** in which steam traps **46** are inserted, and through a conduit **47** into the condenser **1**. Likewise, bleeder steam is conducted from the turbine **27** through bleeder conduits **48** into the high pressure feed water preheaters **10**, **11**, and **12**. The bleeder steam is condensed in the high pressure feed water preheaters while transferring heat to the feed water, the condensate being removed through conduits **49** containing steam traps **50**, and conducted through a conduit **51** into the feed water reservoir **7**. A bleeder conduit **52** containing a check valve **53** is directly connected with the feed water reservoir **7**.

If the feed water is not sufficiently heated by bleeder stream, as is the case during starting of the plant and at low loads, operating medium can be taken from the tube

system of the steam generator, preferably downstream of the most heated zone of the tube system, through a conduit 54. A valve 55 inserted in the conduit 54 is controlled by the pressure in the feed water preheater 15 or in a conduit 56, through which heating medium is supplied to the feed water preheater 15, and which is branched off the conduit 54. A second branch conduit 57 connected with the conduit 54 supplies operating medium from the steam generator to the feed water preheater 13, the operating medium flowing through the conduit 57 being controlled by a valve 58 which is controlled in accordance with the pressure in the preheater 13. The operating heating medium condensed in the preheaters 13 and 15 is conducted through steam traps 59 and a conduit 60 into the feed water preheater 12 and therefrom through the preheaters 11 and 10 into the feed water reservoir 7.

The pressure control devices actuating the valves 55 and 58 are set for a predetermined pressure. If the load on the turbine 27 is reduced, the pressure in the bleeder conduits 48 and 44 drops approximately proportionally to the reduction of the amount of steam flowing through the turbine 27. Consequently, the steam condenses in the feed water preheaters at a lower temperature corresponding to the lower pressure, reducing heating of the feed water and the thermal efficiency of the plant. If the feed water has a lower temperature, the difference between the temperature of the medium in the tube system of the steam generator and of the feed water flowing through the feed water preheaters 13 and 15 is increased, so that the feed water can absorb a greater amount of heat. This causes condensation of a greater amount of the operating medium coming from the steam generator, so that the pressure in the preheaters 13 and 15 is lowered. This causes farther opening of the valves 58 and 55, so that at a reduction of the preheating effect of the bleeder steam, preheating by operating medium taken from the steam generator is automatically increased. If the steam generator is operated at subcritical pressure, the valve 55 may be omitted, because the steam trap 59 receiving heating medium from the preheater 15 has an effect similar to that of the pressure controlled valve 55.

A third branch conduit 61 is connected with the conduit 54 which is connected with the tube system of the steam generator, the conduit 61 being connected with the bleeder conduit 52. A valve 62 is inserted in the conduit 61 which valve is controlled in response to the pressure in the conduit 61 downstream of the valve 62, which is the pressure prevailing in the feed water reservoir 7. The conduit 61 is also provided with a check valve 63 downstream of the valve 62. The pressure control of the valve 62 maintains, in cooperation with the check valves 53 and 63, a predetermined adjustable pressure in the feed water reservoir 7, unless the steam in the bleeder conduit 52 has a pressure which exceeds the pressure to be maintained by the valve 62. In that case, the valve 62 and the check valve 63 are closed. If the pressure of the bleeder steam in the conduit 52 drops below the predetermined pressure to be maintained by the valve 62, the check valve 53 closes, and the valve 62 and the check valve 63 are opened, so that the pressure in the feed water reservoir 7 remains substantially constant. There is no danger that the pressure in the feed water reservoir drops below the atmospheric pressure, in which case air may enter the tube system.

For cases of emergency, a blow-off valve 64 is connected with the conduit 54. A blow-off conduit 65 is connected with the conduit 52 and with the condenser 1. The blow-off conduit 65 contains a valve 66 which opens if the pressure in the reservoir 7 exceeds a predetermined value.

The power plant illustrated in Fig. 2 has the same fundamental elements as the power plant shown in Fig. 1. The conduit 54' which is connected with the tube system of the steam generator, however, does not supply heat to separate feed water preheaters, but is connected with the bleeder conduits 48', so that the same feed water preheaters 10, 11, and 12 can be heated by means of bleeder steam as well as by means of steam taken from the steam generator. Pipes 67, 68, and 69 are branched off the conduit 54', the bleeder steam conduits 48' individually terminating in the pipes 67, 68 and 69. The amount of operating medium flowing through the conduit 68 is controlled by means of a valve 70, and the amount of operating medium flowing through the conduit 69 is controlled by a valve 71. The valves 70 and 71 are controlled, similarly to the valve 62 in the conduit 61, in accordance with the pressure downstream of the valves which is the pressure prevailing in the respective feed water heaters. The total amount of operating medium taken from the steam generator is controlled by means of a valve 55' which is responsive to the pressure in the feed water preheater 12 which is nearest to the steam generator with respect to the flow of the feed water. Check valves 72 are provided in the conduits 67, 68, and 69, and check valves 74 being provided in the bleeder conduits 44'.

The conduit 54' receives operating medium either from a point in the tube system in the steam generator which is downstream and close to a heating section 18 which is located adjacent to the combustion chamber, or it receives operating medium through a conduit 75 which is connected to the steam main at the outlet of the steam generator. A valve 76 in the conduit 75 and a valve 77 in the conduit 54' upstream of the point where the conduit 75 terminates in the conduit 54', afford selective supply of the conduit 54' with medium taken from an intermediary point of the tube system of the steam generator or from the outlet of the steam generator.

The pressure control means for the valves 55', 62, 70, and 71 are set for a predetermined pressure. If the pressure of the bleeder steam in the conduits 48' and 52 drops below the predetermined pressure, for example during periods of low loads of the turbine, all aforementioned valves are opened, so that the predetermined pressure is maintained in the feed water preheaters 10, 11, and 12 as well as in the feed water reservoir 7, the check valves 73 and 53 being closed at this time.

Particularly when starting the plant, the pressure to be maintained is the maximum pressure for which the feed water preheaters are built. In this manner, it is possible that the maximum amount of operating medium whose heat content can be absorbed by the feed water flowing through the feed water preheaters can be taken from the tube system of the steam generator, the remaining portion of the operating medium flowing through the steam generator being used for cooling the superheaters 21 and 23 and being conducted through the by-pass conduit 43 into the condenser 1. In order to reduce the starting time, it is of advantage to take the operating medium for heating the feed water heaters at first at the outlet of the steam generator through conduit 75, because at this point the operating medium will have a higher temperature than at an intermediary point of the tube system of the steam generator, for example downstream of the heating surface 18. It is of advantage of adjust the pressure control devices during starting of the plant in such a manner that they open the controlled valves not simultaneously, but consecutively. For example, the valve 55' may be opened at a pressure in the conduit 67 which is approximately 60% of the pressure in the first bleeder conduit 48' at normal load. The pressure control of the valve 70 may be set at 50% of the normal pressure of the bleeder steam in the second bleeder conduit 48', the pressure control of the valve 71 may be set for a pressure amounting to 40% of the normal pressure of the bleeder steam in the third bleeder line 48', and the pressure control of the valve 62 may be set at 30% of the normal pressure of the bleeder steam in the bleeder conduit 52. If the controls are set in this man-

ner, a gradual transition from normal load operation to low load operation is possible, because the feed water heaters can be heated by means of bleeder steam as well as by means of operating medium taken from the steam generator.

The illustrated arrangements merely serve to explain the invention. Many modifications are possible. The number of feed water heaters may be considerably greater than that shown in the illustrated embodiments of the invention. It is not always necessary to arrange a feed water preheater which is heated by operating medium downstream of a flue gas heated preheater, as is shown in Fig. 1. Operating medium for heating feed water may be tapped at points of the tube system of the steam generator different from those illustrated, so long as the operating medium has a suitably high temperature.

What is claimed is:

1. A system for generating steam comprising a plurality of feed water heaters, a heated tube system, fuel burning means associated with said tube system for heating said tube system, said tube system including an evaporating section and a superheating section, means for forcing operating medium consecutively through said preheaters, through said evaporating section, and through said superheating section, a bleeder conduit connected with said tube system at a point within said heated tube system, operating medium supply conduits connecting said bleeder conduit with said preheaters, flow control means individually interposed in said operating medium supply conduits, and pressure responsive means individually connected with and being responsive to the pressure in said operating medium supply conduits downstream of said flow control means, said pressure responsive means being individually connected with said flow control means for actuating said flow control means according to the pressure of the operating medium downstream of said flow control means.

2. A system for generating steam comprising a plurality of feed water heaters, a heated tube system, fuel burning means associated with said tube system for heating said tube system, the latter including an evaporating section and a superheating section, means for forcing operating medium consecutively through said preheaters, through said evaporating section, and through said superheating section, bleeder conduit means connected with said tube system at a point within said heated tube system and connected with said feed water heaters for supplying hot operating medium from a point within said tube system to said preheaters, a valve interposed in said bleeder conduit means, and a pressure responsive means connected with and being responsive to the pressure of the operating medium in that one of said preheaters through which the operating medium flows last before entering said evaporating section, said pressure responsive means being connected with said valve for actuating said valve for supplying hot operating medium from said tube system to said preheaters in accordance with the pressure of the operating medium in said last preheater.

3. A system according to claim 2, said bleeder conduit means including a conduit connected with said tube system, said valve being interposed in said conduit, pipes individually connecting said conduit downstream of said valve with the preheaters which are upstream of said last preheater with respect to the flow of the operating medium through the preheaters toward said tube system, a flow control means interposed in each of said pipes, and pressure responsive means individually connected with and being responsive to the pressure in said pipes downstream of said flow control means, said pressure responsive means being individually connected with said flow control means for actuating the latter for supplying hot operating medium through said pipes to the respective preheaters in accordance wtih the pressure of the operating medium in the respective pipes.

4. In a steam power plant, a forced flow steam generator comprising a tube system including an evaporating section and a superheating section connected in series relation with respect to the flow of the operating medium through said sections, a steam turbine connected with said superheating section for receiving operating steam therefrom, feed water heaters connected with said evaporating section for supplying preheated feed water to said evaporating section, a bleeder conduit connected with said tube system between said evaporating section and said superheating section, pipes individualy connecting said feed water heaters with said bleeder conduit for supplying hot operating medium to said feed water heaters, bleeder steam conduits connected with said turbine and individually connected with said pipes for supplying heating steam through the latter to said feed water heaters, valves individually interposed in said pipes upstream of the connection of said pipes with said bleeder steam conduits, control means connected with said pipes and being responsive to the pressure in said pipes downstream of said valves, said control means being connected with said valves for opening the latter when the pressure in said pipes falls below a predetermined value, and check valves in said bleeder steam conduits affording flow of operating medium through said bleeder steam conduits toward said pipes and preventing flow in the opposite direction.

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