April 11, 1967 C. STROHMEYER, JR 3,313,111
STARTUP SYSTEM FOR A ONCE THROUGH STEAM GENERATOR
INCLUDING A STARTUP BALANCING HEAT EXCHANGER
Filed April 30, 1965 3 Sheets-Sheet 1

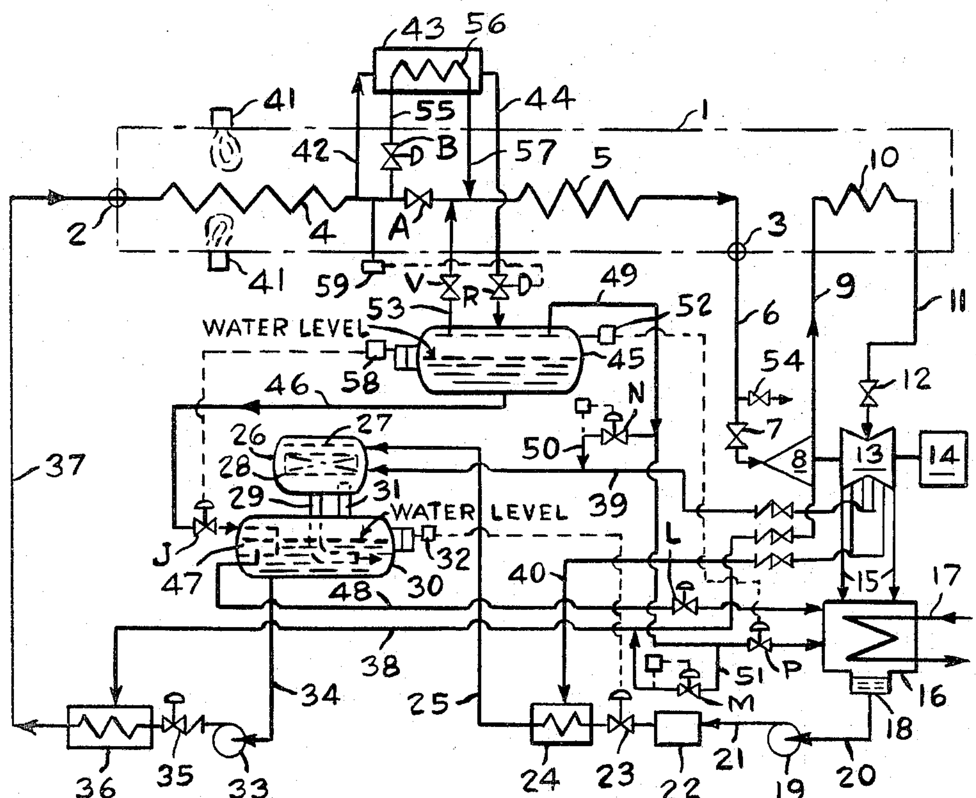

FIG. 1

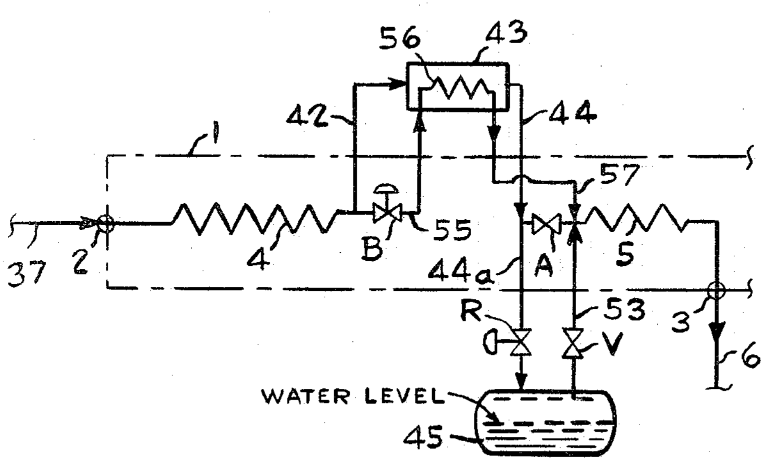

FIG. 2

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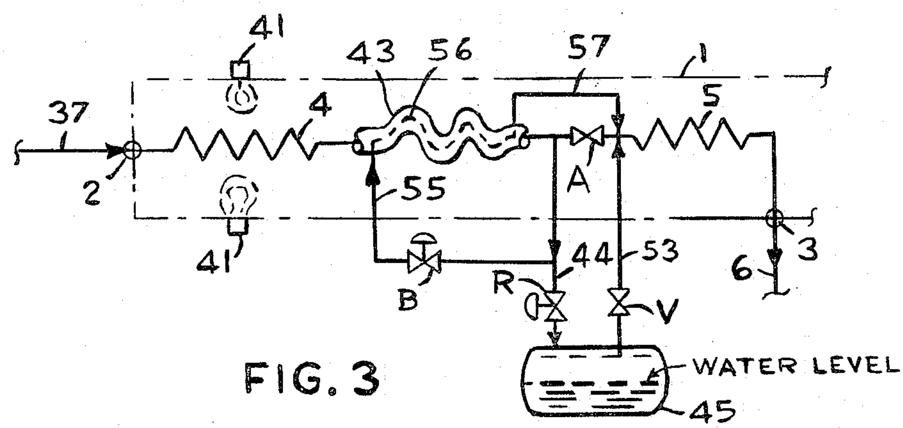

FIG. 3

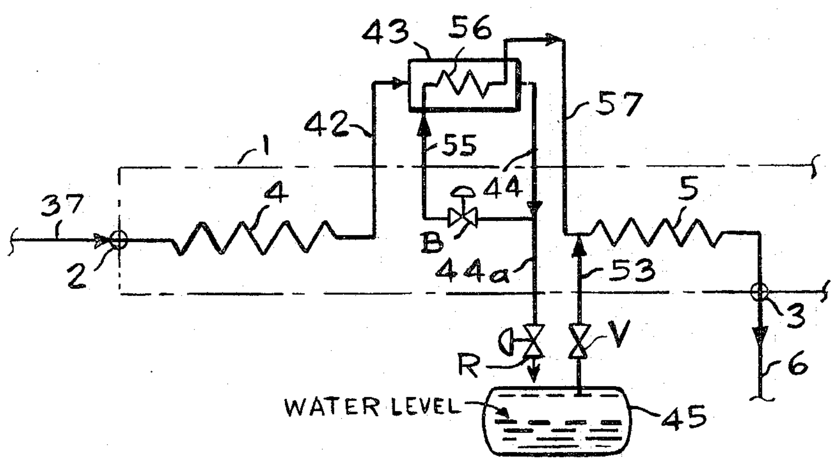

FIG. 4

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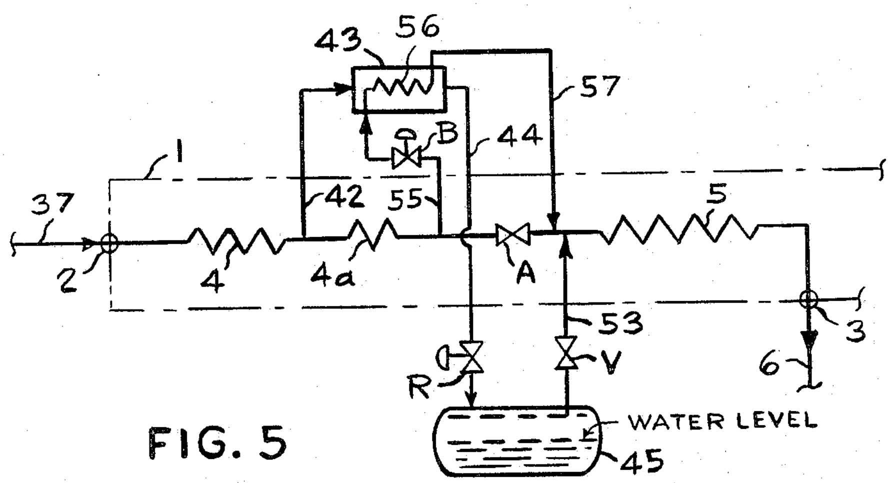

FIG. 5

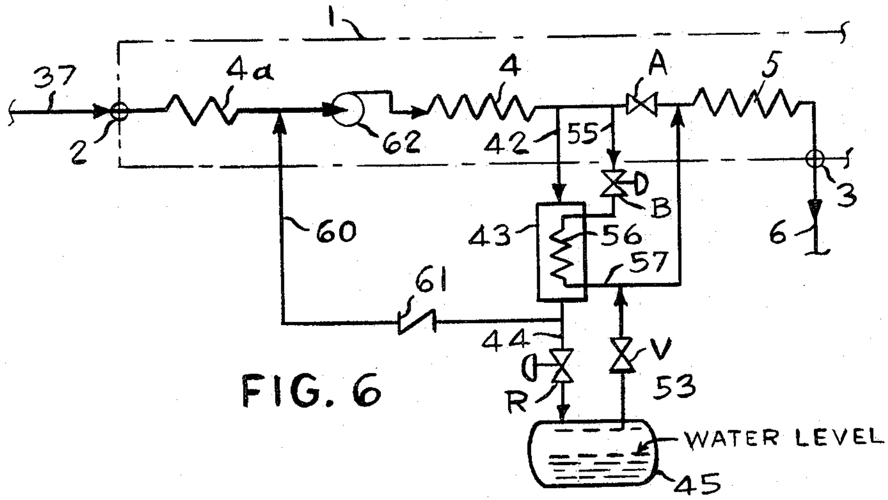

FIG. 6

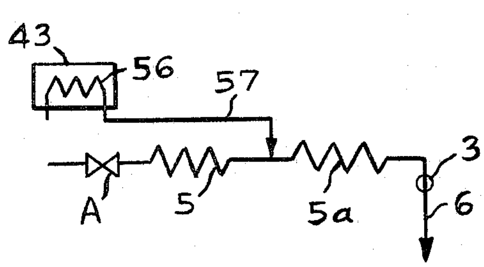

FIG. 7

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3,313,111
STARTUP SYSTEM FOR A ONCE THROUGH STEAM GENERATOR INCLUDING A START-UP BALANCING HEAT EXCHANGER

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1 Claim. (Cl. 60—105)

This invention relates to steam-electric generating units having a steam generator of the once-through type and wherein it is desired to co-ordinate the startup of the steam generator to best suit the requirements of the turbine generator.

Known startup systems for once-through generators include throttling means located intermediately between heat absorption conduits connected at one end of the feedwater inlet and at the other end to the superheater steam outlet. This enables the steam generator heat absorption conduits to be operated at two pressure levels, the highest pressure being upstream of the throttling means.

The generating section upstream of the throttling means, requires a certain cumulative parallel minimum fluid flow through the circuits when the steam generator is fired, to properly proportion flow through the individual circuits in the burner zone which is the area of highest heat input, thus preventing overheating of the individual fluid conduits. Minimum flow required may range from 17 to 70 percent of full load flow. In order to maintain such minimum flow in the generating section circuits, a bypass is usually provided for withdrawing fluid from the steam generator circuits, upstream of at least a portion of the superheater, at times when the superheater outlet flow drops below the upstream minimum value. The bypass flow may be recovered in the feedwater collection system and recycled to the feedwater inlet. Appreciable heat losses are usually associated with such use of the bypass.

In addition to use of the superheater bypass during startup, throttling means are used to reduce fluid pressure in the downstream superheater portion. Where the superheater bypass is upstream of the throttling means, it has been experienced that the fluid directly upstream of the throttling means contains considerable moisture when the throttling means is first opened to pass flow to the downstream superheater, at which time large temperature changes take place in the downstream superheater; temperature instability at the superheater outlet also follows. The firing rate cannot be increased to minimize moisture entering the superheater, without excessively heating the tube elements at the superheater outlet. The difficulty arises from the unbalance in flows upstream and downstream of the throttling means when initially flowing steam directly from the generating section to the superheater outlet.

An object of the invention is to provide a means for better distributing heat absorbed upstream of the throttling means between the flow entering the downstream superheater after passing through the throttling means and the flow exiting from the superheater bypass.

When steam is throttled at constant enthalpy, temperature decreases correspondingly with a pressure decrease. Thus, the fluid temperature downstream of the throttling means decreases although its heat content per unit of flow may be equivalent to that of the fluid upstream of the throttling means. Since the upstream flow is greater than the superheater flow by the amount of flow passing through the superheater bypass, heat in the bypass flow may be effectively exchanged with the fluid discharging from the throttling means to raise the fluid enthalpy and reduce moisture in the fluid entering the downstream superheater. The pressure drop through the throttling means provides the temperature gradient required for heat transfer between the two circuits. The transfer of heat from the bypass flow to the flow entering the downstream superheater reduces the thermal shock to the tube elements. The specific volume of the fluid entering the downstream superheater is increased, increasing flow stability in the superheater, permitting flow through the superheater and firing rate to be increased with minimum thermal upsets at the superheater outlet.

According to the invention, there is provided a startup heat exchanger for a steam-electric generating plant, said plant comprising a steam generator and turbine generator, said turbine generator having a high pressure turbine, said steam generator having a feedwater inlet, steam generating and superheating heat absorption conduits in series, a superheater steam outlet, fluid conduit means inter-connecting said feedwater inlet, heat absorption conduits, superheater steam outlet and high pressure turbine, throttling means for reducing fluid pressure intermediately between portions of said heat absorption conduits between said feedwater inlet and said superheater steam outlet, the portion of said heat absorption conduits downstream of said throttling means being operated during startup of said plant at a lower pressure than is in the portion of said heat absorption conduits upstream of said throttling means, a startup bypass conduit connected to said upstream portion and downstream of at least a portion of said heat absorption conduits which are directly connected to said feedwater inlet of said bypass conduit including means to flow fluid away from said upstream portion and for establishing circulation through at least a portion of said upstream portion independently of flow through said downstream portion during startup of said plant, thereby providing an independent circulation circuit including said bypass conduit and at least a portion of said upstream portion of said heat absorption conduits, said startup heat exchanger being located in the high temperature portion of said circulation circuit, said throttling means including conduit means for passing fluid from said upstream portion through a separate circuit in said startup heat exchanger after throttling and pressure reduction and for discharging the effluent from said separate circuit to said downstream portion, said startup heat exchanger being adapted to transfer heat in the fluid from said circulation circuit to said fluid passing through said separate circuit after pressure reduction.

The invention will be described in detail with reference to the accompanying drawings wherein:

FIG. 1 is a schematic diagram of the steam and water cycle for a steam-electric generating plant embodying the startup heat exchanger, and

FIGS. 2 through 7 inclusive are modified arrangements for the startup heat exchanger.

In FIG. 1, steam generator **1** is provided with feedwater inlet **2** and superheater outlet **3**. Fluid passes from **2** through heat absorption conduits **4**, through valve A, through heat absorption conduits **5** to superheater outlet **3**. Conduits **4** may comprise steam generating circuits only and conduits **5** may comprise superheating circuits only. Conduits **4** alternatively may comprise both steam generating and superheating circuits. Conduits **5** alternatively may comprise both steam generating and superheating circuits.

During operation of the unit in the full load range, pressure drop across valve A is to be maintained at a minimum value to avoid excessive pumping power. Essentially all of the flow entering feedwater inlet **2** passes directly out through superheater outlet **3** in a single pass. Steam from superheater outlet **3** passes through conduit **6** to steam admission valve/s **7** which control flow of steam to high pressure turbine **8**. Steam from turbine **8** exhausts through conduit **9** to steam reheater **10**. Reheater **10** is part of steam generator **1** but is not an essential part of this invention.

After reheating, steam passes through conduit **11**, through interceptor valve/s **12** to reheat turbine **13**. High pressure turbine **8** and reheat turbine **13** are connected through shaft means to electric generator **14**. Steam from reheat turbine **13** exhausts through conduits **15** to steam condenser **16**. Cooling water passing through conduits **17** condenses the exhaust steam which collects as condensate in hotwell **18**.

Condensate pump **19** takes suction from hotwell **18** through conduit **20** and discharges through conduit **21** to water purification equipment **22** and from there through regulator valve **23**, through low pressure feedwater heater **24** and conduit **25** to deaerator **26**.

Water enters deaerator **26** through spray pipe **27** and flows over trays **28** and through conduit **29** to deaerator storage tank **30**. Conduit **31** equalizes pressure between deaerator **26** and storage tank **30**. Water level controller **32** controls the opening of valve **23**.

High pressure feedwater pump **33** takes suction from deaerator storage tank **30** through conduit **34** and raises the discharge pressure to the working level of the steam generator. Feedwater flow control valve **35** at the pump discharge, regulates flow of water to steam generator **1** and is co-ordinated with firing rate controls (not shown). Valve **35** discharges through high pressure heater **36**, and conduit **37** to feedwater inlet **2**.

Turbine extraction steam is fed to high pressure feedwater heater **36** through conduit **38**, to deaerator **26** through conduit **39** and to low pressure heater **24** through conduit **40**.

Steam generator **1** is provided with combustion means. Burners **41** fire oil or coal in a furnace (not shown) which supplies heat to heat absorption conduits **4** and **5**. Fluid enthalpy progressively increases from the feedwater inlet **2** to superheater outlet **3**. At constant pressure, fluid temperature increases as enthalpy increases.

During startup, minimum fluid flow circulates from feedwater inlet **2** through conduits **4**, through conduit **42**, through startup heat exchanger **43**, through conduit **44** and pressure reducing valve R to flash tank **45**. Valve R controls pressure in circuits **4** by means of controller **59**. Liquid draining from flash tank **45** passes through conduit **46**, through valve J to deaerator storage tank **30**. Level controller **58** maintains constant flash tank water level.

Conduit **46** terminates in a spray pipe inside storage tank **30** which discharges into compartment **47**. Compartment **47** isolates the flash tank drain flow from the remainder of the storage tank. Compartment **47** is cross connected with the remainder of the storage tank on the steam and water side, to maintain a common water level by means of gravity.

Conduit **48** is arranged to selectively draw flash tank drain flow from compartment **47** up to the limit of the drain flow collected in compartment **47**. Flow through conduit **48** in excess of that collected from conduit **46** in compartment **47**, is drawn from the remainder of storage tank **30**. Conduit **48** discharges through flow control valve L to steam condenser **16**.

Flow through conduit **46** enters the remainder of the storage tank **30** when there is no flow through conduit **48** or may be proportioned with respect to flow through conduit **48** to the condenser.

Thus, fluid in conduit **46** entering storage tank **30** may be discharged to condenser **16** through conduit **48** and returned to storage tank **30** through pump **19**, conduit **25** to deaerator **26** and conduit **29** before passing through conduit **34**, feedwater pump **33**, high pressure heater **36** and conduit **37** to feedwater inlet **2**. Alternatively, fluid in conduit **46** entering storage tank **30** may flow direct from compartment **47** to conduit **34** to feedwater pump **33**, high pressure heater **36** and conduit **37** to feedwater inlet **2**. Feedwater pump **33** circulates the required minimum flow in conduits **4** when burners **41** are being fired.

Steam separated in flash tank **45** may be drawn off through conduit **49** and conduit **50** to supply steam to deaerator **26** through conduit **39**. Valve N controls pressure in deaerator **26**. Conduit **49** also supplies steam to high pressure feedwater heater **36** through conduits **51** and **38** at a time when turbine extraction steam pressure is very low. Valve M controls steam pressure in heater **36**. Conduit **49** also discharges surplus flash tank steam to condenser **16** through flow control valve P. Pressure controller **52** regulates valve P opening.

When starting up the unit, prior to lighting burners **41**, circulation is established in conduits **4** through the flash tank and feedwater supply system as outlined above, using the feedwater pump **33** as a circulator. Valves A and B are closed. The conduits **4** are pressurized and valve R reduces the downstream pressure to the working pressure of the flash tank.

Burners **41** are fired. Fluid exiting through conduit **42** gradually rises in temperature. Steam is flashed in vessel **45**. Flashed steam in deaerator **26** raises the fluid temperature entering storage tank **30** through conduit **29**. Fluid temperature at the suction of pump **33** rises. Flashed steam in heater **36** raises the fluid temperature at the feedwater inlet **2**. The fluid temperature continues to rise in conduits **4** as the firing rate of burners **41** is increased. Surplus steam becomes available in flash tank **45**.

The surplus steam may be discharged to condenser **16** through valve P to hold flash tank pressure constant. Valve V is opened to pass flash tank steam through conduit **53** to heat absorption conduits **5**. Valve(s) **7** is/are closed and valve **54** is opened to draw steam through conduit **6** to warm up the steam supply conduits upstream of valve(s) **7**. Valve **54** discharges to atmosphere or alternatively may discharge to condenser **16**.

To purify the cycle water, fluid is passed through conduit **48** to condenser **16** and returned to deaerator **26** through pump **19** and water purification equipment **22**.

When the cycle is clean, steam is admitted through steam admission valve(s) **7** to high pressure turbine **8**, reheater **10** and reheat turbine **13** to bring the turbine-generator unit up to speed. Firing of burners **41** is controlled to regulate steam availability and temperature in high pressure turbine **8**, co-ordinated with pressure regulation in flash tank **45** and conduits **5**.

When the turbine generator unit is at synchronous speed, the unit is synchronized and the generator output is increased to a pre-determined minimum value (approximately 5 percent of rating). Firing of burners **41** is increased; flow from flash tank **45** through valve V to conduits **5** and turbine **8** is increased. However, flow from flash tank **45** through valve V to conduits **5** and turbine **8** is substantially below the required minimum flow circulating in conduits **4**, **42** and through valve R to flash tank **45**. As a result, at this time, considerable moisture is present in the fluid upstream of valve R.

In order to continue loading the turbine generator unit, it is necessary to pass fluid directly from conduits **4** to **5** without passing through the flash tank. Up to this time dry steam has been passing from flash tank **45** through valve V to conduits **5**. Therefore, conduits **5**, for the most part, are hot and in the superheat temperature range. If valve A is gradually opened for displacing steam flow to conduits **5** from conduit **53** and valve V, the substantial quantity of moisture in the fluid passing through valve A would quench a substantial portion of conduits **5** at the inlet end. After a time delay, temperature at the superheater outlet **3** would droop substantially causing difficulty in the turbine unless the operation were carefully scheduled and spray water attemperation was used to minimize superheater outlet temperature transients. In any case, temperature transients within the superheater are severe.

The present invention overcomes difficulties associated with differential enthalpies when transferring flow to conduits **5** from the flash tank source direct to the conduits **4** source. During the transfer, the enthalpy of the fluid entering conduits **5** is held relatively constant. This is accomplished by means of startup heat exchanger **43**.

During the transfer, valve A remains closed. Valve B is gradually opened. Fluid from conduits **4** is reduced in pressure in conduit **55** by means of throttling action of valve B.

The pressure reduction is accompanied by a substantial temperature drop. Conduit **55** connects to one end of a closed circuit **56**, passing through startup heat exchanger **43**. The other end of closed circuit **56** connects to conduit **57** which in turn connects to conduits **5**. Thus, as fluid passes through valve B, conduits **55**, **56** and **57** to conduits **5**, the fluid enthalpy is increased by means of heat received from flow passing through conduit **42** to heat exchanger **43**. Since pressure reduction in the superheater bypass flow circuit through valve R occurs downstream of startup heat exchanger **43** and pressure reduction in the valve B circuit occurs upstream of startup heat exchanger **43**, a temperature gradient exists for transferring heat from the valve R circuit to the valve B circuit across closed circuit **56**.

For example, if the fluid pressure upstream of valves A and B is 2700 p.s.i.a. and the fluid temperature is 680° F., reducing pressure in conduit **55** to 500 p.s.i.a. will reduce fluid temperature to 467° F. This will produce a temperature differential of 213° F. across closed circuit **56** for evaporation of moisture in the effluent of valve B, assuming saturated fluid temperatures exist on both sides of conduits **56**. As a result of heat transfer, the fluid passing through the valve R circuit will increase in moisture content and the fluid passing through the valve B circuit will decrease in moisture content, as it passes around and through circuit **56**. However, as the transfer is being made, displacing valve V flow to conduits **5** with flow through valve B, less and less steam is required from the flash tank. In effect, the transfer can be made holding enthalpy of the fluid entering conduits **5** essentially constant.

As flow through valve B is gradually increased above the maximum flow through valve V, firing of burners **41** can also be increased. Increased firing rate raises fluid enthalpy upstream of the throttling means, valve B. Less heat transfer is required through circuit **56** as flow through valve R is substantially decreased below the latter condition.

As load is increased by means of flow through valve B, pressure in conduits **5** can also be increased. Pressure rise in conduits **5** can be coordinated with requirements for heat exchange in startup heat exchanger **43**. Increasing pressure in conduits **5** will reduce heat transfer across closed circuit **56**. Pressure rise in conduits **5** is controlled by coordination of valve(s) **7** opening with valve B opening. When heat exchanger **43** is no longer required for raising enthalpy of fluid downstream of valve B before it enters conduits **5**, valve A opening may be coordinated with valve B opening to produce the required flow to conduits **5** and turbine **8**. Coordination of valve A, B and **7** opening is then required to regulate pressure downstream of valve A and B and upstream of valve(s) **7**.

The configuration of startup flow circuits shown on FIG. 1 is not limiting with respect to the present invention. For example, conduit **53** and valve V could be eliminated. In such case, initial flow to conduits **5** would be through valve B, conduit **55**, through closed circuit **56** and conduit **57** to conduits **5**. The enthalpy of the fluid upstream of valve B would be raised sufficiently by firing burners **41** in conjunction with circulation through conduits **4**, valve R flow to the flash tank system and return flow to the feedwater inlet **2** through the feedwater cycle, before valve B was opened. Heat recovery in the deaerator **26**, storage tank **30** and high pressure feedwater heater **36**, will permit this to be done with sufficiently low firing of burners **41**, so that combustion gas temperatures in the circuits **5** zone will not be excessive for the condition prior to the opening of valve B. When valve B is opened to establish flow through conduits **5**, **6** and valve **54**, heat exchange with the valve R circuit flow in closed circuit **56** will assure reasonably dry steam entering conduits **5**.

Also, the valve B circuit may comprise the main flow circuit and valve A and its connecting conduits could be eliminated. In such case, valve B may consist of a single valve or multiple valves designed to handle full load flow with minimal pressure drop for the full load condition.

As shown by FIG. 1, valve A serves as a bypass for startup heat exchanger **56** and may be used in conjunction with valve B to proportion flow through valves A and B to regulate the enthalpy of the fluid entering conduits **5**, increasing or decreasing the heat transfer rate through closed circuit **56**.

The flash tank **45** shown in FIG. 1 is not essential to this invention, as it is obvious that the discharge from bypass conduit **44** could be connected to some other part of the feedwater cycle and accomplish similar results. The essential elements of the invention are that heat in the circulation flow through conduits **4** is exchanged with the flow entering conduits **5** after pressure reduction and that the flow through conduits **4** is of greater magnitude than the flow through conduits **5** at time of heat exchange.

FIG. 2 is a modified arrangement of startup heat exchanger **43**. Heat exchanger **43** is located in the main flow circuit between conduits **4** and valve A. The superheater bypass conduit **44***a* and valve R are independent of heat exchanger **43** location.

FIG. 3 is a modified arrangement of startup heat exchanger **43**. Heat exchanger **43** is an extension of the heat absorption conduits **4** and receives heat from burners **41**. Closed circuit **56** is located internally in the heat absorption conduits **43**.

FIG. 4 is a modified arrangement of startup heat exchanger **43**. Both the valve B and valve R circuits are in the main flow line.

FIG. 5 is a modified arrangement of startup heat exchanger **43**. The valve B and valve R circuit main line take off points, are separated by heat absorption conduits **4***a*. The take off points from the main flow circuit for conduits **42** and **55** alternatively could be reversed.

FIG. 6 is a modified arrangement of startup heat exchanger **43** in conjunction with a pumped recirculation circuit for heat absorption conduits **4**. Circulation through conduits **4** is accomplished by means of pump **62**. Recirculation flow is from pump **62** discharge, through conduits **4**, **42**, heat exchanger **43**, reverse flow preventer **61** and conduit **60** to the suction of pump **62**. Pump **62** could be located elsewhere in the recirculation loop.

FIG. 7 shows how conduit **57** could discharge intermediately between heat absorption conduits **5** and **5***a* between valve A and superheater outlet **3**.

The comments above relative to valve V and conduit **53**, valve A and the flash tank **45**, also apply for FIGS. 2 through 7 inclusive.

Thus, it will be seen that I have provided an efficient embodiment of the invention, whereby heat absorbed by the conduits in the high heat input zone of the steam generator, can be properly proportioned between the flow which discharges through the steam generator superheater outlet and the flow which bypasses at least a portion of the superheater during startup and at times when flow quantity in the conduits of the high heat input zone substantially exceeds that passing through the superheater outlet. This is accomplished by means of a startup heat exchanger, the temperature gradient for heat transfer resulting from reduction of fluid pressure upstream of the heat exchanger for that portion of the fluid flow which is directed toward the superheater outlet. Therefore, temperature transients are minimized when equalizing fluid flows from the inlet to the outlet of the steam generator.

While I have illustrated and described several embodiments of my invention, it will be understood that these are by way of illustration only, and that various changes and modifications may be made within the contemplation of my invention and within the scope of the following claim.

What I claim is:

A startup heat exchanger for a steam-electric generating plant, said plant comprising a steam generator and turbine generator, said turbine generator having a high pressure turbine, said steam generator having a feedwater inlet, steam generating and superheating heat absorption conduits in series, a superheater steam outlet, fluid conduit means inter-connecting said feedwater inlet, heat absorption conduits, superheater steam outlet and high pressure turbine, throttling means for reducing fluid pressure intermediately between portions of said heat absorption conduits between said feedwater inlet and said superheater steam outlet, the portion of said heat absorption conduits downstream of said throttling means being operated during startup of said plant at a lower pressure than is in the portion of said heat absorption conduits up-

stream of said throttling means, a startup bypass conduit connected to said upstream portion and downstream of at least a portion of said heat absorption conduits which are connected directly to said feedwater inlet, said bypass conduit including means to flow fluid away from said upstream portion and for establishing circulation through at least a portion of said upstream portion independently of flow through said downstream portion during startup of said plant, thereby providing an independent circulation circuit including said bypass conduit and at least a portion of said upstream portion of said heat absorption conduits, said startup heat exchanger being located in the high temperature portion of said circulation circuit, said throttling means including conduit means for passing fluid from said upstream portion through a separate circuit in said startup heat exchanger after throttling and pressure reduction and for discharging the effluent from said separate circuit to said downstream portion, said startup heat exchanger being adapted to transfer heat in the fluid from said circulation circuit to said fluid passing through said separate circuit after pressure reduction.

No references cited.

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