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[54] STEAM TEMPERATURE CONTROL SPRAY SYSTEM

[72] Inventors: **Raymond M. Costello**, Parsippany; **Eugene B. Beckman**, Rockaway Township, both of N.J.

[73] Assignee: **Foster Wheeler Corporation**, Livingston, N.J.

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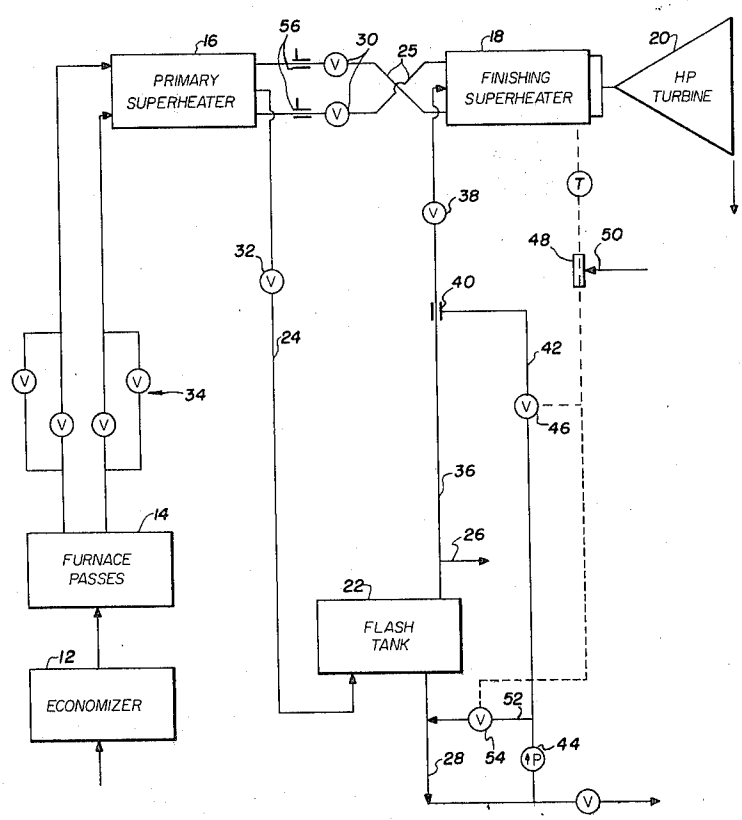
Primary Examiner—Kenneth W. Sprague

Attorney—John Maier, III, Marvin A. Naigur and John E. Wilson

[57] **ABSTRACT**

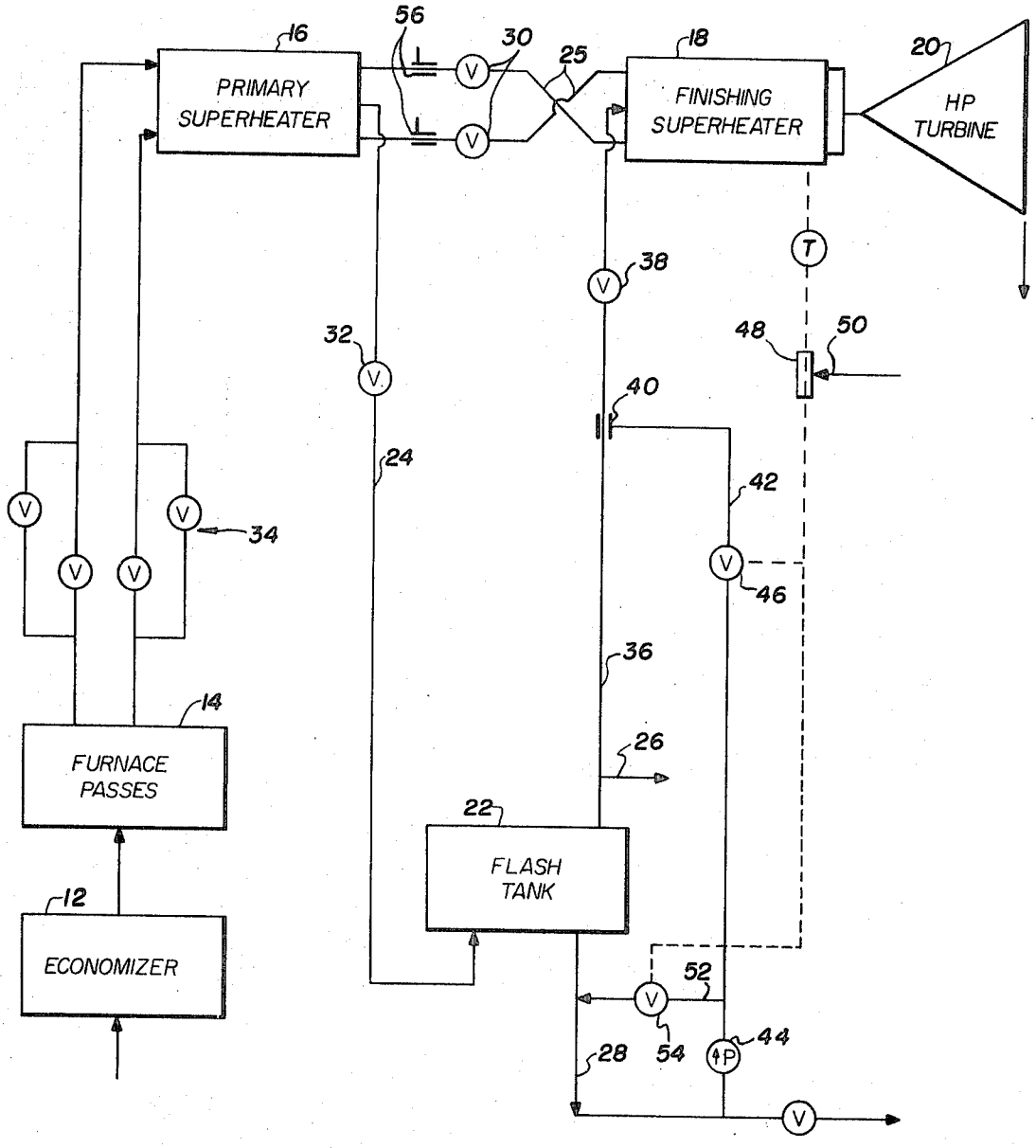
A spray control for adjusting finishing superheater outlet temperature in a once-through generator during startup. The control comprises a low-pressure pump arranged to withdraw liquid from the flash tank of the generator startup bypass and to introduce the liquid into the vapor flow from the flash tank at a point between the flash tank and the finishing superheater. The invention permits exact matching of the enthalpy of the bypass vapor flow entering the superheater with that at the primary superheater outlet at a stage in the turbine loading, when flow is being transferred from the bypass system to the main circuit.

8 Claims, 1 Drawing Figure



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INVENTORS:
RAYMOND M. COSTELLO
EUGENE B. BECKMAN

Oberlin, Maky, Donnelly & Renner
ATTORNEYS

STEAM TEMPERATURE CONTROL SPRAY SYSTEM

The present invention relates to a novel spray control for once-through generators, and in particular to such a control for regulating the superheater final or outlet temperature.

A typical once-through vapor generator, of the type to which the present invention pertains, comprises a plurality of heat transfer surfaces in series ending with the primary and finishing superheater passes. During startup of the generator, the low enthalpy fluid cannot be handled by the high-pressure turbine, and for this reason, the generator is provided with a bypass system to accommodate the flow temporarily. Usually the startup bypass is provided with a flash tank which separates the bypass flow into vapor and liquid streams, the vapor stream being transmitted to various uses such as turbine gland sealing and feedwater heating; and later in the startup period to the turbine for warming, initial rolling, and loading.

The bypass usually is upstream of the finishing superheater surface to protect the superheater as well as the turbine. The superheater generally is composed of pendant surface suspended in the generator, and a portion of the liquid phase contained in the low enthalpy fluid during startup, if allowed to flow in the finishing superheater, is likely to settle in legs of the superheater. This could cause tube burnout in the superheater, and/or possible damage to the turbine.

Up to the time in the startup period when vapor is made available from the flash tank to the finishing superheater and turbine, the firing rate is controlled so that the uncooled superheater tubes are not overheated. However, after steam is made available to the finishing superheater and turbine from the flash tank, then the firing rate is fixed at a set value, normally not predicated on the final superheater temperature. This means that the temperature could be too high for the turbine, particularly if the generator is designed with a large finishing superheater surface or area.

As another problem, switchover from bypass flow to flow directly from the primary superheater to the finishing superheater, during startup, is apt to cause temperature shocks to the turbine. The reason for this is that at the point in the startup period of switchover, the quality of the flow is relatively high, and there is a substantial pressure difference between the flash tank pressure and the primary superheater pressure caused by the pressure drop in the flow-control type of valve employed between the flash tank and the primary superheater required for such switchover. This means that at switchover, the finishing superheater which up to then had been receiving a saturated vapor flow from the flash tank, is now receiving a vapor-liquid mixture flow from the higher pressure primary superheater. This results in a lowering of the temperature at the finishing superheater outlet and a potential temperature shock to the turbine.

It is known to introduce a liquid spray flow upstream of the finishing superheater surface to lower the flow. However, this has conventionally been taken from a low enthalpy part of the circuit, for instance, from the economizer outlet, and has required that a pressure reducing valve for the extracted liquid be employed. Such valves historically have been plagued with mechanical difficulties because of the severe energy dissipation required.

There is also a problem in properly controlling the quality of the flow entering the superheater when a low enthalpy extract is employed. Such an extract not only lowers the quality of the vapor by the amount added, but also condenses some vapor through heat transfer into the spray, so that the percent change in quality is much greater than the percent spray added. A superheater outlet temperature control on the amount of such spray introduced into the flow is inadequate since temperature does not vary proportional with change in quality, and the latter could change substantially with little change in temperature. Accordingly, there is the possibility that the quality of the flow in the superheater could be lowered too much causing slugs of water to settle in the superheater legs, plugging tubes and in turn causing tube burnout and/or turbine damage.

Accordingly, it is an object of the present invention to provide during startup an improved means for controlling the finishing superheater outlet or final temperature and thereby avoid flow of an excessive temperature vapor to the turbine, or temperature shocks to the turbine.

It is also an object of the present invention to provide an improved spray control by which the quality and temperature of the flow entering the finishing superheater can be held more accurately within predetermined limits.

It is also an object of the present invention to provide a spray control system for the finishing superheater outlet temperature which is less expensive and mechanically more reliable than such controls heretofore employed.

To the accomplishment of the foregoing and related ends, the invention, then, comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawing setting forth in detail a certain illustrative embodiment of the invention, this being indicative, however, of but one of the various ways in which the principles of the invention may be employed.

In such annexed drawing:

The FIGURE is a schematic flow diagram illustrating the circuitry of a once-through vapor generator and the concepts of the present invention.

Referring to the drawing, the once-through vapor generator flow circuit comprises a main flow path including an economizer **12**, furnace passes **14**, a primary superheater **16**, and a finishing superheater **18**, the flow from the latter entering high pressure turbine **20**.

The startup bypass system for the generator includes a flash tank **22** in bypass line **24**, and vapor and liquid lines **26** and **28** leading from the flash tank bypassing the finishing superheater and high-pressure turbine. Tight shutoff valves **30** are provided in the main flow path between the primary superheater and finishing superheater to direct the flow into the bypass line **24**. The latter is provided with a valve **32** which is open when the bypass system is in use, and can be closed with opening of the valves **30** to switch the flow back to the main flow path. Pressure reducing station **34** in the main flow path between the furnace passes and the primary superheater maintains full generator pressure in the furnace passes during startup, and establishes a reduced pressure in the bypass system and flash tank. Also provided in the bypass system is a vapor return line **36**, open and closed by valve **38** to provide a vapor flow from the flash tank to the inlet of the finishing superheater.

In accordance with the present invention, a spray **40** is located in the line **36** between the flash tank **22** and the finishing superheater, preferably between the flash tank and the valve **38**. This spray receives drains from the flash tank by means of a drain line **42** which is connected between the flash tank drain line **28** and the spray. A pump **44** is provided in the line **42** to produce the spray flow, the pump having a low pressure differential, for instance in the order of about 100 p.s.i., to produce the flow.

A valve **46** in line **42** controls the spray flow, this valve being responsive to temperature controller **48** sensing temperature at the finishing superheater outlet. Preferably the controller **48** is interlocked by control signal **50** with main flow line valves **30** between the primary and finishing superheaters to close valve **46** when the valves **30** are opened. This takes the spray out of operation when flow in the bypass is terminated. A return line **52** is provided opened and closed by valve **54** to recycle pump flow to drain line **28** if desired, and thereby increase or decrease flow to spray **40**. Preferably valve **54** is also responsive to the control **48**, sequenced with valve **46**.

If desired, the generator may be provided with main superheat sprays **56** in the main flow path between the primary superheater and finishing superheater.

In operation, the generator is started by initially closing valves **30** in the main flow path, opening valve **32** in the bypass line **24** and introducing the startup flow to the flash tank **22**.

This startup flow is in a liquid state, but as the startup period progresses, the quality of the flow increases and flash tank steam becomes available. The flash tank steam first is transmitted through line **26** to various points of use, for instance, the generator deaerator, or turbine gland seals, but as more steam becomes available, valve **38** is opened for initial warming and rolling the high pressure turbine. Subsequently the latter is synchronized and loaded at a percentage of full load.

After steam has been made available to the turbine, the spray pump **44** is started to introduce into line **36** at spray point **40** sufficient saturated liquid flow from the flash tank to reduce the quality of the vapor flow to about the 85 or 90 percent level. The amount of spray introduced is dependent upon the amount of finishing superheater surface in the generator, and should be such that the flow at the superheater outlet is in a slightly superheated state. In this way, temperature controller **48** can closely regulate the amount of spray introduced since in the superheated range too much or too little spray will register a temperature drop or temperature increase at the superheater outlet. The spray is initiated early in the startup period, so that the temperature at the outlet of the finishing superheater is continuously maintained at one which can be accommodated by turbine practices.

At some point in the startup period, after equilibrium at the primary superheater outlet is achieved (that is, when the temperature increase of the flow leaving the primary superheater levels off) valve **32** in the bypass line **24** is closed and main flow valves **30** are opened, for switchover of flow from the primary superheater directly to the finishing superheater. At this point in the startup period, the flow in the primary superheater is of relatively high quality (about 85 to 90 percent), and valve **32**, being of the flow-control type to achieve switchover, causes a substantial pressure drop in the order of about 600 p.s.i. into the flash tank. This means that at such equilibrium point for the primary superheater, although the flow at the primary superheater outlet is at less than 100 percent quality, that transmitted from the flash tank is saturated steam. Accordingly, following switchover, the turbine which up to that point has been experiencing a superheated flow could be suddenly subjected to a much lower temperature flow, and an instantaneous temperature drop or temperature shock.

By introducing spray liquid into the vapor flow from the flash tank, sufficient to lower the quality to the 85 or 90 percent level, such flow is made to match closely the quality of the flow at the primary superheater outlet, and such temperature shocks are thereby avoided.

Advantages of the invention should be apparent.

For one, the temperature control system is very sensitive. As mentioned, it is set to obtain a slightly superheated flow at the superheater outlet, which is at a fairly sensitive point temperaturewise on the temperature-enthalpy diagram. In that the liquid spray is at about the same temperature as the vapor spray, small changes in the amount of spray added are not likely to cause substantial temperature excursions. This provides better protection for the turbine.

In addition, the finishing superheater is protected from the formation of slugs of water in the legs thereof. Since the spray liquid is saturated and at substantially the same temperature and enthalpy level as the flash tank vapor flow, the quality of the resultant mixture will vary almost directly with the proportions of vapor and liquid spray mixed. For instance, a 10 percent addition of spray will produce a 90 percent quality flow into the finishing superheater. (For most superheaters, an 85–90 percent quality flow entering is safe). A small increase in spray added does not produce through heat exchange and condensation such reduced quality as to endanger the superheater.

Because the control over temperature and quality is more sensitive, the invention permits the use of increased finishing superheater surface, and/or increased firing rates during startup.

As a further advantage, a substantial portion of the liquid flow from the flash tank may, in conventional systems, be dumped to a heat sump such as a condenser, and by cycling at least a portion of the liquid flow as spray into the vapor from the flash tank, substantial heat is salvaged.

In addition, the pump **44** employed in accordance with the present invention is more reliable than a pressure-reducing valve of the type which would be required if the spray were taken from the economizer outlet. In a once-through generator of the supercritical type, the economizer is at about 3,600 p.s.i., and a valve such as would be required to reduce the pressure to flash tank level, about 1,000 p.s.i., heretofore has been plagued as mentioned with substantial mechanical difficulties. A pump in accordance with the present invention would be required only to increase extracted liquid pressure about 100 p.s.i. and thus would be more economical to purchase than the above pressure-reducing valve, and would also be economical to operate.

As a further advantage, since the liquid spray introduced into the vapor line leading to the superheater is at substantially the same temperature as the vapor in the line, there is no temperature shock to the line caused by the spray, and the spray can be introduced directly into the vapor flow without the need for liners and other protective means heretofore required with such sprays.

What is claimed is:

1. A steam temperature control spray system for a once-through vapor generator, said generator comprising:

a primary superheater, a finishing superheater, a main flow line between said superheaters including a main flow valve means therein;

a startup system comprising a bypass line connected in flow communication with said main flow line upstream of said valve means and said bypass line containing a flash tank therein, piping connected between said flash tank and said finishing superheater to return saturated steam from the flash tank to the finishing superheater, and a liquid drain line connected to said flash tank; the improvement comprising

spray means located in said piping between the flash tank and finishing superheater; and

means to transmit a portion of the flash tank liquid drain flow as spray flow to said spray means.

2. The system of claim **1** including a low-pressure pump to transmit said spray flow.

3. The system of claim **2** including a conduit means extending between the flash tank liquid space and the spray means including said pump further including valve means therein, and control means responsive to the temperature at the finishing superheater outlet to control said valve means to deliver a variable amount of flash tank drain flow to said spray means.

4. The system of claim **3** including means interlocking said valve means with the main flow valve means to close the valve means on opening the main flow valve means.

5. The system of claim **4** including additional spray means upstream of said main flow valve means.

6. The system of claim **3** including valve means in the bypass line upstream of the flash tank which causes some pressure reduction in the flow therethrough.

7. The system of claim **6** including a pressure reducing station upstream of the primary superheater.

8. The system of claim **3** including means to bleed a variable amount of the output of said pump from said conduit means.

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