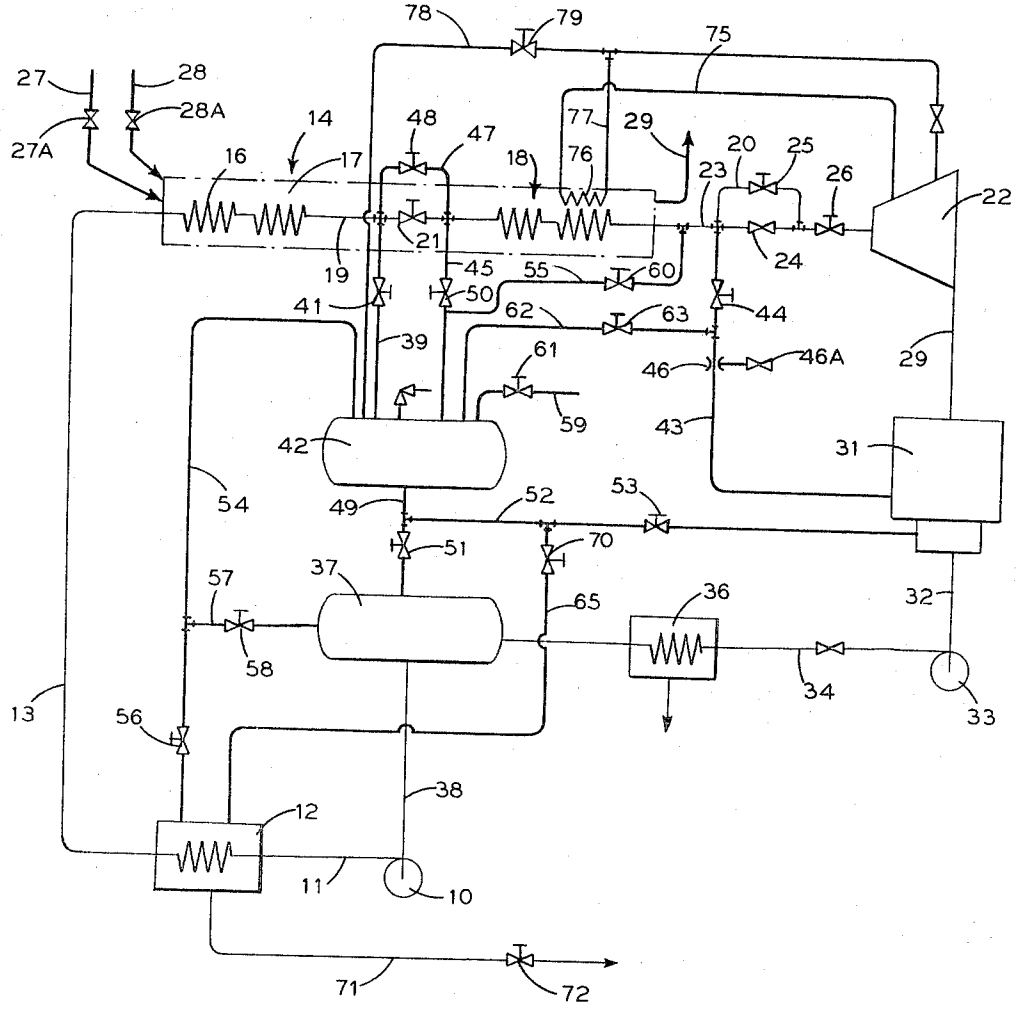
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START-UP SYSTEM FOR FORCED FLOW VAPOR GENERATOR

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START-UP SYSTEM FOR FORCED FLOW VAPOR GENERATOR

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This invention relates in general to a power plant system having a turbine arranged to be supplied with vapor from a forced circulation once-through vapor generator and more particularly to apparatus for and a method of starting up such a system.

The general object of the present invention is the provision of a starting system of the character described so constructed and arranged as to simplify starting procedure; to provide low cost, rapid, controlled start-ups; to provide adequate protection of the turbine and vapor superheating section of the vapor generator to the end that thermal stresses on this equipment are within acceptable limits at all times; to provide maximum heat recovery during starting up and low load operation; and to permit matching of the vapor temperature to turbine metal temperature on hot restarts and a minimum differential of vapor temperature and turbine metal temperature on cold starts.

More specifically, the invention is directed to improvements in the construction and operation of a start-up system of the type described in U.S. Patent No. 2,989,038 in which the discharge from the vapor generating section of a once-through boiler is passed into a flash tank, water from the flash tank is conducted to the inlet end of the vapor generating section of the boiler, vapor from the flash tank is passed through the vapor superheating section of the boiler and then condensed for return to the vapor generating section; and provisions are made for bypassing the flash tank when the working medium is properly conditioned for rolling and loading the turbine. A disadvantage of this system, as well as other prior start-up systems, resides in its inability, especially during cold starts-ups, to provide low temperature steam to the turbine for rolling and loading. As a result, the turbine metal is subjected to excessive rates of temperature change. This drawback is eliminated in accordance with the present invention by special provisions for tempering vapor supplied to the turbine for rolling and loading.

As the generators of the forced flow type are well-known in the art, we have shown in the drawing the elements of such a generator in rudimentary form to assist in understanding our invention. While the starting system of the invention is particularly adapted for use in a forced flow vapor generating and superheating unit designed for the production of superheated vapor at pressures and temperatures below the critical pressure of 3206 p.s.i. and the critical temperature of 705° F., a unit of this general construction being described and claimed in U.S. Patent No. 3,125,995, issued Mar. 24, 1964, it will be understood that the invention starting system can also be advantageously used in a forced flow vapor generator designed for supercritical pressures and temperatures.

In the power plant system illustrated, feedwater is supplied by a boiler feed pump 10 through a conduit 11 to a high-pressure heater 12, then passes through a conduit 13 to the circuitry of a vapor generator 14 of the once-through forced flow type having a series fluid flow path including an economizer 16, vapor generating section 17, and superheater 18. Superheater 18 is connected for series flow of fluid from the vapor generating section by a conduit 19 containing a stop valve 21 and for series flow of fluid to a high pressure turbine 22 by a conduit 23

containing a stop valve 24 and a control valve 26. Valve 24 is by-passed by a conduit 20 containing a stop valve 25. Fuel and air for combustion are admitted to the vapor generator 14 through conduits 27 and 28 respectively; and the gaseous products of combustion, after passing over the economizer and vapor generating and superheating surfaces, are discharged through an outlet, diagrammatically shown at 29. Valves 27A and 28A represent the customary regulating means for the fuel and air respectively.

During normal operation, the working medium passes successively through the economizer 16, vapor generating section 17 and superheater 18. The superheated vapor outflow of superheater 18 passes through conduit 23 to the high-pressure stage of vapor turbine 22 for expansion therein. Partially expanded steam from turbine 22 passes through a conduit 75 to a reheater 76 exposed to the gas stream and connected by a valve-controlled conduit 77 for flow of vapor to a low-pressure stage of turbine 22. Final expansion of the vapor takes place in the low-pressure stage of turbine 22, with the vapor then exhausting through a conduit 29 to a main condenser 31, where it is condensed at a low pressure for return to the feedwater system. From the condenser the condensate passes by way of a conduit 32 to a pump 33 from which it discharges through a conduit 34 and low-pressure heater 36 to a direct contact type deaerating heater 37 which serves to boil the condensate to eliminate any entrained oxygen. Condensate from the deaerator passes through a conduit 38 to the suction side of feed pump 10 for return to the vapor generator.

In accordance with the invention, a special by-pass system is provided around the superheater and around the turbine. This system is constructed and arranged to obtain highest operational flexibility, to minimize heat losses, and to provide full thermal protection of superheater surface and the turbine; and is used for cold and hot start-ups, for low load operation and for shutdown or emergency trip of the vapor generator.

The superheater by-pass comprises a conduit 39 containing a pressure breakdown valve 41 and having one end connected and opening to conduit 19 at a position upstream fluid flowwise of valve 21 and its opposite end connected and opening to a flash tank 42, which serves as a receiving vessel for the by-pass fluid and separates steam and water. A conduit 45, containing a valve 50, is arranged to conduct separated steam from flash tank 42 to conduit 19 at a position intermediate valve 21 and superheater 18. In accordance with the invention, provisions are made for diverting flash tank steam flow from conduit 45 to a position downstream of the superheater by means of a conduit 55 containing a stop and check valve 60 and having its inlet end connected to conduit 45 at a position downstream of valve 50 and its discharge end connected to conduit 23 at a point intermediate superheater 18 and valve 24. This particular feature will be hereinafter enlarged upon. Valve 21 is by-passed by a conduit 47 containing a pressure-reducing valve 48 and having its opposite ends opening and connected to conduit 19 at positions upstream and downstream fluid flowwise of valve 21, with valves 21, 48, 41 and 50 cooperating to allow operation of economizer 16 and vapor generating section 17 at high pressure, while the superheater pressure is varied to obtain acceptable steam conditions entering the turbine during start-up.

The turbine by-pass comprises a conduit 43 containing a pressure-reducing valve 44, spray attemperator 46 and attemperator control valve 46A, with conduit 43 having one end connected and opening to conduit 23 at a position intermediate superheater 18 and turbine stop valve 24 and its opposite end connected and opening to con-

denser 31. Spray attemperator 46 is provided to reduce steam temperature to conditions acceptable to the condenser.

Drainage from the flash tank is provided by a conduit 49 containing a deaerator water pegging valve 51 and extending between flash tank 42 and deaerator 37; by a branch conduit 52 containing a valve 53 and having one end connected to conduit 49 at a point upstream of valve 51 and its opposite end connected to condenser 31; and by a branch conduit 65 containing a valve 70 and having one end connected to conduit 52 at a point upstream of valve 53 and its opposite end connected to the shell side of heater 12.

Steam connections from the flash tank to the turbine seals, deaerator and high-pressure heater provide steam for these components during start-up, thereby recovering heat for the cycle. Thus a conduit 54, controlled by a valve 56, extends between flash tank 42 and the shell side of heater 12; a conduit 57, having a valve 58, has one end connected to conduit 54 at a position upstream of valve 56 and its opposite end connected to deaeator 37; and a conduit 59, controlled by a valve 61 leads from the flash tank to the turbine seals. A steam line 62, containing a valve 63 and leading from flash tank 42 to conduit 43 at a position intermediate valve 44 and spray attemperator 46, acts as a flash tank over pressure control by allowing any excess steam to flow to condenser 31.

In a typical cold start-up of the power plant system illustrated, about one quarter full load water flow is established through the boiler feed pump 10 which takes suction from deaerator 37 and forces fluid successively through conduit 11, heater 12, conduit 13, economizer 16, vapor generating section 17, and conduit 41 to flash tank 42. The high-pressure superheater stop valve 21, pressure-reducing valve 48, and low-pressure superheater stop valve 50 are closed so that there is no flow to superheater 18. Valve 41 is set to maintain full load pressure at the outlet of the vapor generating section throughout the start-up.

From the flash tank 42 the water flows through conduit 49 to deaerator 37 and then back to feed pump 10. Initially valve 51 is set to maintain flash tank water level below normal. Firing is then commenced and gas temperature entering superheater 18 is held to approximately 1,000° F. As the enthalpy of the fluid entering the flash tank increases, more residual heat is introduced to the deaerator, causing deaerator and flash tank pressure to rise. When deaerator pressure reaches about 20 p.s.i.a valve 51 starts to close and the flash tank level control valve 70 opens to allow flash tank drains to flow to the shell side of heater 12 to minimize heat loss, with the drains then passing through a conduit 71 to condenser 31. Conduit 71 is controlled by a valve 72. After 20 p.s.i.a. is reached in the deaerator, valve 51 controls deaerator pressure and the flash tank level control valve 70 now controls flash tank water level. If the flash tank water level exceeds the normal water level, valve 53 opens to divert the excess water to the condenser 31.

As the temperature of the water entering the flash tank increases, flash steam becomes available and pressure in the flash tank continues to increase until the opening pressure of the seal steam control valve 61 is reached at which time separated steam is directed through conduit 59 and valve 61 to seal the turbine. When the turbine is sealed, condenser vacuum can be pulled. As the enthalpy of the fluid continues to rise, the flash tank pressure increases until the opening pressure of the deaerator steam pegging valve 58 is reached, at which point flash tank pressure is about 75 p.s.i.a. and steam from the flash tank goes to the deaerator 37 by way of conduits 54 and 57 until the deaerator pressure reaches 20 p.s.i.a. At this same time valve 51 is partly closed and valve 70 is opened so that some of the flash tank water is diverted to the shell side of heater 12 and thence passes to condenser 31 by way of conduit 71. Thus feedwater temperature is increased and heat is recovered by the use of flash tank steam and water in the high-pressure heater 12. When the flash tank pressure is 50–80 p.s.i.a. above the pressure at which the deaerator is satisfied, the high-pressure feedwater heater steam control valve 56 opens so that excess steam is diverted to the shell side of heater 12. As the flash tank pressure continues to rise, flash tank water flow to heater 12 is increased while water flow to deaerator 37 is decreased until pressure in the flash tank reaches 265 p.s.i.a at which point valve 51 is fully closed, flash tank water is directed through conduit 65 to heater 12 and thence to condenser 31, and water is completely replaced by steam for deaeration.

After deaerator and turbine seal requirements are satisfied, valves 50 and 44 are opened so that steam is directed from the flash tank through conduit 45 to and through superheater 18, and then through conduit 43 to condenser 31, thereby warming up such steam lines and the superheater. This operation can take place at flash tank pressures from above 150 p.s.i.a. up to normal flash tank operating pressure. Valve 44 is throttled to maintain pressure in the superheater near the flash tank pressure. When the pressure, temperature and flow rate of the steam in the turbine by-pass conduit 43 reaches predetermined conditions, then steam flow is diverted into the turbine. At this time there is available about 2 to 3 percent of full load steam flow which is sufficient to roll the turbine up to speed.

Common practice in prior start-up systems for forced circulation boiler-turbine combinations has been to conduct low-pressure flash tank steam to and through the superheater and thence through the turbine by-pass system to attain desired steam conditions before directing flow to the turbine. The prime concern during starting and loading of the turbine is the gradual and uniform heating of the turbine metal to assure that excessive thermal differences do not occur across any portion of the turbine metal. In this connection it is desirable to match the steam and metal temperatures as closely as possible to keep thermal stress at a minimum. One of the main drawbacks of most start-up systems of the character above described resides in their inability, particularly during cold start-ups, to provide low temperature steam to the turbine for rolling and loading, owing to the fact that the through flow of the superheater for turbine rolling is only 2 to 3 percent of full load steam flow. With such low steam flow, the temperature of the steam discharging from the superheater to the turbine approaches the flue gas temperature entering the superheater. Consequently, the turbine metal is subjected to excessive rates of temperature change. This condition is alleviated to some extent on forced circulation vapor generators having provisions for tempering the flue gases, but without such equipment the minimum start-up steam temperature obtainable with prior systems has been about 825–850° F.

In accordance with the invention, flash tank separated steam outflow to conduit 45 may be by-passed around superheater 18 by suitable regulation of valves 50 and 60 so that flow is diverted from conduit 45 through conduit 55 to conduit 23. Combination stop and check valve 60 prevents flow from the superheater back to the flash tank. The temperature of the separated steam leaving the flash tank is the saturation temperature corresponding to the pressure in the flash tank. Thus the start-up system of the invention makes it possible to temper the superheater outflow prior to and during rolling and loading of the turbine and to supply turbine rolling steam through a wide range of temperatures down to as low as about 400° F. while firing the boiler hard enough to make the required amount of steam for turbine rolling and loading. Further, a conduit 78, controlled by a valve 79, is provided to direct flash tank separated steam to conduit 75 for tempering the reheater outflow before it reaches the low-pressure stage of turbine 22.

When the desired throttle steam conditions are attained, steam flow to the turbine is controlled with turbine stop valve **25**, allowing steam admission to the turbine with valve **26** wide open, which results in uniform heating of valve bowls, valve chests and turbine first stage shell area. Following the prescribed rolling period, at or near rated speed, the turbine is synchronized and loaded to 5 to 10 percent load by closing down turbine by-pass valve **44**. Load may then be increased to 20% of full load by increasing firing rate, thus making more steam available from flash tank **42**. Valves **50**, **60**, and **79** are then closed as the pressure-reducing valve **48** is gradually opened. At this time, flow to the flash tank will only constitute the difference between start-up flow and that passing directly to the superheater via the pressure-reducing valve **48**. When valve **48** is wide open, valve **41** is closed and all flow goes directly to the superheater. Thus flows to and from the flash tank cease and the pressure in the flash tank and by-pass system decays. Normal turbine extraction flows will replace flash tank steam and drain flows for deaeration and feedwater heating. At this time, the high-pressure superheater stop valve **21** can be opened wide and valve **48** closed. Superheater by-pass valve **41** is then closed and load is further increased. In the meantime control of steam flow to the turbine is transferred from valve **25** to valve **26**, with valve **25** then being fully closed and valve **24** fully opened.

During the period after the flash tank reaches its normal operating pressure, any steam separated in the flash tank in excess of what is required for turbine sealing, deaeration, feedwater heating and turbine operation is discharged through the flash tank over pressure control valve **63** to the condenser. During a cold start, there is little or no steam flow to the condenser.

The operating sequence for hot restarts and intermediate starts is essentially the same as for a cold start, except that rolling steam for the turbine may be provided through pressure-reducing valve **48** if desired.

While in accordance with the provisions of the statutes, we have illustrated and described herein the best form and mode of operation of the invention now known to us, those skilled in the art will understand that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by our claims, and that certain features of the invention may sometimes be used to advantage without a corresponding use of other features.

What is claimed is:

1. In a power plant having a turbine and a forced flow vapor generator having a through-flow circuit including a superheater connected for series flow of fluid to the turbine, means for starting up the vapor generator and turbine comprising a flash tank for separating vapor and liquid, means for supplying a vaporizable liquid under pressure to the through-flow circuit, means for passing liquid from said circuit from a position upstream of the superheater to the flash tank while reducing its pressure to the extent that a protion of the liquid flashes into vapor, and means for passing separated vapor at the saturation temperature corresponding to the pressure in the flash tank from the flash tank to the discharge side of the superheater for mixing of such saturated vapor with the superheater outflow.

2. In a power plant having a turbine and a forced flow vapor generator having a through-flow circuit including a heating section and a superheater connected for series flow of fluid from the heating section and to the turbine, means for starting up the vapor generator and turbine comprising a flash tank for separating vapor and liquid, means for supplying a vaporizable liquid under pressure to the heating section, means for passing heating section outflow to the flash tank while reducing its pressure to the extent that a portion of the liquid flashes into vapor, means for passing separated vapor at the saturation temperature corresponding to the pressure in the flash tank from the flash tank to the discharge side of the superheater for mixing of such saturated vapor with the superheater outflow, and means for passing separated liquid from the flash tank to the heating section.

3. In a power plant having a turbine, a forced-flow vapor generator having a through-flow circuit including a fluid heating section and a superheater section connected for series flow of fluid from the fluid heating section and to the turbine, and a pump supplying vaporizable fluid to the fluid heating section, means for starting-up the vapor generator and turbine comprising a valve arranged to control fluid flow between the fluid heating and superheating sections, a flash drum, a conduit connecting the fluid heating section to the flash drum and arranged to convey the discharge from the fluid heating section to the flash drum when said valve is closed, a pressure-reducing valve in said conduit arranged to cause fluid discharge from the fluid heating section to flash into vapor, a valve-controlled conduit connecting the flash drum to the superheating section for supplying flashed vapor thereto, and a valve-controlled conduit connecting the flash drum to the discharge side of the superheater for supplying flashed vapor at the saturation temperature corresponding to the pressure in the flash drum for mixing with the vapor discharging from the superheater.

4. The method of starting a power plant system having a turbine and a vapor generator having a through-flow circuit including a superheating zone arranged for flow to the turbine, said method comprising passing a vaporizable fluid through the circuit in indirect heat-transfer relation with high-temperature heating gases, passing a portion of the circuit through-flow to a separating zone while reducing its pressure to cause part of the fluid to flash into vapor, effecting separation of the vapor portion of the fluid in the separating zone, passing separated vapor at the saturation temperature corresponding to the pressure in the separating zone from the separating zone to a position downstream of the superheating zone for mixing of such saturated vapor with superheating zone vapor outflow, passing the vapors so mixed to the turbine for rolling and loading thereof.

5. The method of starting a power plant system in which, during normal operation, a vaporizable fluid is successively passed through a heating zone and a superheating zone to a vapor turbine, said method comprising passing a vaporizable liquid under a substantial pressure through the heating zone in indirect heat-transfer relation with high-temperature heating gases, passing heating zone outflow to a separating zone while reducing its pressure to cause part of the liquid to flash into vapor, effecting separation of the vapor portion of the liquid in the separating zone, passing separated liquid from the separating zone to the heating zone, passing separated vapor at the saturation temperature corresponding to the pressure in the separating zone from the separating zone to a position downstream of the superheating zone for mixing of such saturated vapor with superheating zone vapor outflow, passing the vapors so mixed to the turbine for rolling and loading thereof.

6. The method of starting a power plant system in which, during normal operation, a vaporizable liquid is directed through a through-flow circuit including a superheating zone arranged for flow to a vapor turbine, said method comprising passing a vaporizable liquid through the circuit in indirect heat-transfer relation with high-temperature heating gases, passing a portion of the circuit through-flow to a separating zone while reducing its pressure to cause part of the liquid to flash into vapor, effecting separation of the vapor portion of the liquid in the separating zone, passing separated liquid from the separating zone to the inlet of said circuit, passing separated vapor at the saturation temperature corresponding to the pressure in the separating zone from the separating zone to a position downstream of the superheating zone for

mixing of such saturated vapor with superheating zone vapor outflow, passing the vapors so mixed to the turbine for rolling and loading thereof.

7. The method of starting a power plant system in which, during normal operation, a vaporizable fluid is successively passed through a heating zone and a superheating zone to a vapor turbine, said method comprising passing a vaporizable fluid under a substantial pressure through the heating zone in indirect heat transfer relation with heating gases, passing the fluid so heated to a separating zone while reducing its pressure to cause part of the fluid to flash into vapor, effecting separation of the vapor portion of the fluid in the separating zone and then passing separated vapor through the superheating zone, recirculating separated liquid from the separating zone to the heating zone, condensing the superheating zone vapor outflow and recirculating the condensate to the heating zone, increasing the pressure of the fluid in

the separating zone while passing a portion of the separated vapor from the separating zone to a position downstream of the superheating zone for mixing with the vapor discharging from the superheating zone until predetermined conditions of fluid temperature and pressure for starting the turbine are attained, discontinuing the bypassing of fluid from the heating zone to the separating zone and from the superheating zone to the heating zone so that all the fluid entering the fluid heating zone passes successively through the heating zone and superheating zone to the vapor turbine.

References Cited by the Examiner

UNITED STATES PATENTS

3,175,367 3/1965 Gorzegne et al. ..... 60—73

MARTIN P. SCHWADRON, *Primary Examiner.*

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