ECONOMIC COMBINATION AND OPERATION OF BOILER THROTTLE VALVES

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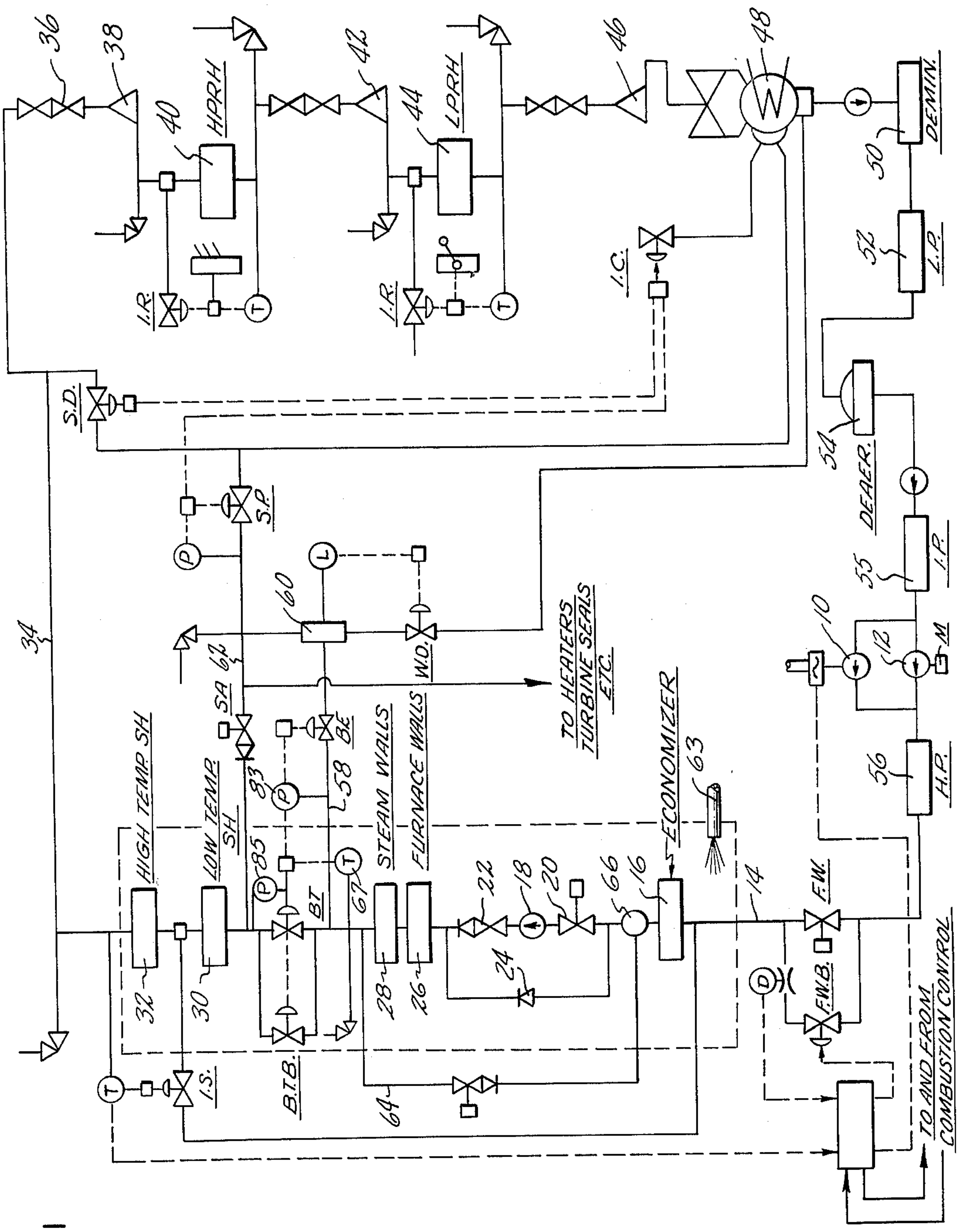

FIG_1

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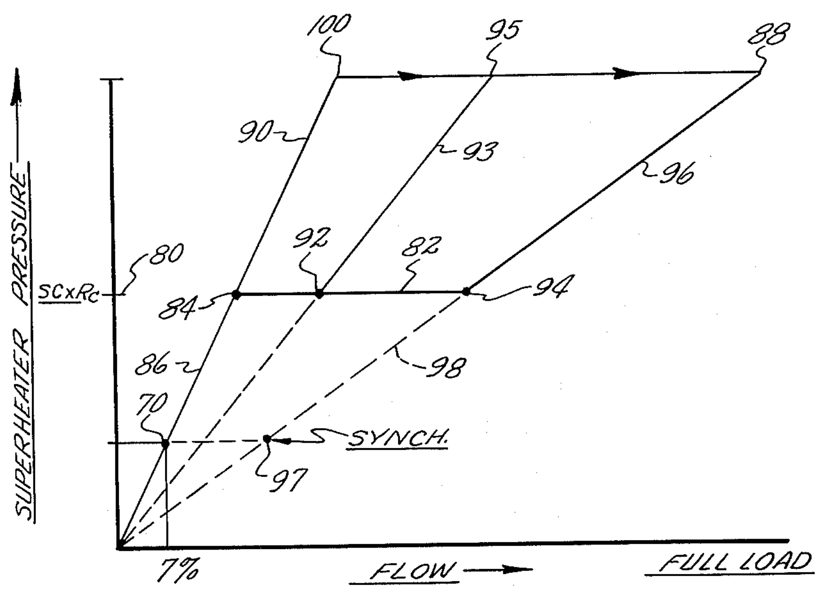
FIG_2



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This invention relates to vapor generators, particularly of the forced flow, once-through type and mechanism relating to the starting up of such generators.

An object of this invention is an economic combination of elements facilitating starting up of the vapor generator.

Another object is an improved method of starting the generator and warming the turbine connected therewith.

A still further object is a combination of turbine controls and vapor control valves for said vapor generator and a method for utilizing them to provide an economical utilization of said valves.

Other objects and advantages will be apparent from the following specification and the attached drawings in which:

FIG. 1 is a schematic showing of the combination of elements, and a flow and control diagram, incorporating the invention; and

FIG. 2 is a graph showing the relation between flow and superheater pressure during startup.

The arrangement of the vapor generator, which is preferably a steam generator, and associated sub-systems within the plant cycle is shown in a simplified manner in FIG. 1. Modern steam generators, regardless of pressure level, have by their very nature, (1) a water heating section or economizer, (2) an evaporator or at supercritical pressures an intermediate section, which by convention is commonly termed "furnace walls" or a vapor generator section, and finally (3) a superheater. The pressure level at which the steam generator operates influences particularly the relative size of these sections and their temperature level.

The flow in economizers or the water heating sections and in superheaters in all steam generators is maintained by the feedwater pump head which for any load balances the pressure drop of the fluid from the pump outlet to the turbine throttle valve.

The circulation of water in the evaporator or furnace walls may be produced by the feedwater pump assisted by a recirculating pump and system for recirculating fluid through the furnace walls.

The feedwater from the feedwater pump 10 or 12, FIG. 1, enters the steam generator system through feedwater valves F.W. or F.W.B. and after some length of piping 14 reaches the economizer 16. From the economizer 16 the fluid passes through the recirculating pump 18 and its associated isolating valves 20 and 22 or the check valve 24 to the furnace walls, where it flows in series through the center wall and outer walls 26, then through the steam cooled closure walls of the rear gas pass 28 which may be considered as a continuation of the outer walls. When in operation the steam from the furnace walls then passes through a system of boiler throttle valves B.T. and B.T.B. and then continues through sections of horizontal and pendant superheaters indicated as 30 and 32 and thence to the steam piping 34 leading to the turbine control valves 36 and the turbine 38. The steam is returned from the turbine to a reheater 40, subjected to heat from the furnace, and then returned to the turbine section 42. Steam from the turbine section 42 may be fed through a second reheater section 44 subjected to furnace heat and then passed through a section 46 of the turbine and then conducted to a condenser 48. The condensate passes

through a filter demineralizer 50 and low pressure heaters 52 to a de-aerator 54 and intermediate pressure heaters 55. The feed pumps 10 and 12 then return the feedwater through high pressure heaters 56 to the feedwater valves.

Components of particular utility in the startup system include the B.T. and the B.T.B. valves mentioned above. Upstream of these valves, piping 58 connects the furnace wall system with the boiler extraction valve B.E. and the water separator or flash tank 60. The steam side of the separator 60 is connected to the superheater system 30 and 32 through piping 62 and a steam admission valve S.A. and to the condenser 48 through a spill-over valve S.P. Water from the separator is discharged to the condenser through the water drain valve W.D. A steam discharge valve S.D. connected to the line 34 between the superheater 32 and the turbine throttle valve 36 may be used to discharge steam used for superheater cooling and heating of steam leads to the condenser. An injection valve I.C. controls desuperheating water flow for condenser protection. The I.S. valve is a superheater injection valve for controlling superheater output temperature and the I.R. valves are reheater injection valves for controlling the reheater output temperatures.

The furnace walls or vapor generator 28 define a furnace within which fuel, supplied by any suitable and well-known means such as pipe 63, may be burned to supply heated gases and a source of heat for heating the fluid contained in the several sections 16, 26, 28, 30, 32, 40 and 44 exposed to the hot gases. A bypass 64 across the furnace and steam cooled walls provides a path for return of recirculated fluid forced through these walls by the recirculating pump 18 which acts as a mixed flow pump, pumping both feedwater and recirculating fluid. The recirculating fluid is mixed with the incoming feedwater in a mixing chamber 66. Reference may be made to application Serial No. 127,395 of W. W. Schroedter filed July 27, 1961, now Patent No. 3,135,252 issued June 2, 1964, for "Recirculation System for Steam Generator" for a more complete description of the recirculation system. With such a recirculation system the flow requirements of the furnace walls, such as 30% of full load flow, no longer determine the feedwater flow requirements during startup so that the through-flow may be limited to 5 or 10% of the full load requirements as determined by the steam cooling requirements of sections such as the superheaters or by steam heating requirements for the piping or by steam requirements for the turbine which may be for example, in the order of 7% of the full load steam flow during the initial turbine rolling and initial loading after synchronizing the generator to gradually bring the turbine and generator up to operating temperatures simultaneously with bringing the entire vapor generator system up to operating temperature and pressure throughout its several sections.

For several reasons, such as assurance that no slugs of water shall get into the turbine and for greater freedom in selection of material for manufacture of the superheaters, it is advisable, during startup particularly, to prevent any water from the furnace wall sections entering the superheater. This is the function of the B.T., B.T.B., and B.E. valves all of which are in the connections between the furnace walls and the superheaters and serve to block the passage of water from one section to the other. The B.T. valves are large, throttling, poppet-type valves designed for low pressure drop which at design load or full load conditions will pass the major part of the vapor flow from the furnace walls to the superheater with a minimum of pressure drop through the valves. The B.T.B. valves act as a bypass around the B.T. valves during startup conditions but remain wide open under full flow conditions when they will transmit a minor part of the full flow from the furnace walls to the superheaters. The B.T.B. valves are heavy duty, relatively expensive valves designed for severe throttling service to control vapor flow at temperatures in the neighborhood of 800° F. and at pressure differences on the opposite sides of the valve equal to and greater than the critical pressure drop.

At pressure differences equal to or greater than the critical pressure drop, flow through the valve reaches sonic velocity and has an eroding effect which leads to rapid deterioration of the valve. The B.T.B. valve is also a poppet-type valve but designed for much more severe service than the B.T. valve which is not adapted to operate at a critical pressure drop but only at flows having less than sonic velocity. Because of the nature of the valve and the service required of it it is desirable to keep the B.T.B. valves as small as possible consistent with the requirements of the remainder of the system and this is one of the objects of the invention.

The B.E. valves which are also throttling poppet valves designed to operate at a critcial pressure drop but differ from the B.T.B. valves in that they are designed to handle water flow at the critical pressure drop as well as vapor flow. These B.E. valves are also expensive and their service is severe so that they should be kept as small as is consistent with the requirements of the remainder of the system.

It should be noted that because of the recirculating system the through-flow requirements which these several valves, B.E., B.T.B. and B.T., are required to handle during initial startup may be reduced to less than 30% of the full load flow and will be determined largely by the load or use supplied during the startup, which in the example chosen is a turbine and generator which can be satisfied with a minimum of say 7% of the normal full flow when generating electrical power. This will permit much smaller valves than if a through flow of 30% of full flow were required during startup.

As a general description of the startup procedure, the relatively small quantities of feedwater flow during all startup operations are regulated by the feedwater bypass valves F.W.B. Their operation is coordinated to proportion feedwater flow to firing rate. For boiler cleanup, which involves firing of the steam generator, and for initial turbine operation, the boiler throttling valves B.T. and B.T.B. are bypassed by way of a low pressure system including the B.E. valves and the flash tank **60**. This boiler throttling valve arrangement keeps the furnace wall operating at its proper pressure under all conditions while allowing the superheater to operate at a lower pressure level. There is thus in effect a liquid compartment provided by the furnace walls and a vapor compartment provided by the superheaters and separated by a valving system by means of which the liquid compartment can be kept under a preselected pressure while the vapor compartment is at a lower pressure.

During the initial phase of a startup, the boiler throttling valve B.T. and B.T.B. are closed and the turbine is heated and rolled on the low pressure separator-superheater system. Furnace wall outlet temperatures are then increased and sufficient low pressure stream is generated to synchronize and initially load the turbine. Furnace wall pressure control which is by way of the pressure controlled B.E. valve is now transfererd from the B.E. valve to the boiler throttling valves B.T.B. The steam admission stop check valve S.A. will close when the steam pressure in section **30** passed through the B.T.B. valve exceeds the pressure in the separator or flash tank. Loading of the turbine then proceeds by increasing boiler input i.e. feedwater flow and firing rate while maintaining the turbine governor valves at a preselected minimum fixed opening and first continuing to open the B.T.B. valve until the pressure drop becomes less than the critical value and then opening the B.T. valve to gradually increase the downstream pressure while maintaining the upstream pressure at the preselected substantially constant value.

The pressure in the superheater system rises proportionally with load and may reach full operating pressure at about 30% load, point **100** in FIG. 2. The boiler throttling valves are then fully open and loading proceeds under control of the turbine control valves at essentially constant turbine throttle pressure.

In detail, to start up the system the liquid compartment including the economizer and the center, outer and steam cooled furnace walls are filled and vented up to the B.T. and B.T.B. valves separating the superheater system from the furnace wall system which valves at this time are closed. These valves are blocked against opening until the temperature at the steam cooled water outlet reaches some preselected temperature, such as 800° F. by known mechanism indicated schematically at **67**, such as a temperature actuated switch or valve, blocking valve actuating servo mechanism. The B.E. valve is closed and set for automatic pressure control at some selected vapor generator pressure, for example 1000 p.s.i. The feedwater pumps are started and establish a minimum feedwater flow of say 5% of full load flow and the feed water flow as controlled by the feedwater bypass valve F.W.B. passes through the economizer and the furnace wall system and is discharged through the boiler extraction valve B.E. to the separator. The water returns to the condenser through the water drain valve W.D. Pressure in the furnace wall system is maintained by the B.E. valve at the selected setting value. The steam admission stop check valve S.A. connecting the separator with the superheater system is open and the recirculating pump **18** is started.

Firing is initiated and maintained at a rate to bring the steam cooled wall outlet steam temperature up at a preselected rate consistent with gas temperature limitations for reheater protection. As the furnace wall outlet temperature rises above the saturation temperature equivalent to the pressure in the separator the fluid begins to flash into steam in the flask tank **60** with the steam portion passing into the superheater at saturated temperature. The steam flow cools the gas touched superheater tubing and heats the headers and interconnecting piping. The rate of flow through the steam piping and its rate of temperature rise is controlled by the manually actuated steam drain valve S.D. through which the low pressure steam is permitted to proceed to the condenser. The boiler extraction valve B.E. pressure control is reset to maintain the pressure in the furnace wall system at higher pressure than the saturation pressure equivalent to the highest fluid temperature in the walls. At some preselected temperature, say 550°, the pressure will be maintained, in the example chosen for illustrative purposes which is a supercritical system, at 3500 p.s.i.

If cleanup is required of the boiler water the steam cooled wall outlet temperature is held at 600 to 650° F. until the solids concentration of the water being circulated reaches acceptable limits. The flow sweeping the furnace wall system during this time is maintained by the recirculating system at a preselected rate which may be at an equivalent level of about 60% of full load flow. During this time the low pressure steam from the superheater outlet may be fed through the turbine to heat and roll the turbine.

As the fluid at furnace wall outlet gradually reaches acceptable levels of purity, firing rate is increased and the temperature level at the furnace wall outlet rises so that the discharge of the B.E. valve to the separator produces increasingly more steam and less water. The S.D. valve may now be closed and the steam not used to bring the turbine to speed increases the pressure in the separator and superheater system until the desired turbine valve chest pressure of say 800 pounds per square inch gage is reached. This level is then maintained by spilling the excess steam through the pressure controlled spill-over valve S.P. to the condenser.

At about 800° F. fluid temperature, all through-flow is turned to steam in the separator. The turbine is synchronized and initially loaded, and the excess steam previously discharged through the S.P. valve is now taken through the superheater and the turbine. In this manner, the startup system acts as a reservoir from which the turbine may be initially loaded without requiring a sudden and comparatively large firing rate or flow input change to the steam generator.

In order to proceed with the boiler loading the bypass operation through the separator is replaced by operation through the boiler throttling valves. This is now possible since the furnace wall outlet enthalpy already is at a level at which throttling a supercritical fluid will produce steam only. The change-over is made by gradually transferring upstream pressure control, maintaining the pressure in the furnace walls at about 3500 p.s.i., from the pressure actuated B.E. valves to the pressure actuated B.T.B. valves As the latter open and the former close the flow of steam through the separator ceases and the S.P. and the S.A. valves will close. All feedwater flow now passes through the superheater to the turbine. Firing rate and feedwater flow may be increased to further load the turbine.

The throttle valve system as described above has another advantage in that low pressure high temperature steam can be made available to the turbine on hot re-starts. The throttle valve combination described above is capable of low flows at critical throttling pressure drop and high flows at low pressure drop both with a high degree of control at different points in the loading sequence.

A hot start follows the principal actions of a cold start by again using the low pressure separator-superheater system in order to provide low pressure, high enthalpy steam to the turbine valve chest. The boiler throttling valves are closed, the upstream boiler sections are pressurized to full operating pressure i.e. 3500 p.s.i. and superheater pressure is reduced to the separator operating level i.e. 800 p.s.i. by opening of the S.D. valve.

Firing may be re-established and about 5% feedwater flow admitted With the higher temperature level in the furnace and furnace wall sections sufficient separator steam for turbine rolling is available immediately. Furnace wall outlet temperature quickly reaches the 800 F. limit, if not there already, and steam to the turbine will be in the order of 850° F. Boiler input is increased to the initial loading level and the turbine synchronized.

The sequence again follows through the transfer from separator operation to boiler throttling operation and loading again follows the vapor generator until the control system can take over. On hot starts where rolling periods prior to synchronizing are comparatively short, the thermal inertia of reheater tubing in the gas pass allows temporary overfiring for higher superheater temperatures.

The most desirable enthalpy performance of steam delivered to the turbine is that which on the critical turbine part produces the lowest possible cumulative thermal fatigue damage under any operating condition. To meet such performance—generally low temperatures on a cold start and high temperatures on a hot start—the present system adds a large measure of flexibility and improved performance.

During startup, while maintaining furnace wall pressure at the supercritical level of say 3500 p.s.i., the turbine is synchronized at some combination of superheater pressure and flow indicated at point 70 in FIG. 2 which assures that the generator will be driven by the turbine and not motorized. It is desirable to have a minimum flow through the turbine when it is synchronized and initially loaded of about 7% of the total full load flow. It is also desirable, from a control simplicity standpoint, to

minimize manipulation of the turbine control valves while the pressure in the furnace walls is under control of the B.T.B. valves. In order to accomplish these two desirable features the position of the turbine control valve is fixed to provide a fixed opening which will provide the desired minimum flow through the turbine under the synchronizing steam pressure of about 800 p.s.i.g. maintained by the spill-over valve S.P. The steam required to operate the turbine, after transferring from the startup system to the main system, i.e. from the B.E. valve to the B.T.B. valve, passes through the B.T.B. valve with a critical throttling pressure drop. It is highly desirable to achieve a superheater pressure which will not require a critical throttling pressure drop through the B.T. or the B.T.B. valves at as low a flow as possible. This superheater pressure is indicated by $SC \times R$ which indicates supercritical pressure, which is 3500 p.s.i. in the example used for illustration, multiplied by the critical throttling drop ratio which is approximately .545. This pressure is indicated by 80 in FIG. 2 and by the line 82. As soon as the superheater pressure is raised above the pressure indicated by the point 80, say to 2000 pounds per square inch, then the B.T. valves may be opened. The B.T. valve is pressure operated or controlled by two different pressures. It is controlled by the pressure in the furnace walls by any well-known mechanism, schematically indicated at 83 on FIG. 1, so as to maintain that pressure at the preselected value of say 3500 p.s.i. and it is controlled by the pressure in the superheater system by known mechanism schematically indicated at 85, such as a pressure actuated switch or valve, blocking operation of servo operating mechanism for the valve so as to prevent opening of the B.T. valve until the drop across that valve is less than the critical pressure drop. The size and hence the economic cost of the B.T.B. valves are minimized when the flow they must be designed for is also minimized. By fixing the opening of the turbine control valves to establish the point 70 with the minimum permissible flow through the turbine and maintaining the turbine control valves at that fixed opening while the flow through the B.T.B. valves is increased by increasing the feedwater through flow rate and correspondingly increasing the firing rate the flow will follow the line 86 to the point 84 indicating say 17% flow at which time the B.T. valves may be opened, the B.T.B. valves being essentially wide open at this point. This procedure will hold for any arrangement of turbine admission throttle valves. After the point 84 has been reached in the startup procedure any of several paths may be followed to reach the point 88 which indicates full superheater pressure and full load depending primarily upon the arrangement of turbine admission valves. For the special condition in which the fixed opening for selecting the point 70 happens to coincide with the wide open position of the then controlling turbine throttle valves as would be the case of the "sequential valve point" or "partial admission" turbine control valve arrangement in which the turbine control valves comprising the first admission arc would be opened wide at synchronizing, both the superheater pressure and the flow would increase along the line marked 90 until the full superheater pressure were reached at point 100. As the feedwater flow was increased to provide this additional flow the B.T. valves would be automatically opened to maintain the 3500 p.s.i. in the water wall section. Thus when the full superheater pressure is reached the B.T. valves would be wide open to pass full flow and the pressure in the entire system would be maintained by operation of the turbine throttle valves and the flow control mechanism. In all cases maximum turbine efficiency is obtained when turbine throttle valves are throttled the minimum amount and in the above case maximum turbine efficiency would be obtained from synchronizing all the way to full superheater pressure. From the point 100 to the full load point 88, normal sequencing of the turbine control valves for the remaining admission arcs is used since this again is the path of maximum turbine efficiency.

In a more general case of the "sequential valve point" or "partial admission" turbine control valve arrangement in which the synchronizing would be obtained at a fixed valve opening as above but which would be less than the full valve opening for the valves of the first admission arc, the flow and superheater pressure rise would be along the line **86** from point **70** to **84** as in the special case. At point **84** the B.T. valve would open and the increased flow produced by the feedwater pumps would be used to maintain the superheater pressure substantially constant and the same as that at point **80**. This could be done by opening the turbine control valves as the flow increased or could be accomplished by a pressure responsive mechanism which would automatically open the turbine throttle valves to maintain the pressure at the level indicated by the point **84**. The turbine would then be controlled by the first admission arc which would be wide open at point **92** and the turbine would operate at its maximum efficiency for those pressure conditions.

From point **92** increased feedwater flow, with, of course, increased firing to optimize the temperature at the furnace wall outlet, will open the B.T. valve further to pass the increased flow while the valve controlling the first admission arc of the turbine would remain wide open until the full superheater pressure was reached at **95**. A further increase in flow after the full superheater pressure is reached at **95** will result in normal sequencing of the turbine control valves for the remaining admission arcs until the full load position **88** would result in the substantially wide open turbine throttle valves. In this way the most efficient operating condition of the turbine valve would be maintained over the full load range.

A third example of turbine control would be the so-called "single point" or "full admission" turbine control valve or arrangement. In this arrangement the turbine operates at its best efficiency with the turbine throttle valves wide open but this is the valve condition designed for full load flow to the turbine and is the valve condition utilized when the turbine and generator are delivering essentially their full rated load. In this case as before, the turbine control valves would be fixed at a limited open position to provide the conditions indicated by point **70** giving the turbine a fixed predetermined throttle opening. As before the increasing feedwater flow through the system will open the B.T.B. valves automatically to maintain and limit the furnace wall pressure to the selected pressure 3500 p.s.i., in the selected example, and the pressure and flow would follow along the line **86** from point **70** to point **84**. At this point the B.T.B. valves being wide open and the B.T. valves being released for operation, increased feedwater flow will as in the second example open the B.T. valves to prevent an increase in pressure above the selected value in the furnace walls and the turbine throttle valve will be manipulated either manually or automatically, to maintain the selected superheater pressure substantially constant until the turbine throttle valves are wide open at point **94**. At this point a further increase in flow of feedwater will result in a further opening of the B.T. valves and an increase of the superheater pressure along the line **96** until at point **88** both the B.T. valve and the turbine throttle valves are wide open and the unit is at essentially full flow and load. As before, the B.T.B. valves would handle as small a flow as practicable and the turbine throttle valve would be opened to maintain the constant pressure along the line **82** thereby minimizing throttling and maximizing efficiency.

Taking the 7% flow as the necessary requirement for synchronizing in the last cited example if we were to allow the turbine control valves to take their most efficient and wide open position at synchronizing which would be at point **97** and continue with that wide open position along line **98** up to the critical pressure drop line indicated by line **82** and point **94** we would then require B.T.B. valves which would handle a flow indicated by the point **94** which obviously would require much more expensive equipment than B.T.B. valves only large enough to handle the flow at point **84**.

Where it is convenient or practicable to control the turbine throttle valve to provide a gradually increasing superheater pressure while maintaining a substantially constant feedwater flow, B.T.B. valves having a flow capacity not substantially greater than the flow capacity required for synchronizing may be utilized. When the pressure in the superheater becomes high enough to eliminate the critical pressure drop, the turbine throttle valves could then be left in the position which produced the desired superheater pressure and the through flow increased to increase the superheater pressure or they could be manipulated to maintain the superheater pressure substantially constant until the turbine control valves reached an opening position, i.e. a wide open position for the then operating turbine control valves, resulting in a path of maximum efficiency, and the superheater pressure could then be raised to the rated maximum value by increasing the through-flow with that selected turbine throttle valve position as in the previous examples. For control simplicity it is now preferred to set the turbine throttle valves at a fixed predetermined opening for synchronizing when raising the superheater pressure from the synchronizing pressure to a pressure which will cause less than the critical pressure drop across the B.T. valves as described above. If desired, in the case of the second illustration above instead of operating the turbine throttle valves at point **84** to bring them to the wide open condition at point **92** and then traveling along the line **93** to the full pressure wide open position at **95** the valves could be left in their fixed position and the pressure and load raised along the line **90** to the point **100** and then the turbine throttle valves could be operated along this full superheater pressure line to the wide open positions of the turbine throttle valves at **95** at which point the control of the entire system could be turned over to the usual coordinated control system. This would provide not quite as efficient a path of operation of the turbine from the point **84** to **95** as would be occasioned by traveling to the point **92** and then along the line **93**. It is to be understood that the invention is not limited to the specific embodiment herein illustrated and described but may be used in other ways without departure from its spirit and that various changes can be made which would come within the scope of the invention which is limited only by the appended claims.

I claim:

1. In a vapor generator system for supplying vapor to a load having a selected minimum flow requirement and having first and second heating sections and first and second valve means in parallel connecting said sections in series and an adjustable restriction at the outlet of said second section, in combination, means forcing a flow of fluid through said first section, said valve means said second section and said restriction in series, said first valve means being adjustable to impede said flow and maintain a predetermined working pressure in said first section, said restriction having a preselected opening position at which said selected minimum flow will produce a preselected pressure in said second section and a greater than critical pressure drop across said first valve means, said first valve means having a maximum flow capacity at said working pressure only sufficient to raise the pressure in said second section to a raised pressure only slightly above that which will eliminate the critical pressure drop across said first valve means with said restriction in said preselected opening position, said second valve means being adjustable to maintain said working pressure in said first section at increased flows.

2. A combination as claimed in claim **1** having a third valve means in parallel with said first and second valve means and said third valve means having a maximum capacity less than 30 percent of full load flow and being adjustable to impede flow and maintain a predetermined working pressure in said first section, a separator receiving the output of said third valve means and delivering vapor to said second section, means limiting the pressure in said separator and second section to said preselected pressure, means blocking said separator and limiting means from said second section including means transferring control from said third valve means to said first valve means for maintaining said working pressure.

3. A combination as claimed in claim 1 including means responsive to the pressure in said first section adjusting both said valve means.

4. A combination as claimed in claim 3 including means responsive to the pressure downstream of said second valve means preventing said second valve means from opening until the critical pressure drop across said second valve has been eliminated.

5. A system as claimed in claim 1 in which said maximum flow capacity is less than 30 percent of full load flow and said first section has a minimum flow requirement greater than said load minimum flow requirement, and including a recirculation system in said first section augmenting the through flow in said first section.

6. A combination as claimed in claim 1 including means responsive to the temperature at the outlet of said first section preventing both said valve means from opening until a preselected temperature is attained in said first section.

7. In a vapor generator system for supplying vapor to a load having a selected minimum flow requirement and having first and second heating sections and first and second valve means in parallel connecting said sections in series and an adjustable restriction at the outlet of said second section, in combination, means forcing a flow of fluid through said first section said valve means said second section and said restriction in series, said first valve means being adjustable to impede said flow and maintain a predetermined working pressure in said first section, said restriction having a preselected opening position at which said selected flow will produce a preselected pressure in said second section and a greater than critical pressure drop across said first valve means, said first valve means having a maximum flow capacity at said working pressure substantially equal to said selected flow, said second valve means being adjustable to maintain said working pressure in said first section at increased flows.

8. A forced flow once-through vapor generator system having an initial startup flow requirement comprising a superheater section connection in series with and receiving vapor from a vapor generator section, throttle valve means in parallel connecting said sections and including pressure responsive valve means for maintaining the pressure in said generator section at a preselected pressure and constructed and arranged to accommodate critical pressure drop and having a limited flow area insufficient to supply said initial startup flow at pressure differences across said valve materially less than said critical pressure drop and said throttle valve means also including a second throttle valve means unsuited for use with critical pressure drop, said second valve being pressure responsive and throttling to maintain said preselected pressure in said generator section, and having a flow area sufficient to pass the full load flow of said vapor generator system.

9. In a forced flow once-through vapor generator system having a through flow path and a vapor generator section connected in series with a superheater section in said path, pressure responsive main valve means in the connection between said sections for maintaining a preselected pressure in said generator section, pressure responsive means preventing opening said valve until the downstream pressure increases to a value slightly above that required to eliminate a critical pressure drop across said valve, an adjustable throttle valve in said superheater outlet and said path having a preselected limited opening position which will produce a pressure in said superheater less than said downstream pressure with a preselected minimum through flow and increasing the superheater pressure to said downstream pressure with increased through flow, a bypass around said main valve having a maximum through flow capacity at least as great as said minimum through flow and not substantially greater than said increased through flow, and means effective to open said main valve upon further increase in flow.

10. In a forced flow once-through vapor generator system having a through-flow path, and having a vapor generator section connected in series with a superheater section in said flow path, a pressure responsive main valve in the connection between said sections for maintaining a preselected pressure in said generator section, pressure responsive means preventing opening of said valve until a preselected downstream pressure substantially equal to the product of said preselected generator pressure and the critical pressure ratio is attained, adjustable throttle means in said superheater outlet and flow path having a preselected limited opening position, a bypass around said main valve including means maintaining said preselected pressure in said generator section, a separator and means limiting the pressure in said separator and superheater to a pressure producing greater than critical pressure drop across said bypass, means for blocking said bypass, a second bypass around said main valve including a pressure responsive valve for maintaining said preselected pressure in said generator section with critical pressure drop conditions across said bypass and having a maximum flow capacity at least as great as the flow capacity of said throttle valve in its limited opening position at said limited pressure but not materially greater than the flow capacity of said throttle valve in its limited opening position at said preselected downstream pressure.

11. A forced flow once-through vapor generator for supplying vapor to a device having a minimum startup flow requirement, comprising, a vapor generator section, a superheater section and valve means in parallel connecting said sections for series flow through said sections, a first one of said valve means constructed to efficiently pass liquid and vapor at substantially sonic velocity, connected to the outlet of said vapor generator section, a separator receiving the liquid and vapor through flow from said first valve means and passing only vapor to said superheater section and throttle, means limiting the pressure in said separator and superheater to a selected limited pressure, said first valve means having a maximum flow capacity at sonic velocity and the normal working pressure of said generator section substantially equal to said minimum flow requirement, a throttle at the outlet of said superheater section having a selected position for, and producing said limited pressure at, said minimum flow requirement, a second one of said valve means for passing only vapor at sonic velocity, and having a maximum flow capacity at substantially sonic velocity substantially equal to the flow capacity of said throttle in said selected position at a superheater pressure, higher than said limited pressure, and substantially equal to the product of the critical pressure ratio and said normal working pressure, and a third valve means for passing vapor at less than sonic velocity, having a flow capacity to pass substantially the full load flow of said generator.

12. In a force flow vapor generator and superheater system, a vapor generator section, and a superheater section, means for forcing fluid through said sections in series, means in parallel connecting said sections and including a first means impeding flow to less than 30 percent full load flow to maintain said generator section at a preselected pressure, a separator tank receiving flow from said generator section and said first means and means for delivering vapor from said tank to said superheater section and means limiting the pressure in said tank to a limited pressure and providing a greater than

critical pressure drop across said connecting means, means for blocking flow through said separator and first means, a second means connecting said sections and including a pressure reducing valve connecting said sections when said separator and first means are blocked, and impeding flow to maintain said generator section at said preselected pressure, an adjustable outlet opening for said superheater section having a preselected limited opening position producing said limited pressure at a selected flow rate less than 30 percent of full load flow, means increasing the through flow to less than 30 percent full load flow and increasing the pressure in said superheater section to a pressure above said limited pressure but less than said preselected pressure while maintaining said preselected pressure in said generator section to eliminate said critical pressure drop while maintaining said limited opening position of said outlet opening, including means completely opening said pressure reducing valve, a third means connecting said sections including a throttle valve, in parallel with said reducing valve, impeding flow to maintain said generator section at said preselected pressure value when the pressure drop to the pressure in the superheater section is less than critical, and means responsive to further increased through flow increasing the pressure in said superheater section to substantially said preselected pressure while maintaining said outlet opening at some preselected limited opening position, including means completely opening said throttle valve.

13. In a forced once-through flow vapor generator having a through-flow circuit with first and second heating sections in series and first and second valve means in parallel in said circuit between said sections, said first valve capable of operating with critical pressure drop and said second valve incapable of so operating, an improved operating method comprising the steps of maintaining the pressure upstream of said valve means at a predetermined value, restricting said through-flow downstream of said second heating section while maintaining critical pressure drop across said valve means, substantially completely opening said one valve means and raising the pressure in said second heating section to a pressure only slightly above that which will give critical pressure drop and thereafter manipulating said second valve means to further increase the pressure in said second heating section.

14. In a vapor generator system having a vapor generator section, a superheater section, valve means in parallel connecting said sections in series, including one valve means constructed for operation with critical pressure drop and a second valve means of substantially larger flow area unsuited for such operation, means forcing flow through said sections in series and a throttle between said superheater section and a load having a minimum initial loading fluid flow requirement less than 30 percent of full load flow, the method of operating comprising the steps of forcing substantially the same through flow of vaporizable fluid through said sections and said throttle in series while maintaining the pressure in said generator section at a preselected value by actuating said one valve means in response to generator section pressure, restricting said through flow downstream of said superheater section to said minimum flow and establishing a preselected superheater pressure substantially less than that required to produce critical pressure drop across said valve means, then decreasing said pressure drop to slightly less than said critical pressure drop but materially less than said generator pressure and substantially completely opening said one valve and then controlling further increases in superheater pressure and decreases in said pressure drop by manipulating said second valve.

15. The method of operating a vapor generating system having a vapor generator section, a superheater section, valve means in parallel connecting said sections including one valve means constructed for operation with critical pressure drop and a second valve means of substantially larger flow area unsuited for such operation, means forcing flow first through said generator section and then through said superheater section in series and a throttle controlling the flow from said superheater section to a load having a minimum initial loading fluid flow requirement, comprising the steps of forcing substantially the same through flow of vaporizable fluid through said sections and said throttle in series while maintaining the pressure in said generator section at a preselected pressure, establishing said initial load flow and setting said throttle in a preselected opening position which will provide a preselected superheater pressure substantially less than that which will just produce a critical pressure drop across said valve means with said initial load flow, increasing said superheater pressure to a higher pressure substantially less than the pressure in said generator section to eliminate said critical pressure drop across said valve means and substantially completely open said one valve means, then varying the through flow and opening said second valve means while maintaining said generator section at said preselected pressure to vary said superheater pressure between said higher pressure and said generator section pressure.

16. A method as claimed in claim 15 in which the throttle is maintained in the selected opening position and the through flow is increased while maintaining said generator section at said preselected pressure to bring said superheater pressure up to said higher value.

17. A method as claimed in claim 16 in which said throttle is maintained in said selected opening position while the flow, and the flow area between sections, is increased to raise the superheater pressure from said higher pressure to substantially said preselected pressure.

18. A method as claimed in claim 16 in which the superheater pressure is maintained at said higher value while said through flow is increased and the throttle is then opened to a more efficient control position and the flow, and the through flow area between said sections, are then increased with the throttle retained at said more efficient control position to control said superheater section pressure between said higher pressure and said preselected pressure.

19. The method claimed in claim 15 in which the pressure in said superheater section is maintained substantially constant at said higher pressure while said flow is increased and the throttle is opened to a more efficient control position.

20. In a vapor generator system having a vapor generator section, a superheater section, valve means in parallel connecting said sections in series, including one valve means suitable for operation with critical pressure drop and a second valve means of substantially larger flow area unsuited for such operation, means forcing flow through said sections in series and a throttle between said superheater section and a load having a minimum initial loading fluid flow requirement, an improved operating method comprising the steps of forcng substantally the same through flow of vaporizable fluid through said sections and said throttle in series while maintaining the pressure in said generator section at a preselected value, setting said throttle in a preselected opening position and adjusting said through flow to provide said minimum initial flow and a superheater pressure substantially less than that required for critical pressure drop across said valve means, maintaining said through flow at said minimum initial flow and reducing said throttle opening to increase said superheater pressure to a higher pressure substantially less than the pressure in said generator section and slightly above that which will give critical pressure drop across said valve means and substantially completely opening said one valve means then manipulating said through flow and actuating said second valve means while maintaining said generator section preselected pressure to vary said superheater pressure between said high pressure and said generator section pressure.

21. A method as claimed in claim 20 including the step of maintaining said superheater pressure substantially constant at said higher pressure and increasing said through flow and opening said throttle to a second preselected position.

22. In a vapor generator system supplying a vapor to a load having a minimum initial loading fluid flow requirement materially less than 30 percent of full load flow, and having a vapor generator section having a predetermined minimum flow requirement of approximately 30 percent of full load flow and substantially greater than the minimum flow requirement of said load, a superheater section, valve means in parallel connecting said sections in series, including one valve means suitable for operation with critical pressure drop in a second valve means of substantially larger flow area unsuited for such operation, means forcing flow through said sections in series and a throttle between said superheater section and said load, an improved operating method comprising the steps of forcing substantially the same through flow of vaporizable fluid through said sections and said throttle in series while maintaining the pressure in said generator section at a preselected value, setting said throttle in a preselected opening position and adjusting said through flow to provide said minimum initial load flow and a superheater pressure substantially less than that required for critical pressure drop across said valve means, increasing said superheater pressure to a higher pressure substantially less than the pressure in said generator section to eliminate said critical pressure drop and substantially completely open said one valve means with said second valve means closed while maintaining said through flow sufficient to satisfy the minimum through flow requirements of the load but substantially less than 30 percent of full load flow and the minimum flow requirements of the vapor generator section, then manipulating said through flow and actuating said second valve means while maintaining said generator section preselected pressure to vary said superheater pressure between said higher pressure and said generator section pressure, and recirculating fluid through said generator section to augment the through flow in said generator section and supply at least the minimum flow requirements of said generator section.

23. In a vapor generator system having a vapor generator section, a superheater section, valve means in parallel connecting said sections in series, including one valve means suitable for operation with critical pressure drop and a second valve means of substantially larger flow area unsuited for such operation, means forcing flow through said sections in series and a throttle between said superheater section and a load having a minimum initial loading fluid flow requirement materially less than 30 percent of full load flow, an improved operating method comprising the steps of forcing substantially the same through flow of vaporizable fluid through said sections and said throttle in series while maintaining the pressure in said generator section at a preselected value, setting said throttle in a preselected opening position and adjusting said through flow to provide said minimum initial flow and a superheater pressure substantially less than that required for critical pressure drop across said valve means, increasing said superheater pressure to a higher pressure substantially less than the pressure in said generator section to eliminate said critical pressure drop and substantially completely open said one valve means while maintaining at least said minimum through flow but less than 30 percent of full load flow, then manipulating said through flow and actuating said second valve means while maintaining said generator section preselected pressure to vary said superheater pressure between said higher pressure and said generator section pressure.

24. The method of starting a vapor generator system having a vapor generator section, a superheater section, parallel circuits including valve means and a separator connecting said sections, means forcing fluid through said sections in series, and a throttle between said superheater section and a load having a minimum initial loading fluid-flow requirement of approximately 7 percent to 17 percent of full load flow, comprising the steps of filling said generator section with vaporizable fluid and raising the generator section pressure to a preselected pressure, applying heat to said generator section and heating said liquid in said generator section, passing said heated liquid and its vapor through one circuit and valve means into said separator, maintaining the pressure in said separator at a regulated pressure smaller than said preselected pressure by an amount greater than a critical pressure drop across said one circuit and valve means, directing vapor from said separator through said superheater and said throttle, increasing the flow of fluid through said superheater and throttle and the application of heat while maintaining said preselected pressure in said generator section to provide a vapor stream through said separator and throttle equal to said minimum load flow, fixing said throttle opening at a predetermined value as determined by said minimum flow, directing said vapor to a second circuit and valve means and closing said one valve means and disconnecting said separator while maintaining said minimum flow through said superheater and said fixed throttle, gradually increasing the superheater pressure and reducing the pressure drop between said sections to slightly less than critical pressure drop, then increasing said flow and gradually opening said throttle to a more efficient control position at substantially constant superheater pressure, then increasing the flow and application of heat to said stream of fluid and opening a third circuit and valve means while there is still a material pressure difference between said sections to further increase the pressure in said superheater section and substantially equalize the pressure in said sections and provide a flow of fluid greater than said minimum flow.

25. The method of starting a forced flow once-through vapor generator system having a vapor generator section having a predetermined required flow rate of approximately 30 percent of full load flow, a superheater section, parallel circuits including valve means and a separator connecting said sections, means forcing fluid through said sections in series, a recirculating system around said vapor generator section, a throttle of the partial admission sequential valve point type between said superheater section and a load having a minimum initial-loading fluid-flow requirement less than the flow requirement of the vapor generator section, comprising the steps of filling said generator with vaporizable fluid and raising the generator pressure to a preselected pressure, applying heat to said generator section and heating said fluid in said generator, passing said heated fluid and vapor through one circuit and valve means into said separator, maintaining the pressure in said separator at a regulated pressure smaller than said preselected pressure by an amount greater than critical pressure drop across the said one circuit and valve means, directing vapor from said separator through said superheater and said throttle, increasing the flow of fluid through said superheater and throttle and the application of heat while maintaining said preselected pressure in said generator to provide a vapor stream through said separator said superheater section and throttle equal to said minimum flow but less than 30 percent of full load flow, recirculating heated fluid through said generator section to augment said through flow and satisfy the flow requirements of said generator section, fixing said throttle opening at a preselected limited opening value smaller than one of its setting points as determined by said minimum flow, directing said vapor through a second circuit and valve means and closing said one valve means and disconnecting said separator while maintaining said preselected pressure in said generator and at least said minimum through flow but less than 30 percent full load flow through said superheater and fixed throttle, gradually increasing the superheater

pressure to a higher pressure and reducing the pressure drop between said sections to less than critical pressure drop and completely opening said second valve means then increasing said through flow and opening a third circuit and valve means and gradually opening said throttle to one of its setting points while maintaining said superheater pressure at said higher pressure, and then further increasing the flow and flow area between said sections and the pressure in said superheater section to substantially said preselected pressure while said throttle is retained in its said one setting point position.

26. The method of starting a vapor generator system having a vapor generator section, requiring a predetermined flow rate, a superheater section, valves, comprising one valve means adapted for flow at and above critical pressure ratio and a second valve means adapted for flow at less than critical pressure ratio, arranged in parallel and connecting said sections, means forcing fluid through said sections in series, a recirculation ssytem for said generator section, and a throttle between said superheater and a load having a minimum initial-loading fluid flow requirement smaller than said generator section required fluid flow, comprising the steps of applying heat to said sections and forcing vaporizable fluid through said generator and the vapor from said fluid through said superheater section, maintaining a preselected, substantially full load, pressure in said vapor generator section, manipulating the flow through said sections and the heat applied thereto to establish said minimum load flow of vapor through said throttle with said one valve means positioned to maintain said preselected pressure in said generator section and said throttle in a preselected fixed position to maintain the pressure in said superheater section at a predetermined lower pressure to provide a pressure difference across said valve means greater than a critical pressure drop, recirculating fluid through said generator section to augment said minimum flow and increase the flow in said generator section to at least said required rate, increasing the pressure in said superheater section to a higher pressure and reducing the pressure difference across said valve means to less than the critical pressure drop while maintaining a flow through said throttle with said first valve in wide open position at least as great as said minimum load flow but less than 30 percent full load flow and no greater than the flow required to produce said higher pressure with said throttle in said fixed position, then increasing the flow through said sections and throttle and opening said second valve means to accommodate said additional flow until the pressure in the superheater section is substantially equal to the pressure in said generator section with said throttle in a selected restricted opening position, and said second valve means in substantially wide open position, then increasing the flow through said sections and said throttle and manipulating said throttle to maintain said preselected pressure in said sections.

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