This invention relates in general to improvements in the construction of power plants having forced circulation vapor generating units of the once-through type having vapor generating and superheating sections. More particularly it relates to the arrangement of the transition zone within the high temperature zone of the vapor generating unit.

In the generation of vapor during forced flow through a heated tube system, the most difficult problem is experienced in that part where the last remnants of the liquid are finally evaporated, the so-called transition zone. It has been found that during this final evaporation salts are deposited on the inside walls of the tube and when the tube is directly heated in the high temperature zone, tube failures often occur due to the resultant overheating thereof.

In prior practice a portion of the vapor generating tubes were installed within a heat exchanger located outside of the vapor generating unit and heated by vapor. However, in that arrangement the transition zone was located inside the vapor generating unit in contact with the high temperature zone and afforded no protection from tube failure due to deposition therein.

The present invention includes a once-through vapor generator having transition zone tubes in a high temperature zone with each transition zone tube enclosed in an outer tube forming an external flow passage around the transition zone tubes and through which superheated vapor is passed to heat the transition zone tubes and simultaneously to receive heat from the high temperature zone.

The invention also provides a once-through vapor generator with transition zone tubes in the high temperature zone and a vapor superheater which receives dry vapor from the transition zone tubes and supplies superheated vapor to outer tubes. These outer tubes each enclose a transition zone tube so that the superheated vapor heats the transition zone tubes to cause complete vaporization and at the same time receives heat from the high temperature zone.

The invention moreover includes a once-through vapor generator with transition zone tubes located in a high temperature zone and with provisions to pass low pressure vapor through an outer tube which encloses a transition zone tube, the low pressure vapor receiving heat from the high temperature zone and in turn heating the transition zone tubes.

This arrangement while placing the transition zone in a high temperature zone protects it from the injurious effect of direct contact with the high temperature. The transition zone receives heat from the superheated vapor flowing within the outer tube which encloses the transition zone tube. The low pressure vapor receiving heat from the high temperature zone and in turn heating the transition zone tubes.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawing and descriptive matter in which are illustrated and described the preferred embodiments of the invention.

In the drawings:

FIGURE 1 is a schematic illustration of one embodiment of the invention;
FIGURE 2 is a perspective view of the transition zone tube and its enclosing outer tube; and
FIGURE 3 is a schematic illustration of one embodiment of the invention.

In FIGURE 1 is illustrated a vapor generating unit of the once-through type with a setting 10 and a plurality of burners 20 arranged to provide high temperature flowing gases, resulting from the combustion of fuel, to heat a tube system. A feed pump 11 delivers a vaporizable liquid under substantial positive pressure to the tube system located wholly within the setting of the vapor generating unit. The vaporizable liquid flows in succession through an economizer 12 and then passes to the radiation vapor generating portion 13 where at the exit thereof the fluid has received the greater part of the heat necessary for complete vaporization and this normally amounts to approximately 80 percent of such heat. From the radiantly heated vapor generating portion 13 a mixture of vapor and liquid is delivered to the transition zone tubes or section 14 located in the high temperature zone where the remainder of heat necessary for complete vaporization is added to the fluid and the resulting vapor is slightly superheated. The dry vapor from the transition zone section passes through the first portion of the primary superheater 15 also located in the high temperature zone of the unit setting wherein it receives a predetermined degree of superheat. The superheated vapor then passes through a second portion of the primary superheater 17 which is arranged in indirect heat exchange relationship with the highly heated fluid in the transition zone. Further the superheated vapor is interposed between the hot gases and the highly heated fluid to receive heat from the heating gases and give the final vaporization heat to the highly heated fluid.

Therefore the transition zone section 14 does not come in contact with the high temperature zone but receives its heat from the superheated vapor flowing in the second portion of the primary superheater 17. The superheated vapor then flows from the second portion of the primary superheater 17 to the secondary superheater 16 where it is brought to the final degree of superheat for passage then on to a high pressure supply line 18.

In FIGURE 2 is shown the arrangement of the indirect heat exchanger which shields or protects the transition zone tube from exposure to the high temperature zone. A tube 31 of the transition zone 14 of FIGURES 1 and 3 is completely enclosed by an outer tube 32 adapted to afford an exterior annular shaped flow passage 33 surrounding the evaporator tube. Superheated vapor inlet 34 and outlet 35 are provided in the outer tube for passing the superheated vapor heating the interior flow passage or transition zone tube. Therefore, though the transition zone is located in the high temperature zone, the tube within which the final evaporation occurs is heated by superheated vapor. This arrangement allows carried solids to be deposited in the transition zone without the danger of tube overheating. Further the transition tubes are located within the setting of the unit, thus avoiding complicated and expensive arrangements of the prior art.

A second embodiment illustrating the present invention is shown in FIGURE 3 wherein a vapor generating unit of the once-through type with a setting 10 and a plurality of burners 20 arranged to provide high temperature flow-
ing gases, resulting from the combustion of fuel, to heat a tube system. A feed pump 11 delivers a vaporizable liquid under substantial positive pressure to a tube system located wholly within the setting of the vapor generating unit. The vaporizable liquid flows in succession through an economizer 12 and then passes to the radiation vapor generating portion 13 wherein at the exit thereof the fluid has received the greater part of the heat necessary for complete vaporization. From the radiantly heated vapor generating portion 13 a mixture of vapor and liquid is delivered to the transition zone tubes or section 14 located in the high temperature zone where the remainder of heat necessary for complete vaporization is added to the fluid and the resulting vapor is slightly superheated. The dry vapor from the transition zone section flows through the primary superheater 15 and the secondary superheater 16 to receive the predetermined degree of superheat.

At this point the superheated vapor leaves the vapor generating unit 10 and flows through the high pressure line 18 to the high pressure turbine 19. In the high pressure turbine 19 the superheated vapor expands to do work and it leaves at a reduced pressure. The lower pressure vapor then passes through the low pressure line 21 back into the vapor generating unit and through the re heater 17 which is arranged in indirect heat exchange relationship with the highly heated fluid in the transition zone. Further the low pressure vapor is interposed between the hot gases and the highly heated fluid to receive heat from the heating gases and give the final vaporization heat to the highly heated fluid. Therefore the transition zone section 14 does not come in contact with the high temperature zone but receives its heat from the reheated vapor flowing through the re heater 17.

The reheated low pressure vapor then passes from the vapor generating unit through the low pressure turbine 22 and then to the condenser 23.

While the invention has been described with reference to schematic diagrams FIGS. 1 and 3, it is contemplated that the once-through vapor generator will be composed of a plurality of parallel flowing tubes, each having preheating vapor generating and transition zone portions. Accordingly, the annular configuration of the tubes, as illustrated in FIG. 2 may be used on each of the transition zone tubes.

The general description of the invention has been with respect to a vaporizable fluid generally operating at below critical pressure, in which a mixture of vapor and liquid may simultaneously exist for an appreciable portion of the flow path. However, the invention is equally applicable to a vaporizable fluid operating at above the critical pressure, such as water at 3500 p.s.i.a. Under such conditions liquid and vapor may not simultaneously exist and the fluid as it is heated progressively rises in temperature until it manifests the characteristics of a vapor. The transition from liquid to vapor occurs in a very short portion of the tubes. However, it is known that depositions occur therein and the present invention will alleviate the overheating characteristics from such depositions.

The vapor generators of FIGURES 1 and 3 were described in which high temperature heating gases are used as the heat source. It will be understood by those skilled in the art that the invention may be effectively carried out with other heating fluids, such as high temperature liquid metal, hot water, and fluidized solids. The effectiveness of the invention is high in any of these cases where the heating fluid temperature is higher than the safe operating temperature of the transition zone tubes.

While in accordance with the provisions of the statutes there is illustrated and described herein a specific embodiment of the invention, those skilled in the art will understand that changes may be made in the form of the invention covered by the 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 forced flow once-through vapor generator having a tube system comprising serially arranged economizer tubes, vapor generating tubes and superheater tubes arranged within a setting and having transition zone tubes thereof positioned within a high temperature radiation zone therein, a burner disposed within said setting to provide flowing gases to heat said tube system, the improvement comprising outer tubes exposed to said high temperature radiation zone, each of said outer tubes enclosing one of said transition zone tubes to form an annular shaped flow passageway thereabout, and means for passing superheated vapor which has been generated within said tube system through said flow passageway in interposed and indirect heat exchange relationship whereby the superheated vapor receives heat within the high temperature radiation zone and gives up heat to the protected transition zone tubes.

2. In a forced flow once-through vapor generator having a tube system arranged within a setting and having transition zone tubes thereof positioned within a high temperature radiation zone therein, a burner disposed within said setting to provide flowing gases to heat said tube system, a turbine disposed at a point remote from said vapor generator, means arranged to supply high pressure vapor from said vapor generator to said turbine, the improvement comprising outer tubes exposed to said high temperature radiation zone, each of said outer tubes enclosing one of said transition zone tubes to form a closed annular shaped flow passageway thereabout, and means for passing low pressure vapor from said turbine to said flow passageway for flow therethrough in interposed and indirect heat exchange relationship, whereby the low pressure vapor receives heat from the high temperature radiation zone and is reheated while it gives up heat to the protected transition zone tubes.

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