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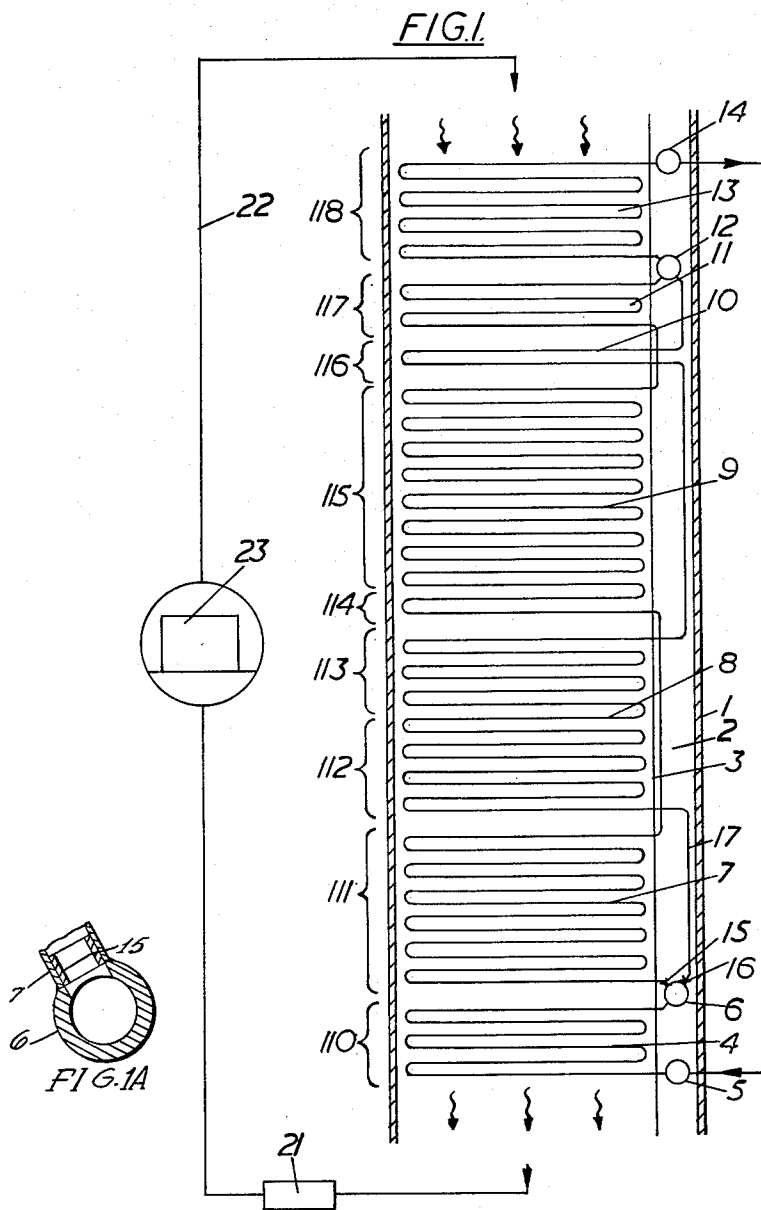
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3,254,631

TUBULOUS VAPOUR GENERATOR

Filed June 14, 1963

2 Sheets-Sheet 1



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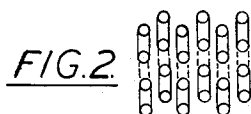
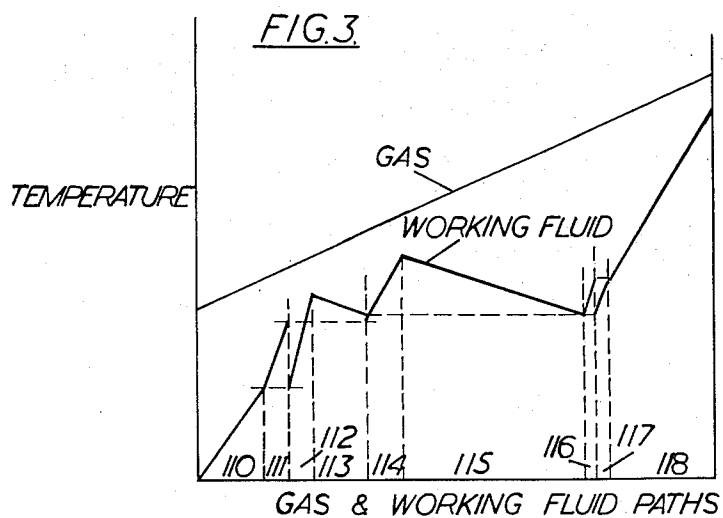
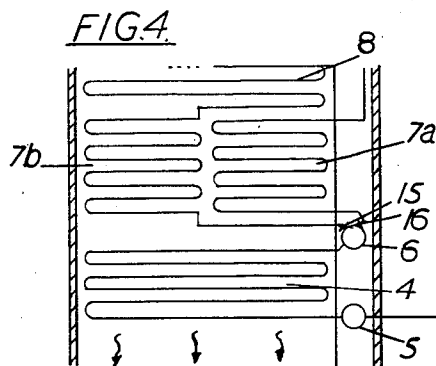
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TUBULOUS VAPOUR GENERATOR

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5 Claims. (Cl. 122-7)

This invention relates to tubulous vapour generators and particularly to forced flow, once through vapour generators. Such vapour generators differ from those operating with forced circulation in that in the case of the latter the forced circulation maintains the flow through the vapour generating tubes at low load, whereas in a once through vapour generator the flow velocity decreases as the load falls. Since, for practical reasons, the flow velocity in the tubes of the vapour generating section of a once through vapour generator must at the lowest load be maintained above a minimum value, it follows that at full load the pressure drop through those tubes is relatively great. As a consequence, the working fluid pressure at the inlet to the vapour generating part of a once through vapour generator is considerably greater than at the outlet of that part. Since the temperature of evaporation of the working medium is determined by the pressure and since at the region where evaporation commences the pressure cannot therefore be made very high in view of the necessity for an adequate temperature difference between the heating fluid and the working fluid, the pressure drop through the tubes of the vapour generating part acts to reduce the pressure at which the vapour can be delivered.

In plant, such as nuclear power plant including a vapour generator associated with a nuclear reactor, for example, a gas cooled or an organic liquid cooled reactor, in which the temperature of the heating fluid at the inlet to the vapour generator is relatively low it is important for the purpose of efficiency to generate the vapour at as high a pressure as possible. The invention enables an increase in the pressure of vapour generation in such plant to be effected.

The present invention provides a forced flow, once through tubulous vapour generator including first and second parallel connected sections in which evaporation occurs having the region of the second section in which evaporation commences disposed downstream in the heating fluid flow path of the region of the first section in which evaporation commences and arranged to operate with a lower pressure in the said region of the second section than in the said region of the first section.

The two sections, which may be arranged to operate at full vapour generator load with substantial respective economizer zones, may divide between them the heat exchange surfaces of the vapour generator between a common economizer bank and a common superheater bank and the second section may comprise 10% or substantially 10% of said heat exchange surfaces. Generally it will provide less than 25% of said surfaces.

The invention will now be described by way of example with reference to the accompanying drawings, in which:

FIGURE 1 shows schematically an arrangement of vapour generator tube banks in a downflow heating gas pass.

FIGURE 1A is an enlarged view of one of the ferrules in tube bank 7 of FIG. 1,

FIGURE 2 illustrates an arrangement of tubes in a bank of the vapour generator of FIGURE 1,

FIGURE 3 shows graphically the temperatures in the fluid paths of the said vapour generator, and

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FIGURE 4 shows schematically a modification of the said vapour generator.

Referring to FIGURES 1 to 3 of the drawings, banks of tubes of a forced flow, once through steam generator are arranged one above another in a column within a vertical pressure vessel tower 1, in which heating gas flows. The gas flow is maintained by circulating means, e.g. an axial flow compressor 21, which drives the gas continuously in a circuit 22 in which the gas flows generally upwardly in a graphite-moderated nuclear reactor 23 in order to cool the said reactor, then flows downwardly within the tower in which it transfers to the steam generator the heat it has absorbed in the reactor and then re-enters the circulating means. Each tube bank consists of horizontal tube lengths extending across the gas flow and connected together by end loops in any suitable manner so that the fluid contents thereof may flow in the tube bank in a plurality of streams in parallel each passing from tube length to tube length upwardly from the bottom to the top of the tube bank. The streams flow in parallel into and/or out of appropriate headers that will be referred to which are accommodated in a space 2 within the tower which is separated from the gas flow by a suitable partition 3. The tube lengths may be in staggered array in each tube bank in the manner indicated in FIGURE 2.

The lowermost tube bank 4 is arranged to receive water from an inlet header 5, to which it is supplied by the steam generator feed pump, not shown, and to deliver partly heated water to a distributor header 6 which distributes water to a tube bank 7 next above the tube bank 4 and also to a tube bank 8 next above the tube bank 7. Next above the tube bank 8 is a tube bank 9 which receives its water from the tube bank 7. Next above the tube bank 9 is a tube bank 10 which receives steam from the tube bank 8 and next above the tube bank 10 is a tube bank 11 which receives steam from the tube bank 9. The two tube banks 10 and 11 discharge steam into a common collector header 12 and above the tube bank 11 is a tube bank 13 which receives steam from the collector header 12 and discharges the steam to an outlet header 14 from which the steam is taken to a point of use, not shown. It will be perceived that the working fluid, in its flow from the distributor header 6 to the collector header 12, flows in one section comprising the series-connected tube banks 7, 9 and 11 and also, in parallel to that section, in a second section comprising the series-connected tube banks 8 and 10.

The tube bank 4 is designed for operation at full load on the steam generator as a common economiser zone 110 of the steam generator and the tube bank 13 as a common superheater zone 118. In the tube bank series 7, 9 and 11 the tube bank 7 is designed for operation at full load on the steam generator as an economiser zone 111, the lower part of the tube bank 9 as an economiser zone 114, the upper part of the tube bank 9 as an evaporating zone 115 and the tube bank 11 as a superheater zone 117. In the tube bank series 8 and 10 the lower part of the tube bank 8 is designed for operation at full load on the steam generator as an economiser zone 112, the upper part of the tube bank 8 as an evaporating zone 113 and the tube bank 10 as a superheater zone 116. The tube bank series 7, 9 and 11 provides 90% of the total heat exchange surface of the tube banks 7 to 11 and is designed for operation with a high fluid speed therethrough, for the attainment of which a pressure difference across the said tube bank series of 80 lb. per square inch may be necessary. The tube bank series 8 and 10 provides the remaining 10% of the total heat exchange surface of the tube banks 7 to 11 and is also designed for operation with a high fluid speed therethrough, for

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the attainment of which a small pressure difference across the tube bank series 8 and 10 of 15 lb. per square inch may suffice.

The tubes of the tube bank series 7, 9 and 11 receive water from the distributor header 6 through respective ferrules indicated at 15 adapted to impose flow resistances to the water flow equal at full load on the steam generator to a pressure loss of 40 lb. per square inch, the purpose of which is to maintain or promote proper equalised flow distribution between the various parallel-connected tubes of the tube bank series. Similarly, the tubes of the tube bank series 8 and 10 receive water from the distributor header 6 through respective ferrules indicated at 16; these ferrules 16, however, are adapted to impose flow resistance to the water flow equal at full load on the steam generator to a pressure loss of 105 lb. per square inch, sufficient not only for the maintenance or promotion of proper equalised flow distributions between the various parallel-connected tubes of the tube bank series but to restrict the pressure at the inlet to the tube bank 8 to the low value corresponding to the low pressure drop across the tube banks 8 and 10 necessary to give the desired velocity of flow at full load.

During operation of the steam generator the working fluid flows upwardly through the steam generator and in each tube bank thereof in counterflow to the heating gas which falls in temperature while flowing from top to bottom of the tube bank column. Referring to FIGURES 1 and 3, the water rises in temperature in the common economiser zone 110. The water entering the tube bank series 7, 9 and 11 rises in temperature in the economizer zone 111, rises further in temperature in the economizer zone 114 and is converted to steam in the evaporating zone 115 in which it is at saturation temperature, which falls with pressure; the resulting steam is slightly superheated in the superheater zone 117. The water entering the tube bank series 8 and 10 rises in temperature in the economiser zone 112 and is converted to steam in the evaporator zone 113 in which it is at saturation temperature, which falls with pressure; the resulting steam is slightly superheated in the superheater zone 116. The steam flows from the two sections unite and the united steam flow is superheated in the superheater zone 118.

The region of the tube bank 9 in which evaporation commences in the first section, i.e. the high working fluid temperature end of the evaporator zone 115, is disposed at a location in the heating gas path at which there is a sufficient temperature difference between the gas and the water for effective steam generation at the pressure prevailing within the tubes at that location. The region of the tube bank 8 in which evaporation commences in the second section, i.e. the high working fluid temperature end of the evaporator zone 113, is disposed downstream in the heating gas flow of the corresponding region of the tube bank 9 and is, therefore, subjected to heating gas of reduced temperature. However, thanks to the large pressure drop across the ferrules 16 through which water is supplied to the second section the water at the water inlet or high temperature end of the evaporator zone 113 has a relatively low temperature of evaporation with a consequent adequate temperature difference between the gas and the water. Consequently the tube bank 8 is effective to generate steam and deliver it through the superheater bank 10 at the same pressure as that at which the greatest part of the steam, after generation in the tube bank 9, is delivered by that bank through the superheater bank 11.

Since the evaporation in the steam generator is effected in two zones of heat exchange surface occupying different parts of the heating gas path and connected in parallel, the maximum pressure required to force the evaporating water through the tubes at customary high speeds to issue therefrom at or near a given common pressure is lower than that which would be required if all the

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evaporation was to be effected in a single zone only of heat exchange surface. Since the said pressure is lower, the maximum saturation temperature within the tubes is lower and for a given adequate temperature difference between gas and water at the so-called "pinch point" a higher final superheater temperature is achieved or/and less evaporating surface is installed.

The tube banks 10 and 11 connected subsequent to the tube banks 8 and 9 and normally providing a slight degree of superheating reduce or preclude the possibility that during fluctuations in operation water may attain to the collector header 12 and to the superheating tube bank 13.

Water attains to the evaporating part of the tube bank 8 only after passing through an economiser part of the tube bank 8 and attains to the evaporating part of the tube bank 9 only after passing through the tube bank 7 and the economiser part of the tube bank 9, and the arrangement is such that the working fluid at the ferrules 15 and 16 is always in liquid phase under all conditions of operation.

The ferrules 15 and 16 suitably consist of rings welded internally of lengths near the header 6 of the tubes connecting with the header 6 to reduce the flow area of those tubes or welded internally of tube stubs secured in the header to which the tubes leading to the tube banks 7 and 8 are welded. Alternatively, more particularly in the case of the tubes 17 leading within the space 2 to the tube bank 8, all or some of the flow resistance required may be provided by the flow resistance of said tubes 17 which may for the purpose be provided of small bore.

FIGURE 4 refers to a modification in which the tube bank 7 is in two parts 7a and 7b side by side in the gas stream, of which one part 7a serves to heat water on its way to the tube bank 9 and the other part 7b serves to heat water on its way to the tube bank 8.

I claim:

1. A forced flow once-through tubulous vapor generator including means forming a gas flow path, means supplying heating gases to said gas flow path, inlet header means, outlet header means, means supplying vaporizable fluid to the inlet header means, means forming a vapor generating section disposed in said gas flow path and comprising first and second sections arranged in parallel flow relation and extending between and connected to said inlet and outlet header means so that the fluid pressure drop between the inlet and discharge sides of the first section is substantially the same as the fluid pressure drop between the inlet and discharge sides of the second section, the first section having a substantially greater amount of heat exchange surface than the second section and disposed upstream in the gas flow path of the second section, flow resistance means effecting a fluid pressure drop in the inlet portion of the second section such that the region of the second section in which evaporation commences is disposed downstream in the heating gas flow path of the region of the first section in which evaporation commences and providing a substantially lower operating pressure in the said region of the second section than in the said region of the first section.

2. A vapor generator as claimed in claim 1, wherein each of said first and second sections is formed of parallel connected tube lengths, and ferrules are provided in the inlet portions of the tube lengths of the first and second sections to maintain proper fluid flow distribution between the tube lengths.

3. A vapor generator as claimed in claim 2, wherein the ferrules associated with the second section are adapted both to maintain proper flow distribution to the tube lengths and to give the relatively low pressure at the region of the second section in which evaporation commences.

4. A vapor generator as claimed in claim 1, wherein the first and second sections are disposed between and

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are connected to a common economizer bank and a common superheater bank and the second section comprises less than 25 percent of the heat exchange surface of said vapor generating section.

5. A vapor generator as claimed in claim 1 in combination with a nuclear reactor and means for effecting circulation of said gas flow path outflow through the nuclear reactor back to said gas flow path.

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