Dec. 27, 1966 A. BELL 3,294,070

GAS-COOLED REACTORS

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Fig. 3.

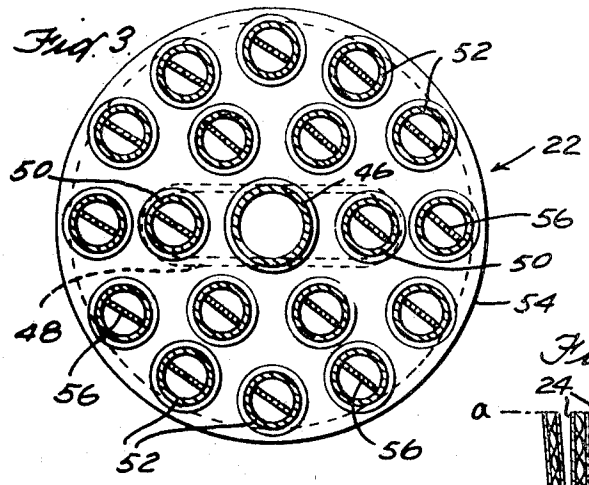


Fig. 1A.

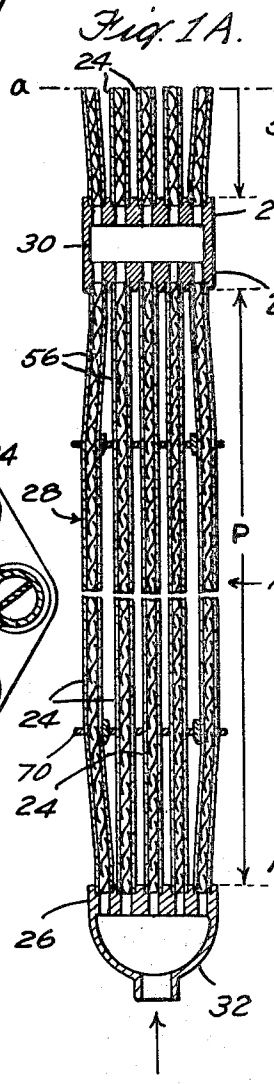
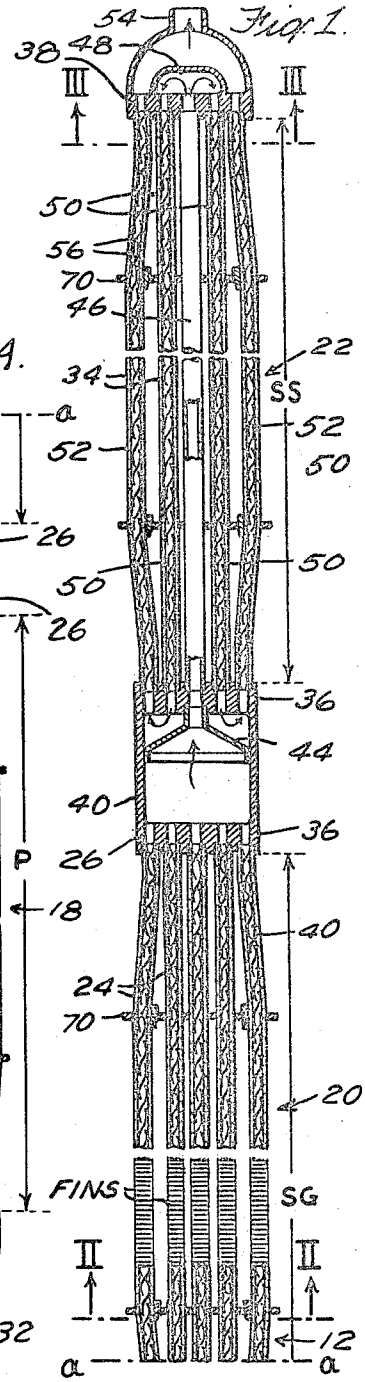


Fig. 1.



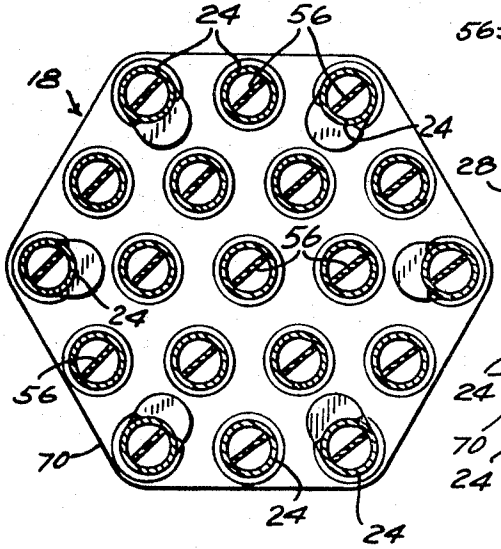


Fig. 2.

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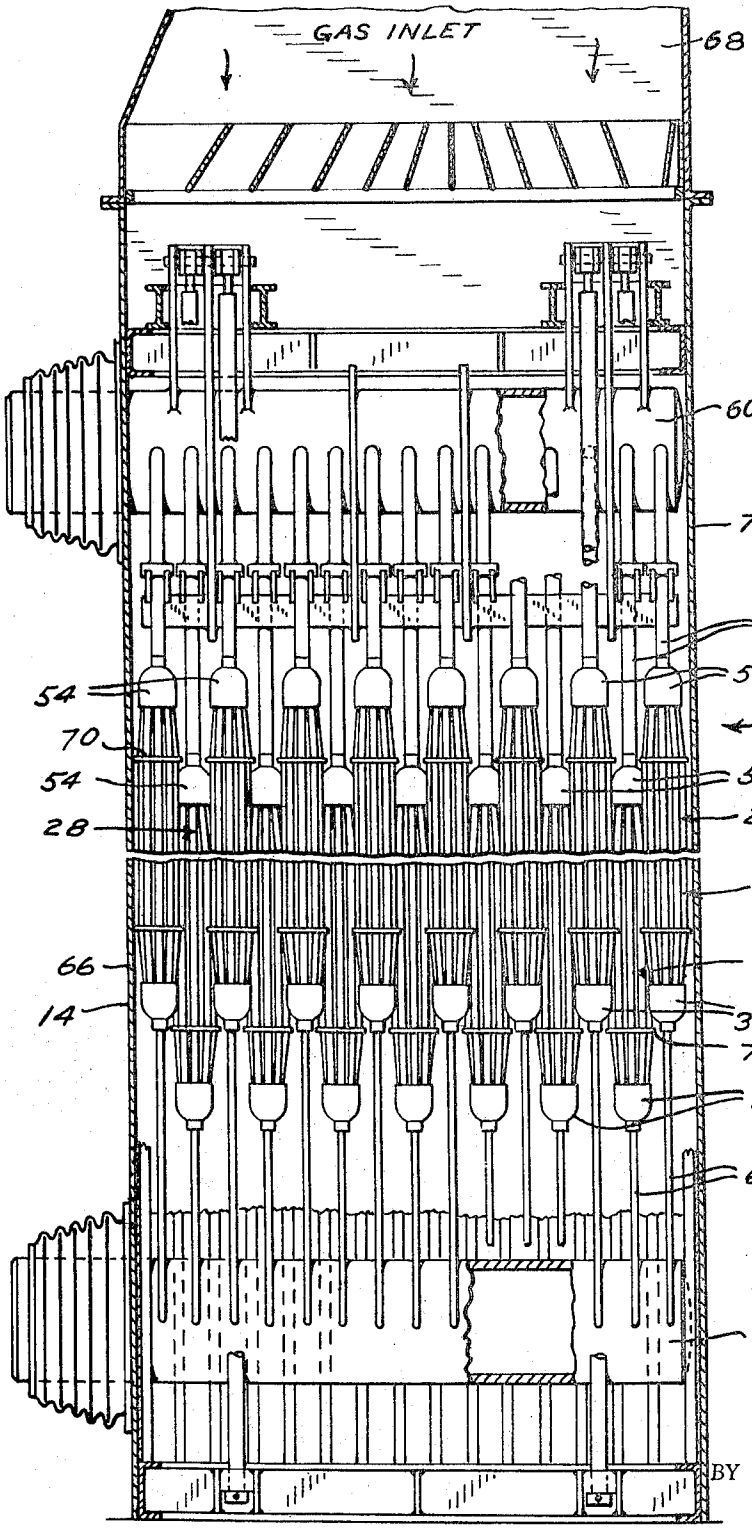


Fig. 4

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GAS-COOLED REACTORS

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5 Claims. (Cl. 122—32)

This invention relates to a once-through forced circulation tubular steam generator, and in particular to a final evaporation and superheating section of a once-through generator. The terms "water" and "steam" are used herein to denote any suitable liquid and its vapour.

Such steam generators generally include preheating, evaporating and superheating sections connected in series. The steam and water mixture produced in the evaporator may be very heterogeneous and there is then the danger that the mixture may pass through the superheater without complete evaporation of its water content. It is to the solution of that problem that the present invention is directed.

In a steam generator in accordance with the invention, the steam and water mixture produced in a tubular evaporator is passed to a tubular superheater in which it is subjected to high speed turbulent flow in order to improve the homogeneity of the mixture before being subjected to lower speed flow for evaporation of the dispersed water and the finally desired superheating.

Preferably the high speed turbulent flow is effected by passing the whole of the mixture flowing from the evaporator through a single tube. This can be important because, if the mixture from the evaporator is offered alternative paths, there may be segregation of water and steam from the mixture with the result that the streams passing over the said paths will be of different composition.

It is important that sufficient heat transfer surface is provided to allow evaporation of any water in the steam to occur. This can be conveniently achieved by providing as long as flow path for the steam-water mixture as possible. To this end, the mixture can be flowed at high speed from one end to the other of the superheating section and then back again before being flowed at the lower speed in the original direction to the superheated steam outlet. In the preferred form of the invention, the mixture is flowed first through a single tube of relatively large diameter disposed along the axis of the superheating section, then in the opposite direction through two tubes the aggregate cross-section of which is approximately equal to the cross-section of the single tube and which are connected thereto in parallel and finally in the original direction through a number of relatively small diameter tubes surrounding the other tubes and connected in parallel with the intermediate tubes.

The rate of heat transfer in the final stage of flow through the superheater section should be as high as possible and this can be achieved by making that flow turbulent, the turbulence here being thus for a different purpose from that for which turbulence is created in the initial stage of superheating.

An example of the invention will now be described with reference to the accompanying drawings in which:

FIGURES 1 and 1A are sectional elevation views of an element in accordance with the invention;

FIGURE 2 and FIGURE 3 are enlarged cross-sections taken on the lines II—II and III—III respectively of FIG. 1; and

FIGURE 4 is an elevation section view of a steam generator using an element in accordance with the invention.

The element 12 shown in FIGS. 1 and 1A may, in practice, have an overall length of about 25' and may be arranged vertically side-by-side as shown in FIG. 4 with a large number of identical elements within a shell or casing 14 to form a steam generator 16. Each element comprises a preheating section 18, a steam generating section 20, and a steam superheating section 22 connected together for series flow of fluid through the element.

The preheating and steam generating sections may be identical and comprise (FIGS. 1 and 2) nineteen substantially straight tubes 24 connected at their ends to tube plates 26 to form a cluster 28 of tubes. The two sections are connected together in series by welding an intermediate header member 30 between adjacent tube plates of each section. To the tube plate at the other end of the preheating section is attached a header 32 for receiving the water to be evaporated.

The superheater section 22 comprises a cluster of nineteen tubes (FIG. 3) generally designated 34 connected at their ends to tube plates 36 and 38 respectively. The section is connected in series with the steam generating section 20 through an intermediate header 40 in which is provided a funnel shaped baffle 44 which serves to direct the mixture from the steam generating section into the central tube 46 of the tube cluster. The fluid leaving this central tube is deflected by a hemispherical member 48 attached to the tube plate 38 into two tubes 50 adjacent the central tube 46. The fluid flows through these two tubes in a direction opposite to the flow through the central tube 46 and at the outlet thereof is deflected by the baffle 44 into the remaining sixteen tubes 52 of the cluster 18 through which it flows in the same direction as through the central tube 46. The fluid finally leaves the cluster through a header 54.

In the arrangement described above, the steam and water mixture produced in the nineteen parallel tubes of the evaporator section is on leaving that section caused to flow through the single tube 46 of the superheater section and then through the two adjacent tubes 50. The speed of the mixture flowing through that part of the superheater section constituted by the tubes 46 and 50 is thus considerably higher than through the evaporator section and by adjusting the rate at which water is supplied to the element, the speed of the mixture through the tubes 46 and 50 may be made sufficient to cause the flow through them to be highly turbulent. This improves the homogeneity of the mixture and the homogeneity is still further improved by the change in direction twice imposed on the flow through the superheater section. On leaving the two tubes 50, the mixture flows through the remaining sixteen tubes 52 of the superheater section where the velocity of flow is reduced to that through the evaporator section.

The tubes of each section may all be of the same diameter. Preferably, however, the central tube 46 of the tube cluster 34 through which the mixture leaving the evaporating section is flowed is of a diameter such that its cross-sectional area is approximately equal to the sum of the cross-sectional areas of the two tubes 50. This has the advantage of enabling each tube cluster to be composed of nineteen tubes, evenly and closely pitched on their end tube plates. In a typical example of the element described above, the inside diameter of the central tube 46 is 1" and that of the remaining tubes of the superheater section is ½".

It will be appreciated that the tubes of the heat exchange elements need not be exactly arranged as described and shown here. For example, the tube arrangement described in the co-pending application Serial No. 276,048, filed April 23, 1963, now Patent No. 3,195,517 may be used in the preheating and steam generating sections. Also the single tube which forms the first part of the flow path

through the superheating section need not be the central tube of the cluster, although this arrangement is the easiest to construct.

As shown in FIG. 1, all the tubes except the central tube **46** are provided with means **56** in the form of fluted bars for increasing the turbulence of the fluid flow through them. This improves the heat input into each tube and enables the overall length of the heat exchange element to be kept short.

Although not illustrated here, the vapour generating section **20** may be constructed as shown in our copending application Serial No. 276,048, filed April, 1963, now Patent No. 3,195,517 with a central water downcomer tube.

Any number of the heat exchange elements may be arranged in any desired manner within a shell or casing to form a steam generator. An example is shown in FIG. 4. In the unit of FIG. 4, a plurality of the tube systems of FIGS. 1–3 extend between lower and upper collecting headers **58** and **60**, the small headers **32** and **54** being joined to the collecting headers by lower and upper risers **62** and **64**. A rectangular shell **66** surrounds the tube systems, provided with a gas inlet **68** at the top thereof. The gas flow is essentially longitudinal of the elements, i.e., parallel to the tube axes. As shown the headers **32** and **54** are staggered for this purpose, but in addition, the headers and spacer plates **70** (to be described) cause a partial cross flow.

A typical generator may consist of a plurality of units bolted together, each unit being shop assembled. One unit may contain nineteen tubes. The generator then with a length of about 25 feet will provide a heating surface comparable to that of a conventional unit a hundred feet plus. In gas cooled nuclear stations, the saving in pressure vessel volume and thickness should be apparent. The size of the casing in any given case can be kept to a minimum by arranging the elements close together so that there is as little lost casing space as possible. This is assisted by having the tubes arranged on the tube plate as shown in FIGS. 2 and 3, by using intermediate headers **30**, **40** which have a circular or hexagonal cross-section and by springing or otherwise deforming the tubes of each section so as to achieve uniform distribution of the tubes of the elements over the cross-section of the casing. This may be done as shown in FIGS. 1, 1A and 2 by spacer plates **70** whose detailed construction and method of assembly on each tube cluster is described in our copending Application Serial No. 243,926, filed December 11, 1962, now Patent No. 3,227,142.

Although the invention has been described with relation to specific embodiments, it is to be understood that many variations are within the spirit and scope of the invention as claimed.

What is claimed is:

1. In a forced circulation boiler having a tube system including in series preheating, evaporating and superheating sections, the improvement comprising in said superheating section a plurality of tubes in a cluster including a center tube and first and second sets of tubes substantially parallel to, coextensive with and removed from said center tube on opposite sides thereof, the center tube having a cross-sectional area of flow substantially less than the cross-sectional area of flow in the evaporating section, said cluster of tubes defining a circular array encompassing the center tube, said first set of tubes being two tubes on opposite sides of the center tube, said cross-sectional areas of the center tube and first set of tubes being substantially equal, means for directing the flow from the evaporating section to said center tube, second means for directing the flow from the center tube to said first set of superheating section tubes, and third means for directing the flow therefrom to the second of said sets of tubes so that the flow leaves the superheating section at an end removed from the evaporating section.

2. In a forced circulation boiler, a tube system comprising

a plurality of tube elements,

each element including in series a preheating section, an evaporating section, and a superheating section, the sections being axially aligned,

each section comprising a center tube and inner and outer circular arrays of tubes, the tubes being substantially parallel and coextensive,

inlet and outlet headers for each element communicating with the preheating and superheating sections respectively,

intermediate headers communicating the sections with each other,

the center tube of the superheating section including a funnel-shaped baffle disposed in the header intermediate the evaporating and superheating sections arranged to direct the flow from the evaporating section into the center tube, the center tube having a cross-sectional area of flow substantially less than the cross-sectional area of flow in the evaporating section,

the superheating section further including a hemispherical shaped baffle to direct the flow from the center tube to two tubes adjacent and on opposite sides of the center tube,

the funnel-shaped baffle further being arranged to direct the flow from said two tubes to the remaining tubes of the superheating section, whereby the flow enters the outlet header at an end of the element removed from the inlet header.

3. A boiler according to claim **2** further including means for increasing turbulence in said remaining tubes of the superheating section.

4. A boiler according to claim **1** wherein said means for directing the flow from the evaporator section to said center tube includes a funnel-shaped baffle.

5. In a forced circulation boiler having a tube system including in series preheating, evaporating and superheating sections, the improvement comprising in said superheater section a plurality of tubes in a cluster including a center tube and first and second sets of tubes substantially parallel to, coextensive with and removed from said center tube on opposite sides thereof, the center tube having a cross-sectional area of flow substantially less than the cross-sectional area of flow in the evaporating section, means including a funnel-shaped baffle for directing the flow from the evaporating section to said center tube, second means including a hemi-spherical-shaped baffle for directing the flow from the center tube to said first set of superheating section tubes, and third means coextensive with said funnel-shaped baffle for directing the flow therefrom to the second of said sets of tubes so that the flow leaves the superheating section at an end removed from the evaporating section.

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