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Klein et al.

[11] **3,907,029**

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[54] **STEAM GENERATOR**

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[73] Assignee: **Siemens Aktiengesellschaft**, Munich, Germany

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **165/161**; 122/32

[51] **Int. Cl.** **F28f 9/22**

[58] **Field of Search** 165/134, 159, 161; 122/491, 32, 34

[56] **References Cited**

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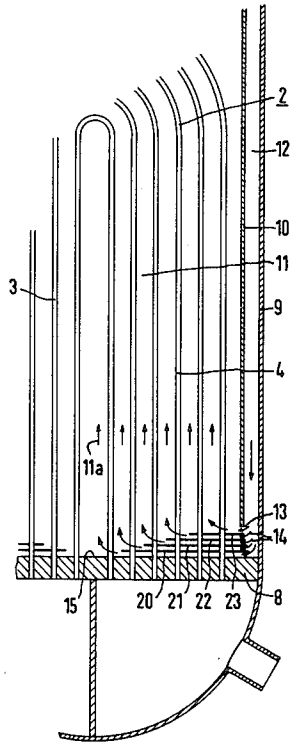
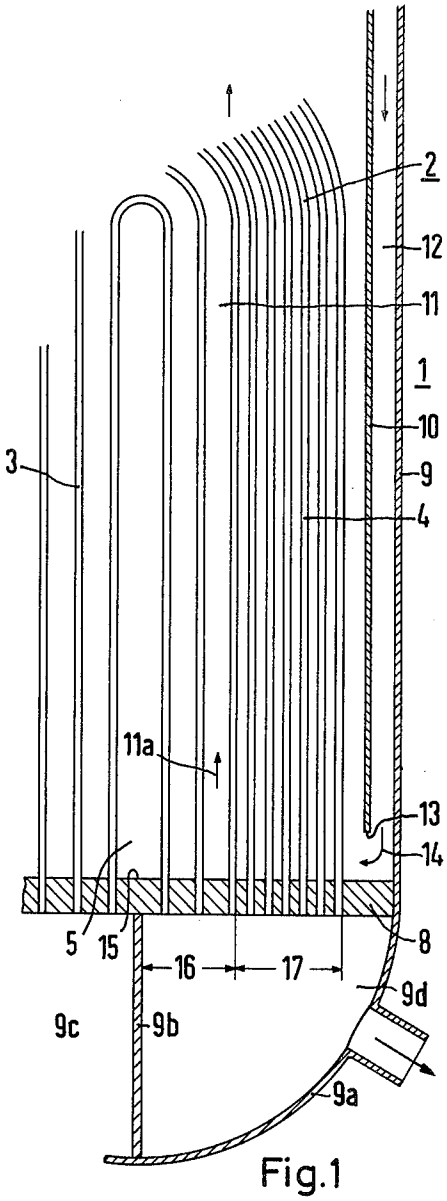
[57] **ABSTRACT**

A steam generator includes a U-shaped nest of tubes having vertical legs with their lower ends mounted in the holes of a circular tube sheet and centrally forming a vertical corridor or passage extending upwardly from the tube sheet, the nest and the upper surface of the tube sheet being enclosed for containment of water and generated steam. Feed water flows radially inwardly from the periphery of the tube sheet towards its center, the heating fluid flowing through the tube's nest via the tube sheet's lower surface. To prevent the feed water from prematurely converting to steam, or boiling, on the upper surface of the tube sheet and in the corridor or passage, means are provided for reinforcing the inward radial flow force of the feed water, assuring an adequate flow of the feed water throughout those areas to prevent such premature boiling or conversion to steam.

1 Claim, 3 Drawing Figures




2
12
11
1
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9d
9c
9b
9a

Fig.1

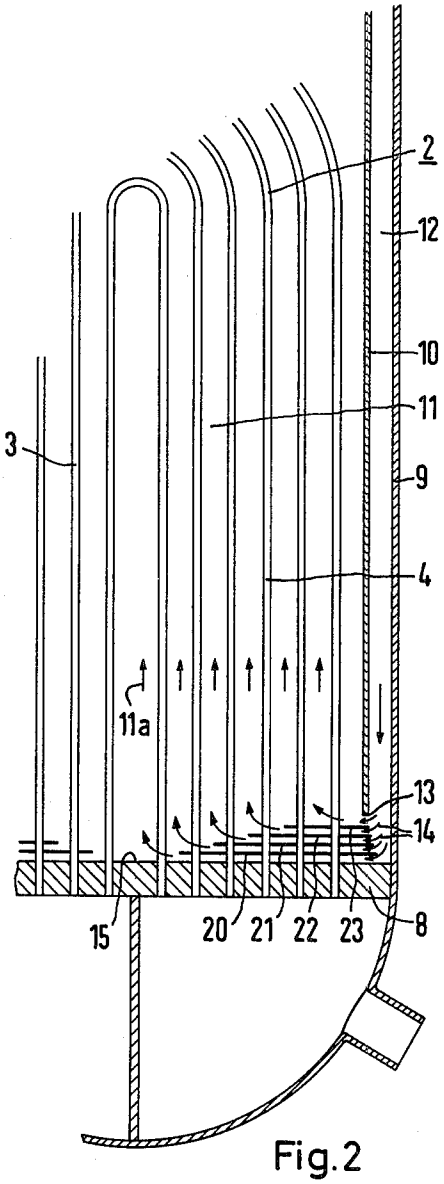
2
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Fig.2

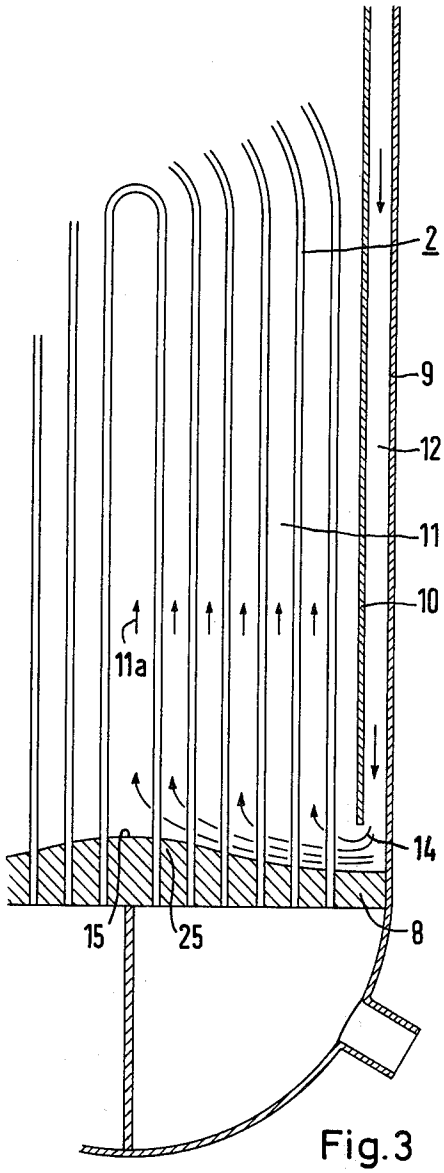

Fig.3

STEAM GENERATOR

BACKGROUND OF THE INVENTION

A nuclear reactor using pressurized-water coolant produces useful power via a steam generator characteristically comprising an upstanding, inverted, U-shaped nest of tubes through which the coolant is passed as a heating fluid, the tubes having vertical legs with lower ends mounted in the holes of a horizontal circular tube sheet and centrally forming a vertical corridor or passage. An enclosure for the tube sheet's upper surface and the tube nest contains water and generated steam. The enclosure has a steam outlet in its top and means for flowing feed water into the enclosure radially inwardly from the periphery of the tube sheet and over the latter's upper surface for conversion to steam by upward circulation through the tube nest. Two chambers below the tube sheet are respectively provided with a coolant inlet and outlet, the two chambers connecting respectively with inlet and outlet ends of the tube nest's tubes. Therefore, the coolant flow is via the lower surface of the tube sheet.

If the feed water prematurely converts to steam, or boils, while flowing over the upper surface of the tube sheet or while flowing upwardly through the tubes of the tube nest, salts or other corrosion-promoting substances unavoidably contained by the feed water, deposit on the tube sheet and tubes. This is undesirable because of the risk of localized corrosion and reduction in the desired heat exchange rate between the coolant and the water.

SUMMARY OF THE INVENTION

One object of the invention is to prevent such premature conversion of the water to steam, or localized boiling, in a steam generator of the type described.

According to the invention, this object is attained by providing such a steam generator with means for reinforcing the inward radial flow force of the feed water over the upper surface of the tube sheet and within the lower portion of the passage or corridor formed by the tube nest, to an extent preventing the water's conversion to steam, or boiling, locally adjacent to the center portion of the flow over the tube sheet and upwardly through the passage or corridor. By reinforcing this radial inward flow component, the volume of the feed water flowing over the central portion of the tube sheet and upwardly is increased relative to that provided by prior art constructions of this type of steam generator.

In one form the reinforcing means comprise making the tube pitch of the vertical legs of the tubes of the tube nest, smaller around the periphery of the tube sheet than at its central portion. In other words, the tube's vertical legs are interspaced more closely together around the periphery of the tube sheet than at its central portion. This construction inherently provides flow resistance to the upward flow of the feed water around the peripheral portion of the tube sheet, thus increasing the inward flow force or component of the feed water, resulting in an increase in the volume of feed water that reaches the center of the tube sheet and flows upwardly through the tube nest center.

When introduced to the steam generator the feed water, of course, has a relatively low temperature, substantially below its boiling temperature at the pressures involved, and with the present invention, the feed water remains in its liquid phase throughout not only the peripheral portion of the tube sheet and tube nest, but centrally as well, as the feed water flows upwardly from the tube sheet through the tube nest, thus eliminating, or at least substantially reducing, the risk that the feed water will locally prematurely convert to steam so as to result in the build-up of undesirable deposits.

In another form, the feed water flow reinforcing means comprise a series of vertically interspaced annular plates having outer peripheral proportions of substantially the same diameter positioned to receive the initial feed water flow, and having inner diameters which progressively increase from the uppermost one of this series of plates downwardly to the lowermost one. With this arrangement the radial inward flow of feed water is held against upward flow around the peripheral portion of the tube sheet and tube nests while inwardly being gradually released for upward flow.

In still another form, the flow reinforcing means comprise the upper surface of the tube sheet having substantially a convex surface. This may be done by making the entire tube sheet convex and with substantially the same thickness throughout, the bottom of the tube sheet then having a corresponding convexity, as by thickening the tube sheet appropriately, in which case the bottom of the tube sheet is a plane or flat surface.

BRIEF DESCRIPTION OF THE DRAWINGS

Examples of the invention are schematically illustrated by the accompanying drawings in which:

FIG. **1** in vertical section shows the essential portions of a steam generator to the extent required to understand the invention;

FIG. **2** is like FIG. **1** but shows a second example; and

FIG. **3** illustrates a third example.

DETAILED DESCRIPTION OF THE INVENTION

Having reference to the above drawings, FIG. **1** shows a steam generator **1** of the type used for generation of steam from the heat of a pressurized-water coolant in circuit with the pressure vessel of a nuclear reactor using such a coolant.

Thus, FIG. **1** shows the inverted U-shaped nest of tubes having the vertical inlet legs **3** and corresponding outlet legs **4**, the innermost of the legs **3** and **4** necessarily forming a vertical passage or corridor **5**. The lower ends of the legs **3** and **4** are mounted in the holes of a circular, horizontal tube sheet **8** which divides the lower end of the cylindrical wall **9** of the generator's casing. Although not shown, in the usual way this casing has its upper end formed as a steam dome having an outlet for the steam. Spaced inwardly from the wall **9**, a cylindrical shell **10** separates the boiling space **11** in which the feed water rises in the direction shown by the arrow **11***a*. The annular space **12** between the cylindrical walls of the two parts **9** and **10** form the descent space **12** down through which feed water descends for preheating and thermal circulation of the water; a feed water inlet (not shown) located in the upper part of the steam generator casing or housing maintains an input of water.

The lower end **13** of the shell **10** is spaced above an outer peripheral portion of the tube sheet **8**, the feed water descending through the space **12** and, as indicated by the arrow **14**, flowing radially over the upper surface of the tube sheet **15** for upward flow as indicated by the arrow **11***a*. This radial flow of water should reach the center **15** of the tube sheet **8** and flow up-

wardly without initially boiling, until it reaches a higher portion of the boiling space **11**, if the undesirable deposits are to be avoided.

Beneath the tube sheet **8** the steam generator's casing or housing forms a hemispherical chamber **9***a* divided by a wall **9***b* into inlet and outlet coolant manifolds **9***c* and **9***d* respectively. Therefore, the coolant flow through the tubes of the tube nest is via the lower surface of the tube sheet **8**, resulting in the upper surface of the tube sheet having relatively higher temperatures. In addition, the innermost ones of the vertical tube legs **3** and **4** of the tube nest, provide shorter coolant flow paths than do the outermost ones of these legs. If the radial inward feed water flow indicated by the arrow **14** is inadequate to provide a sufficient flow to the center **15** of the tube sheet **8** and upwardly through the tube sheet, the water will convert to steam or boil prematurely and form the undesirable deposits.

A reinforcement or increase in the radial inward flow **14** is provided by this invention. As previously indicated, the flow is upwardly from the tube sheet **8**, the flow **14** therefore having both a radial force component and an upward axial force component.

In the example of FIG. **1**, such reinforcing means is provided, the tube pitch, or radial interspacing, of the tube legs **3** and **4** throughout the innermost portion of the tube nest, this annular area being indicated at **16**, being substantially twice as large as in the area outwardly and more adjacent to the periphery of the tube sheet **8** and the tube nest, indicated at **17**.

With this construction, the feed water entering over the upper surface of the tube sheet **8** and into the outer portion of the tube nest, has its normal upward axial component reduced because of the increase density of the tube pitch, or in other words, the closer interspacing of the vertical tube legs adjacent to the peripheral portion of the tube nest. The inward radial component is therefore increased or reinforced relative to the upward component, preventing the formation of stagnant or dead water zones adjacent to the tube sheet center **15** and upward therefrom, such as would result in premature conversion of water to steam, or boiling, in those areas.

In the second example, shown by FIG. **2**, four annular flat plates or baffles are vertically interspaced, these baffle plates having outer peripheries of substantially the same diameter positioned to receive the initial feed water flow, again indicated by arrow **14**. This series of annular baffle plates may have outer peripheries which become larger, the outer peripheries of this series being located adjacent to the lower end **13** of the shell **10** which, with the housing or casing **9** and the tube sheet **8**, define an annular feed water inlet. These baffles are marked **20** through **23**, their outer peripheries having diameters approximately the same as the diameter of the shell **10**. The inside diameters of the series of baffles **20** through **23** progressively decrease downwardly with respect to the series of baffle plates. The lowermost baffle **20** closest to the tube sheet **8** has the smallest inside diameter, and the baffle **23**, which is farthest away, has the largest inside diameter.

With this FIG. **2** construction, the feed water flow is prevented from upward flow throughout the outermost peripheral tube sheet and tube nest. This radial flow is gradually released inwardly, for the upward flow. The vertical interspacing of these annular baffles is shown as all being the same, but this interspacing may be varied as required to assure that an adequate flow velocity exists reliably up to the center portion **15** of the tube sheet **8** and the corridor or passage formed by the tubes above this area. With this arrangement of FIG. **2**, the prior art uniform interspacing of the tube legs **3** and **4** may be maintained because the annular baffle plates perform the function of reinforcing the radial inward component of the flow **14** as compared to the upward or axial flow **11***a*.

FIG. **3** shows a third example of a means for increasing the radial feed water flow component relative to its upward axial flow component. This is done in this instance by making the upper surface of the tube sheet **8** with a convex shape. As previously indicated, this may be done by appropriately thickening the tube sheet so that its lower surface remains a plane flat surface or, although not shown, by making the tube sheet with the same thickness throughout and with a corresponding concave lower surface.

In either case, the convex upper surface increases the upward axial component of the feed water flow, adjacent to the tube sheet center **15**, to a greater extent than near the peripheral portion, this of necessity increasing the radial flow component towards the center portion **15**.

The convex shape may be contoured to fit the naturally developing flow as indicated in FIG. **3**. That is to say, the curvature may be such that the convexity gradually increases in degree towards the center **15** of the tube sheet **8**. In any event, the convexity should be such as to adequately increase or reinforce the radial component of the feed water flow sufficiently to prevent localized boiling with the consequent formation of deposits which should be avoided.

What is claimed is:

1. A steam generator including an upstanding, inverted U-shaped nest of tubes through which heating fluid is passed, said tubes having vertical legs, a horizontal circular tube sheet having holes formed therethrough and in which the lower ends of said legs are mounted, an enclosure for the tube sheet's upper surface and the tube nest for containing water and generated steam, means for flowing feed water into the enclosure radially inwardly from the periphery of the tube sheet and over the latter's upper surface for conversion to steam by upward flow therefrom through the tube nest, and means for flowing the heating fluid through the tube nests' tubes via the tube sheet's lower surface; wherein the improvement comprises means for reinforcing the inward radial flow force of the feed water to an extent preventing its conversion to steam locally adjacent to the central portion of the tube sheet and nest of tubes, said reinforcing means comprising a series of vertically interspaced annular plates having outer peripheral edges of substantially the same diameter all of which are positioned to receive the initial feed water flow via all of said edges, and having inner diameters which progressively increase from the uppermost one of said series downwardly to the lowermost one of the plates.

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