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Reisacher

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[54] **STEAM GENERATOR**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **122/32;** 165/160

[51] **Int. Cl.²** **F22B 1/06**

[58] **Field of Search** 122/32, 33, 34, 491; 165/158, 159, 160, 161

[56] **References Cited**

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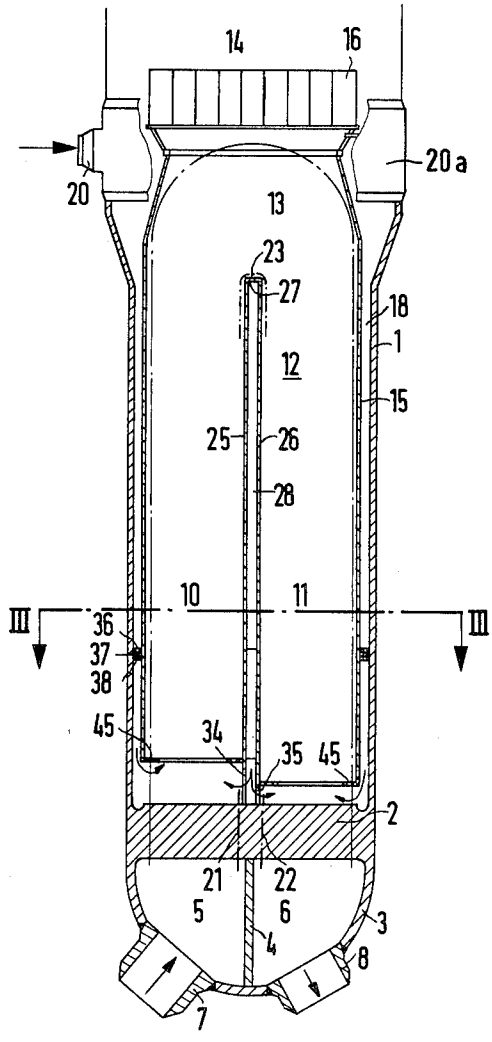
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Primary Examiner—Kenneth W. Sprague
Attorney, Agent, or Firm—Kenyon & Kenyon Reilly Carr & Chapin

[57] **ABSTRACT**

A pressurized-water reactor steam generator has a vertical casing with its bottom closed by a tube plate in which the two legs of a U-tube bundle heat exchanger, are mounted, the bundle being encircled by a shroud forming between it and the casing's inside, a descent space with which the top and bottom of the shroud communicates, feed water in the casing rising inside of the shroud while vaporizing, and descending through the descent space, the feed water in the casing being thus in continuous circulation. The two bundle legs (each have a generally semicylindrical contour) having flat interfacing sides, forming a corridor extending for the width of the tube bundle and vertically from the tube plate up to the tube return bends of the innermost tubes of the tube bundle. A duct is formed in this corridor by interspaced partitions which extend between the inside of the shroud, the bottom of the duct being made in the form of a funnel which opens generally centrally above the central portion of the tube plate, the shroud being slotted so that the duct is horizontally open down to the beginning of the funnel. This duct forms a second descent space internally within the tube bundle and down through which some of the descending water can flow and be funneled to the central portion of the tube sheet.

7 Claims, 3 Drawing Figures



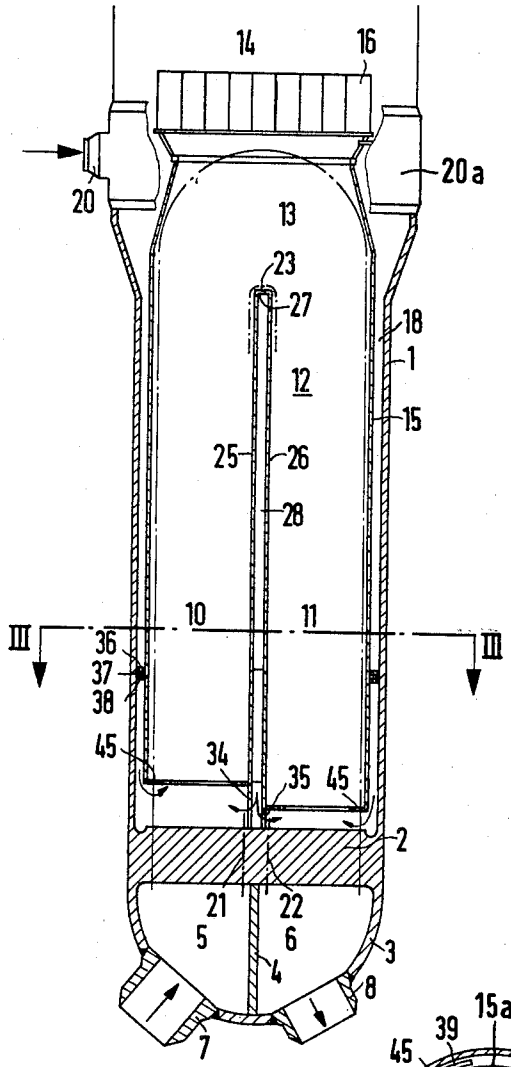


Fig.1

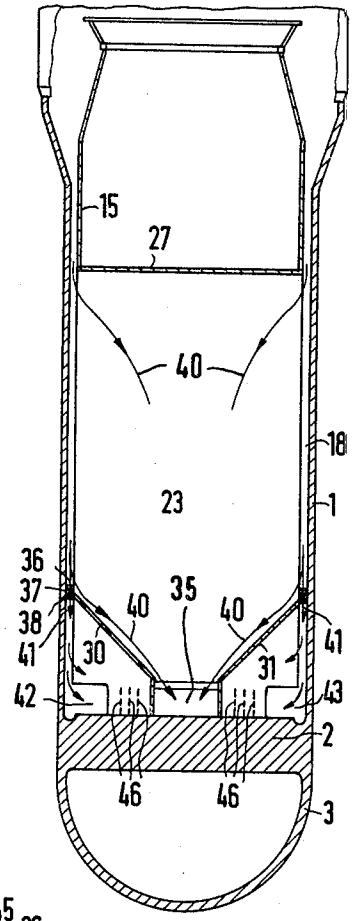


Fig.2

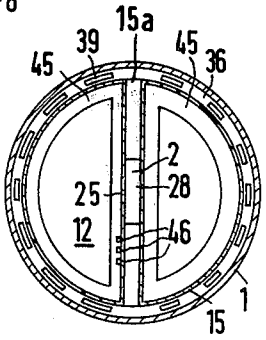


Fig.3

STEAM GENERATOR

BACKGROUND OF THE INVENTION

A steam generator of the type conventionally used as part of the coolant loop of a pressurized-water reactor, comprises a vertical casing having its lower portion closed by a horizontal tube plate in which the bottoms of the tubes of the hot and cold legs of a U-tube bundle are mounted, the tube bundle extending upwardly within the casing and being encircled by a shroud having a bottom end spaced above the tube plate but adjacent to this plate, the shroud extending upwardly around the tube bundle to at least slightly above the top of the bundle. This shroud forms an annular space between itself and the inside of the casing, the latter having a feed-water inlet and an enlarged upper portion having a top closed by a steam dome with a steam output nozzle, this enlarged portion normally containing an array of horizontally interspaced water separators mounted on top of the shroud. A primary header below the tube plate sends the coolant from the reactor through the tube bundle's hot leg and from the cold leg back to the reactor for cooling the reactor's core.

Feed-water in the casing rises up through the shroud and the two tube bundle legs, while vaporizing, water separated from the steam by the separators, together with an input feed water feed through the feed-water inlet, descending in the annular descent space and flowing over the top of the tube plate to again rise within the shroud. Thus, the feed water is maintained in circulation within the steam generator casing.

After descending the feed water is formed by the annular space between the bottom of the shroud and the tube plate, into a flow converging towards the center of the tube plate. The tube plate is one of the hottest parts within the steam generator, and if this flow over the tube plate is uniform and of adequate velocity, the feed water under the steam generator pressure, remains in its liquid phase.

Unfortunately, the above described flow is not always obtained, the inwardly directed flow from the annular space beneath the shroud, being greatly impeded by the multiplicity of tubes packed relatively closely together, which form the two legs of the tube bundle.

To provide for a more uniform flow over the tube plate, German Utility Model No. 7,226,418 suggests the possibility of positioning plates at the bottom of the shroud above the tube plate, the plates having holes formed in them and being inclined towards the tube plate to form with this plate a duct of wedgeshaped cross section. The purpose is to equalize the flow over the tube plate but this arrangement substantially increases the flow resistance because the flow must not only be through the tubes of the tube bundle, but also is hampered by the flow equalizing plates.

The U-tube bundle has a generally cylindrical outside contour encircled by the shroud which is also generally cylindrical, the two legs being substantially semicylindrical in contour with flat interfacing sides formed by the innermost rows of the tubes. Because of the tube return bends at the top of the bundle, these flat sides are necessarily horizontally interspaced. The result is that the U-tube bundle contains a vertically extending corrodor free from tubes, extending vertically from the tube plate to the tube return bends of the innermost tubes and horizontally for the width of the tube bundle. The feed water vaporizes to steam while rising through the shroud, through the tube bundle, and this space enclosed around the tube bundle is normally called the boiling space. However, the feed water rising in the corridor is not in direct contact with the heat exchanger tubes and, therefore, receives no direct heat exchange from the reactor coolant.

SUMMARY OF THE INVENTION

According to the present invention, interspaced, upstanding walls enclose the previously referred to corridor within and respect to the previously referred to flat sides of the tube bundle, but leaving this corridor open adjacently above the tube plate. These walls extend transversely between and connect with the shroud and the shroud has openings above the tube plate and connecting with the corridor between the walls, and with the descent space formed between the shroud and the inside of the steam generator's casing.

In other words, a duct is formed having narrow open sides, opening through the shroud, so that this duct forms a second descent space within the area formerly representing the corridor and up through which, with the prior art construction, the feed water ascended. However, with the present invention the feed water through the transverse openings through the shroud, has access to the enclosed descent space between the two legs of the U-tube bundle, so that the down-flow, is through this second descent space, into the central portion of the tube plate.

To guide the feed water descending through this new descent space formed between the two legs of the U-tube bundle, to the central portion of the tube plate, downwardly converging baffle plates are positioned between the two walls forming the new descent space, and which define an opening substantially directly above or open to the central portion of the tube plate. The two walls which define this new descent space between the two flat sides of the legs of the tube bundle, may also be enclosed between their tops, and the funnel-like bottom of the new descent space may open at right angles with respect to the interspacing flat sides of the tube bundle, for flow over the tube plate, starting substantially at the center of the tube plate, and extending counterflow to the normal flow introduced peripherally towards the center of the tube plate by the usual opening formed between the bottom of the shroud and the tube plate.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings, the foregoing is illustrated in more detail, in which:

FIG. 1 is a vertical section through the described type of steam generator and oriented at right angles to the corridor formed between the two generally semicircular legs of the tube bundle;

FIG. 2 is the same as FIG. 1 but is taken on a plane rotated approximately 180° with respect to the FIG. 1 view; and

FIG. 3 is a cross section taken on the line III—III in FIG. 1.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the above drawings, they show a pressurized-water reactor steam generator comprising a mainly cylindrical vertical casing 1 having a lower end closed by a horizontal tube plate 2 below which is shown the usual semispherical header 3 forming an

inlet or hot chamber **5** and an outlet or cold chamber **6,** these chambers being separated by a partition **4.** The inlet chamber **5** has a nozzle **7** for connection into the coolant loop of a pressurized-water reactor (not shown), while the chamber **6** has a generally corresponding nozzle **8** for connection with the pipe of the loop that returns the coolant to the reactor, normally through the main coolant pump (not shown).

The bottom ends of the tubes of the hot leg **10** and cold leg **11** of the U-tube bundle **12,** which may comprise around 1,000 tubes, are mounted in the tube plate **2** in the usual manner. The two legs are, of course, interconnected by the top bend **13,** the individual tubes all being U-shaped.

Although not shown in detail, the casing **1** has above the tube bundle the usual enlarged portion which defines a space **14** into which the steam discharges and passes through the steam output in the steam dome (not illustrated). In this enlarged portion of the casing **1,** there is a space **14** in which the water separators **16** are located by being mounted on top of the cylindrical shroud **15** which encircles the U-tube bundle of the heat exchanger. Steam dryers are normally located above the separator **16** and within the steam dome which is not shown.

The steam, of course, represents the useful power output of the steam generator and, in turn, of the reactor (not shown).

The cylindrical shroud **15** has the bottom end spaced above the top of the tube plate **2,** and a top end above the upper end of the U-tube bundle, as previously indicated. The shroud forms an annular descent space **18** between itself and the inside of the casing **1.** The casing **1** has a feed-water inlet **20** which through an annular distributing manifold **20***a*, feeds water uniformly above the annular descent space **18** formed between the cylindrical shroud **15** and the cylindrical inside **1** of the casing.

As previously described, the innermost tubes of the U-tube bundle heat exchanger, shown at **21** and **22** where they extend through the tube plate **2,** vertically define the corridor previously referred to and up through which the feed water normally ascends with the prior art constructions.

However, according to the present invention, the corridor, shown at **23** in FIG. **2,** is converted into a duct **28,** both flat interspaced sides of the tube bundle legs, being closed off by vertical upstanding walls **25** and **26** and which extend transversely between the upstanding wall of the cylindrical shroud **15.** The top of the duct is closed by a transverse wall **27** adjacently beneath the bends **23** of the tubes of the two legs, and the shroud **15,** which forms the descent space **18** between itself and the inside of the casing **1,** is formed with openings or vertically extending slots **15***a* as shown in FIG. **3.**

With the construction as described so far, the corridor between the two legs of the U-tube bundle, has been converted into a descent space. Feed water descending in the normal descent space **18** has access via the slots **15***a* in the shroud, to this new descent space **28** now formed by the vertical walls **25** and **26.**

To concentrate the descending feed water, in this new descent space, two downwardly converging baffle plates **40** are positioned between the two walls **25** and **26,** the bottom ends of these walls opening above the tube plate **2** adjacent to its central portion, the previously referred to slots **15***a* extending downwardly only so far as is required to reach the tops of the converging baffle plates **40** which form a funnel of the lower portion of the new descent space.

The two walls **25** and **26** may have bottom ends substantially contacting the top of the tube plate **2,** making allowance for thermal expansion clearance requirements, and both plates may have cutouts forming transverse outlets **34** and **35,** and other cutouts **42** and **43** adjacent to the outer edges of the two plates.

In operation, the space between the two legs now forms a descent space. The flow, having access through the slots formed in the shroud, can be discharged inwardly and downwardly as shown by the arrows **40** in FIG. **2,** with the flow discharging through the transverse openings **34** and **35,** the downward descent flow thus being directed centrally to the generally centralized portion of the plate **2** and from there horizontally outwardly and into the two legs, now each substantially enclosed by the shroud **15** and one or another of the walls **25** and **26.** The openings **34** and **35** have differing cross-sectional areas. The opening **34** leading over the plate beneath the hot leg **10,** is from **50** to **500%** larger than the opening **35** which feeds the water from the new descent space, over the portion of the tube plate **2** below the cold leg. The cross section ratio between the openings **34** and **35** is preferably about **4:1** so that the division of the flow rate between the two legs **10** and **11** in the ratio of **2:1** is provided.

The feed water descending normally in the descent space **15** can distribute over the top of the tube plate **2** by way of the cutouts **42** and **43.**

The bottom edge of the shroud **15** is provided with inwardly extending flanges **45** which extend inwardly across at least several rows of the tubes of the two legs of the U-tube bundle, thus deflecting water from the descent space **15** inwardly, thus to some extent bypassing the descent water. For the same purpose, vertically disposed rods **61** can be positioned between the two walls **25** and **26** above the tube plate **2.**

For the purpose of forcing more of the descent water through the new descent passage **28,** baffles may be arranged in the normal annular descent space outside of the shroud. For example, three rings **36, 37** and **38,** provided with slots **39,** may be positioned in the usual annular descent space **18.** One or another of these rings may be rotative relative to the balance so that the slots **39** may be more or less mutually registered. In this way more or less of the descending feed water may be forced through in the area of the cutouts **42** and **43** so that with proper porportioning of the cutouts **42** and **43** an appropriate supply of feed water to the two legs of the tube bundle may be provided. For example, the feed-water supply indicated by the arrows **41** may have 40 to 70%, preferably 60%, of the total descent feed of water. The passage openings **34,** for the water descending through the new descent space **28** may be from 50 to 500% larger than the passage openings **35** which lead into the cold leg **11.** The cross sectional ratio between the openings **35** is preferably about 4:1 so that the division of the flow rate between the two legs **10** and **11** in the ratio of 2:1 is provided.

As shown by FIG. **3,** the two declining or converging plates or partitions **40** reduce the cross section of the new descent space **28** to less than one-third of the width of this space, thus providing a high velocity flow of the descending feed water directed against the generally central portion of the tube plate **2.** It is this por-

tion where with prior art constructions, water boiling is most apt to occur. The inclined angles of the parts **40** is shown as being in the area of about 45%, but this angularity can be varied.

What is claimed is:

1. A steam generator comprising an upstanding casing having a lower portion, a tube plate closing said portion, a U-tube bundle heat exchanger inside of said casing and having upstanding legs with lower ends mounted in said plate, said bundle having a top formed by return tube bends joining said legs at said top and said legs forming flat-interfacing upstanding interspaced sides defining an upstanding corridor between the legs below said top, a shroud having an open top and bottom encircling said bundle inside of said casing and forming an annular descent space between the shroud and the inside of said casing, the bottom of said shroud being spaced adjacently above said plate, means below said plate for passing a primary fluid through said bundle, means for introducing feed-water into said casing, a steam outlet for said casing, and interspaced, upstanding walls enclosing said corridor within and with respect to said flat sides of the tube bundle but leaving said corridor open adjacently above said tube plate, said walls extending transversely between and connecting with said shroud and the shroud having openings above said plate and connecting said corridor between said walls, with said descent space.

2. The generator of claim **1** having means for forming a funnel for said corridor between said walls and above said plate and having an outlet mouth substantially over the center of the plate.

3. The generator of claim **2** in which said funnel-forming means comprise two downwardly converging baffle plates extending between said walls and with bottom ends adjacent to said plate, said openings in said shroud comprising slots formed longitudinally in the shroud from the upper ends of said walls down to the upper ends of said baffle plates.

4. The generator of claim **3** in which means forming down-flow restrictors are positioned in said annular descent space at a level adjacent to the upper ends of said downwardly converging baffle plates.

5. The generator of claim **3** in which said walls extend down substantially to said tube plate and said outlet mouth for said tunnel is formed by openings through said walls adjacent to said plate and facing said legs.

6. The generator of claim **5** in which one of said legs of said tube bundle is a hot leg and the other is a cold leg and the one of said openings facing said hot leg is larger than the one of the openings facing the cold leg.

7. The generator of claim **6** in which the bottom edges of said shroud and said walls above said openings have inwardly extending flanges.

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