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EUROPEAN PATENT SPECIFICATION

45 Date of publication of patent specification: **18.10.89**

51 Int. Cl.⁴: **F 22 B 1/02, F 28 D 7/06**

71 Application number: **85113455.1**

22 Date of filing: **23.10.85**

54 **Perforated flow distribution plate.**

30 Priority: **15.11.84 US 671822**
15.11.84 US 671821

43 Date of publication of application:
04.06.86 Bulletin 86/23

45 Publication of the grant of the patent:
18.10.89 Bulletin 89/42

84 Designated Contracting States:
BE DE FR GB IT SE

50 References cited:
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FR-A-2 458 781
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Description

The present invention relates generally to nuclear reactor steam generators, and more particularly to a perforated flow distribution plate operatively connected to the lower end of the steam generator tube wrapper for effectively minimizing turbulent flow conditions conventionally exhibited within the water, which traverses the region of the steam generator defined beneath the lower end of the steam generator tube wrapper, as the water flows from the lower end of the downcomer region of the steam generator, the downcomer region being defined between the steam generator shell and the steam generator tube wrapper, into the interior portion of the steam generator tube wrapper. Uniform flow conditions, free of conventionally generated or induced vortices, are thus imparted to the water flowing through the aforementioned steam generator regions, and particularly within the interior portion of the steam generator tube wrapper, whereby excessive vibrational motion and movement of the steam generator heat exchanger tube bundle tubes, which phenomena could possibly lead to tube wear, erosion, structural fatigue, stress cracking, and the like, is effectively precluded. In addition, foreign objects, having a predetermined size, are effectively prevented from entering the tube bundle section of the steam generator heat exchanger so as not to similarly cause degradation of the steam generator heat exchanger tube bundle tubes as a result of conventional erosive impaction or impingement of such foreign particles upon the tubes.

A nuclear reactor produces heat as a result of the fission of nuclear material which is disposed within fuel rods, and the fuel rods are secured together in predetermined arrays so as to define fuel assemblies. The fuel assemblies, in turn, define the nuclear reactor core, and the core is disposed within a reactor or pressure vessel. In commercial nuclear reactor facilities, the heat produced by means of the aforementioned fission processes is utilized to generate electricity. In particular, a conventional facility may comprise, for example, a primary coolant flow and heat exchange or transfer loop to which conventional steam generators and steam turbines, as well as electrical generators, are fluidically and mechanically connected, respectively. A typical energy conversion process for such commercial nuclear reactor facilities would therefore comprise, for example, the transfer of heat from the nuclear core to the primary coolant flow loop system, and from the primary coolant flow loop system to the steam generators by means of suitable heat exchangers incorporated within the steam generators. The steam generated within the steam generators is then of course transmitted to the steam turbines to which the electrical generators are operatively connected, and from which electricity is ultimately generated. A steam generator of typical construction is for example disclosed in US—A—3 916 844.

The principal object of the present invention is to

provide a nuclear reactor steam generator wherein turbulent fluid flow conditions are effectively prevented from being generated or established within the heat exchanger tube bundle section of the generator defined within the steam generator wrapper, and concomitantly, low velocity uniform fluid flow conditions free of vortices are in fact established and wherein foreign particles entrained within the infeed water, provided for the generation of steam, are effectively prevented from entering the heat exchanger tube bundle section of the generator so as not to cause any substantial degradation on the heat exchanger tubes as a result of impaction or impingement thereon, the aforementioned foreign particles being of a predetermined size.

As claimed the present invention resides in a steam generator, comprising a plurality of heat exchange tubes through which a heated fluid flows, said tubes being mounted on a tube sheet; a wrapper disposed about said heat exchange tubes so as to define a heat exchange tube section interiorly of said wrapper; an outer shell disposed substantially concentrically about said heat exchange tube wrapper so as to define a downcomer region between said outer shell and said heat exchange tube wrapper means for introducing water into said downcomer region of said steam generator for flow into said heat exchange tube section so as to permit said water to undergo a heat exchange process with said heat exchange tubes and thereby be converted into steam. According to the invention, a foraminous structure is arranged at the bottom end of said heat exchange tube wrapper so as to extend between the lower end of said wrapper and said tube sheet around to bottom end of said tubes for protecting said tubes from impacts of debris and for imparting to said water nonturbulent uniform flow conditions as said water flows from said downcomer region of said steam generator into said heat exchange tube section of said steam generator.

The foraminous structure may be a perforated plate whose apertures have a diameter of approximately 6.3 mm and in this manner, foreign particles which may be entrained within the incoming or feed water are effectively prevented from entering into the heat exchanger tube bundle section or region of the steam generator wherein such particles would ordinarily impart considerable wear and erosive damage to the heat exchanger U-bent tubes as a result of impaction and impingement. While particles having a diametrical extent of less than one-quarter inch would be permitted to pass through the perforated plate of the present invention and into the heat exchanger tube bundle region of the steam generator, such particles are not apt to cause any substantial degradation or erosive problems with respect to the heat exchanger U-shaped tubes, and in addition, the provision of the apertures having the diametrical extent of one-quarter inch preserves the desired fluid flow characteristics of the incoming or feed water through the perforated

plate and into the heat exchanger tube bundle section of the steam generator. A trade-off or balancing of operational objects is therefore achieved.

The present invention will be more fully appreciated as the same becomes better understood from the following detailed description when considered in connection with the accompanying drawings, in which like reference characters designate like or corresponding parts throughout the several views, and wherein:

Figure 1 is a perspective view of a conventional nuclear reactor steam generator showing the cooperative parts thereof;

Figure 2 is a front elevation view of the new and improved perforated flow distribution plate constructed in accordance with the present invention and illustrated as being installed within, for example, a steam generator facility such as that illustrated within Figure 1, and mounted in operative relationship with respect to the steam generator tube bundle wrapper and tube sheet;

Figure 3 is a vertical cross-sectional view of the new and improved perforated flow distribution plate illustrated in Figure 2 and taken along the lines 3—3 of Figure 2; and

Figure 4 shows another embodiment of the invention.

With reference initially being made to Figure 1 of the drawings, a conventional steam generator structure or facility is disclosed. In particular, the steam generator is seen to comprise a vertically oriented, elongated entity which includes a hollow, substantially cylindrical shell 12 having an upper shell section 14, a lower shell section 16, and a transition zone section 18 integrally interconnecting together the upper and lower shell sections 14 and 16. The diametrical extent of the upper shell section 14 is greater than that of the lower shell section 16, and consequently, the transition zone section 18 has the configuration of a conical frustum. A multitude of steam generator heat exchanger tubes 20 extend vertically within the central portion of the lower shell section 16 of the steam generator so as to define together a tube bundle. The uppermost portion of each of the tubes 20 extends upwardly within the transition zone section 18 of the steam generator and is seen to have an inverted U-shaped configuration. In this manner, the lower extremities of each tube 20 can be fixedly secured within a tube sheet 22 disposed within the lower end of the lower shell section 16. Integrally formed or secured to the outer periphery of the lower end of the lower shell section 16 within virtually the same horizontal plane as that of the tube sheet 22 is an annular support ring 24 by means of which the entire steam generator structure is capable of being supported upon the nuclear reactor facility or plant foundation. The lowermost end of the steam generator lower shell section 16 is sealingly enclosed by means of a hemispherically shaped shell portion 26, and disposed within hemispherical shell 26 is a vertically oriented divider plate 28 which serves to divide hemispherical shell 26 into

two spherical quadrants. As may readily be appreciated, each of the quadrants is fluidically connected to one of the extremities of each of the heat exchanger tubes 20, and each quadrant is also provided with a fluid nozzle 30 and 32, respectively, which serve to introduce nuclear reactor core coolant into, and discharge nuclear reactor core coolant from, the steam generator. In this manner, during operation of the nuclear facility, primary core coolant is conducted throughout its heat exchange or transfer loop from the nuclear reactor core, not shown, through inlet nozzle 30, the left steam generator hemispherical shell quadrant 34, the steam generator tube bundle U-shaped heat exchanger tubes 20, the right steam generator hemispherical shell quadrant 36, as viewed in Figure 1, outlet nozzle 32, and back to the nuclear reactor core.

In order to provide for the generation of steam within the steam generator, an inlet feedwater nozzle 38 is provided within a sidewall portion of the upper shell section 14 of the steam generator, and a water conduit 40 is disposed internally of nozzle 38. The conduit 40 is integrally connected with an annular manifold 42 which has operatively associated in a fluidically connected manner, a multitude of upstanding, inverted J-tubes or nozzles 44 through means of which the incoming feedwater is projected downwardly in cascading sheets. In order to define a flowpath of the cascading water flowing downwardly through the steam generator, the entire tube bundle is enveloped or encased within a cylindrical tube wrapper 46 which extends vertically, and substantially concentrically, within the lower and transitional zone sections 16 and 18 of the steam generator shell 12, the tube wrapper 46 being rigidly secured within the shell 12 by suitable means, not shown. In this manner, the tube wrapper 46 and the lower and transitional zone sections 16 and 18 of the shell 12 serve to define an annular downcomer region 48 through which the water flows downwardly toward the bottom of the steam generator facility. It is seen that the lower peripheral edge of the tube wrapper 46 is suspended above the upper surface of the tube sheet 22 whereby a transverse flow region is defined between the downcomer region 48 of the generator and the tube bundle section of the generator which is disposed interiorly of the tube wrapper 46. The water therefore enters the tube bundle section of the generator, and the heat exchange process between the water and the heated tube bundle tubes 20, through which the hot reactor core coolant is being conducted and circulated, begins to take place with the water passing between all of the heat exchange tubes 20. As a result, steam is generated; and the water and steam flow upwardly through the entire tube bundle, between the tubes 20, under natural convection. In order to provide lateral support and stabilization for the heat exchange tubes 20 throughout their vertical extent, a plurality of horizontally disposed, vertically spaced tube support plates 50 are fixedly secured to the

interior wall surface of the tube wrapper 46. As is conventional, the heat exchange tubes 20 pass through holes or apertures 52 defined within the tube support plates 50, there being sufficient spatial clearance defined between the tubes 20 and the plate apertures or holes 52 so as to provide for the desired, limited lateral support and restricted movement of the tubes 20, in response to the water flow thereabout as well as thermal expansion and contraction conditions, without hindering the passage therethrough of the water and steam flowing upwardly through the generator. It is to be further noted that in view of the U-shaped configuration of the tubes 20, a tube passageway or lane 54 is defined between the legs of the tubes 20, and within each of the horizontally disposed support plates 50, with the exception of the lowermost plate 50', there are defined a plurality of radially aligned slots 56 through which water and steam may likewise pass from one vertically spaced or defined section of the generator heat exchanger portion to another. The lowermost support plate 50' has the configuration of an annular disc with the central portion thereof open, and in this manner, the plate 50' serves as a flow distribution baffle which effectively causes a high percentage of the incoming water to flow from the radially outer portion of the tube bundle section of the steam generator, beneath the undersurface of the plate or baffle 50', and upwardly through the large central aperture defined within the plate or baffle 50', with the remaining portion of the incoming water flow passing upwardly through the apertures or holes 52 defined within plate or baffle 50'. Water and steam can therefore flow upwardly through the various vertically spaced stages of the heat exchanger, through means of the holes or apertures 52, as well as the slots 56 and the lanes 54, in a predeterminedly defined pattern which seeks to achieve flow uniformity. In addition to the support plates 50, antivibration bars 58 may be provided within the uppermost portion of the wrapper 46 so as to engage the uppermost, U-shaped bent sections of the heat exchanger tubes 20 for likewise performing restrictive and stabilizing functions with respect to tubes 20 in a manner similar to that of support plates 50 under steam and water flow, as well as thermal expansion and contraction, conditions. As a result, excessive wear of the heat exchanger tubes 20 is effectively prevented or substantially reduced, as is vibrational noise.

The upper end of the steam generator heat exchanger tube wrapper 46 is integrally provided with a horizontally disposed deck or cover 60 so as to seal the interior of the wrapper 46 within which the heat exchanger U-bent tubes 20 are disposed, however, in order to permit the upward escape of the generated steam from the heat exchanger portion of the generator and out of the wrapper 46, a plurality of holes 62 are defined within the cover or deck 60. A plurality of upstanding swirl vane primary moisture separators 64 in the form of, for example, cylindrical tubes

approximately 50 cm in diameter, are vertically supported atop tube wrapper deck or cover 60 with the lower ends thereof respectively in fluidic communication with the apertures or holes 62. A pair of horizontally disposed, vertically spaced lateral support plates 66 are fixedly secured with respect to the moisture separator tube systems at the upper ends and the axially central portions thereof, and in particular, it is seen that a plurality of apertures 68 are defined within the axially central or lower support plate 66 so as to permit the separator tubes 64 to pass therethrough. A plurality of outer cylindrical casings 70 concentrically surround those portions of the swirl vane separator tubes 64 which are disposed between the lateral support plates 66, and the upper ends of the casings 70 are in contact with the undersurface of the lower lateral support plate 66. Orifice bushings 72, having a diametrical extent which is less than that of the casings 70, are disposed within apertures 74 defined within the upper lateral support plate 66 such that the upper ends of the bushings 72 extend slightly above the upper surface of the upper support plate 66 while the lower ends of the bushings 72 are disposed within the upper ends of the casings 70. The upper ends of the swirl vane tubes 64 terminate at a level within the casings 70 which is below that of upper lateral support plate 66, and in this manner, water thrown radially outwardly under centrifugal force as a result of the passage of the steam/water mixture through the swirl vane separator tubes 64, and in particular past the swirl vane separators 76 respectively disposed within each tube 64, can collect upon the inner surface of each casing 70 while the steam can continue to travel axially upwardly so as to pass through the upper ends of the separator casings 70 and orifice bushings 72. The lower ends of the casings 70 are provided with rectangularly shaped cut-outs or apertures 78 so as to permit the aforementioned separated water to pass outwardly therethrough and over the peripheral edge of the lower lateral support plate 66 and be discharged back into the downcomer region 48 for recirculation back upwardly through the heater exchanger tube bundle within wrapper 46.

Within the uppermost section of the steam generator shell portion 14, there is defined a steam dome chamber 80 into which the steam exiting from the orifice bushings 72 enters, and within which there is disposed a plurality of stacked positive entrainment steam dryers 82. The dryers 82 have the configuration of cubes or rectangular parallelepipeds, and the upper surface of the dryer 82 is open so as to mate with a similarly configured cut-out or aperture 84 defined within a divider plate 86 disposed within the steam dome chamber 80. In this manner, the steam exiting from the orifice bushings 72 and passing into the steam dome chamber 80 is forced to enter the sidewalls of the dryers 82 before being further passed through dryer 82 and upwardly out of dryer opening 84 for discharge from the steam generator through means of an

axially upstanding steam nozzle 88 disposed atop the steam generator. The dryers 82 serve to separate any remaining or residual water entrained within the steam before the latter is conducted to the steam nozzle 88 for further passage to the steam turbines and electrical generators, not shown, and any such separated water is conducted vertically downwardly to a suitable pool or reservoir 89, defined within the central portion of the wrapper deck or cover 60, by means of an axially central drain pipe 90 dependently affixed to the floor 92 of the lower dryer 82. The lower end of pipe 90 is vertically spaced above wrapper deck or cover 60, and in this manner, the water collected within reservoir or pool 89 may ultimately flow radially outwardly over the wrapper deck or cover 60 so as to cascade downwardly into the annular downcomer region 48.

Having now generally described the heat exchange operation of a conventional or typical steam generator, it has been observed that when the infed water flowing vertically downwardly within the steam generator annulus or downcomer region 48 defined between the lower outer shell section 16 and the heat exchange bundle tube wrapper 46 traverses the region defined beneath the lower free end of the wrapper 46 so as to commence the upward flow within the wrapper 46 and between the heat exchanger U-bent tubes 20, considerable turbulence within the flow may develop due to the generation of vortices within the fluid flow as a result of the fluid encountering the upper surface of the tubesheet 22 as well as the lower ends of the legs of the heat exchange tubes 20 affixed within the tubesheet 22 as the flow seeks to achieve the 180° reversal in flow directions as defined by means of the flow vertically downwardly within the downcomer region 48 and vertically upwardly interiorly of wrapper 46 and between heat exchanger tubes 20. Such turbulent flow conditions may result in excessive vibrational motion of the heat exchanger tubes 20 within wrapper 46 so as to lead to rapid wear and erosion of the same. In addition, it is likewise possible that entrainment of foreign particles within the fluid flow could cause rapid degradation of the tubes 20 as a result of impaction or impingement of the same upon the tubes 20 under high velocity turbulent flow conditions.

With reference now being made to Figures 2 and 3 thereof, there is illustrated a perforated flow distribution plate arrangement generally indicated by the reference character 100. It is to be appreciated that the perforated flow distribution plate 100 of the present invention comprises an annulus disposed circumferentially about the entire interior portion of the steam generator although, of course, only a limited section of the plate 100 is illustrated. As particularly seen from the drawing figures, the perforated plate 100 has the form of a conical frustrum and is, in effect, a perimetrical skirt adapted to be interposed between the lower free edge portion 202 of the

annular steam generator heat exchanger tube bundle wrapper 146 and the upper surface 204 of the tube bundle tube sheet 122. It is to be noted at this juncture that the reference characters denoting, for example, the various components of the steam generator system illustrated within Figures 2 and 3 are similar to those reference characters denoting the same components of the steam generator system illustrated within Figure 1 with the exception that the reference characters employed within Figures 2 and 3 are in a 100 series of numbers.

As a result of the interdisposition of the perforated flow distribution plate 100 between the lower free end or edge portion 202 of the steam generator tube bundle wrapper 146 and the upper surface 204 of the tube bundle tube sheet 122, the downcomer region 148 of the steam generator, within which incoming feed water is flowing vertically downwardly as seen in the direction of arrow 206 between the steam generator outer shell 116 and the wrapper 146, is physically separated from the portion 208 of the steam generator which is radially internally or interiorly of the steam generator wrapper 146 and within which the heat exchanger U-shaped tubes 20 would be disposed, although the latter are not illustrated within Figure 3. It is seen that the perforated flow distribution plate 100 comprises a plurality of main body portions or segments 210 within each of which there is defined a multitude of through-bores or apertures 212 which are uniformly distributed throughout each plate main body portion or segment 210 in an array which comprises diagonally extending rows, all as best seen in Figure 2. In light of the foregoing structure, then, when the incoming infed water flowing vertically downwardly in the direction of arrow 206 within the downcomer region 148 of the steam generator seeks to cross-over or traverse the region of the steam generator which is located directly beneath the lower free end or peripheral edge 202 of the tube bundle wrapper 146 so as to pass from the downcomer region 148 of the generator into the tube bundle section or region 208 of the generator, the water is forced to pass only through the through-bores or apertures 212 of the perforated flow distribution plate segments or sections 210. As can thus be appreciated from Figure 3, therefore, uniform flow, exhibiting substantially parallel flow paths as designated by the arrows 214, is achieved through the perforated flow distribution plate segments or sections 210, and such flow is free from turbulent conditions which characterizes the flow within such regions of a steam generator within which the perforated flow distribution plate 100 of the present invention is not employed, such as, for example, as illustrated within Figure 1. Viewing the flow conditions in a slightly different light or from a slightly different viewpoint, the disposition of the perforated flow distribution plate 100 within the transition zone 216 defined between the downcomer region 148 and the tube bundle region 208 serves to interrupt the fluidic com-

munication between the downcomer and tube bundle regions 148 and 208, respectively, whereby the normal 180° flow path of the incoming infeed water 206, which serves to induce the turbulence and the generated or developed vortices, is in fact unable to establish or generate such vortices and turbulent flow conditions because such conventional 180° flow path has been effectively severed, and in lieu thereof, there has been established a plurality of substantially parallel flow paths as schematically illustrated by the arrows 214.

In addition to aforementioned structural features per se of the perforated flow distribution plate 100 of the present invention, and its particular disposition within the transition zone 216 of the steam generator, it is also of importance to appreciate the fact that the plate 100 likewise serves to drastically alter the flow velocity characteristics of the incoming infeed water flow 206. More particularly, the lower free end or peripheral edge portion 202 of the steam generator wrapper 146 is conventionally disposed above the upper surface 204 of the tube bundle tube sheet 122 a distance approximately between 30 and 35 cm, while the distance defined between the tube bundle wrapper 146 and the steam generator shell 116 is approximately 5 or 7.5 cm. The flow velocity of the incoming infeed water 206 flowing vertically downwardly within the downcomer region 148 is approximately 5 m per second, and therefore, in view of the fact that there is an approximate factor of five defined between the fluid flow spaces between the wrapper lower edge-tube sheet upper surface and the shell wrapper, the flow velocity of the incoming or feed water through the transition zone or region 216 would normally be reduced by one-fifth so as to exhibit a speed of 1 m per second. In reality, however, the actual flow velocity is substantially higher, and on the order of 2.6 or 3.3 m per second due to the turbulent conditions induced within the flow path. Continuing further, by the provision of the perforated flow distribution plate 100 of the present invention, wherein the same is provided with a porosity factor of approximately fifty per cent (50%) by means of through-bores or apertures 212, a factor of two is introduced into the system, and consequently, the flow velocity of the water through the holes or apertures 212 within the perforated flow distribution plate 100 of the present invention is approximately 1.83 m/s (6 fps). This compares quite favorably with the aforementioned velocity characteristic of the conventional steam generator system, and in addition, it is also to be emphasized, of course, that the resulting flow through the perforated flow distribution plate 100 of the present invention is uniform flow which is free of turbulence, vortices, and the like. Still further, in view of the uniform flow paths through the flow distribution plate 100 as schematically designated by the arrows 214, it has been experienced that the turbulent and vortex flow conditions which possibly occur within a conventional steam generator which does not employ

the flow distribution plate 100 of the present invention do not in fact tend to be re-established or regenerated within the tube bundle region 208 of the generator. As a result of all of the foregoing, no substantial vibrational forces are induced upon the steam generator tube bundle tubes 20 whereby excessive wear of the tubes 20 is effectively prevented with a concomitant extension in the service life of the heat exchanger tubes 20. As an additionally desirable characteristic or feature of the flow distribution plate 100 of the present invention, each of the through-bores or apertures 212 has been predetermined so as to have a diametrical extent of approximately 6.3 mm, and in this manner, foreign particles which may be entrained within the incoming infeed water 206, and having a diametrical size greater than 6.3 mm are prevented from entering the tube bundle section of the generator. In this manner, erosive degradation of the tubes 20 of the generator is minimized as a result of eliminating such particles from the tube bundle region 208 of the generator wherein such particles would normally impact and impinge upon the tubes 20.

With reference still being made to Figure 3 of the drawings, it is seen that in order to provide for the installation of the perforated flow distribution plate 100 of the present invention in connection with, for example, already existing steam generator facilities, the upper edge of each perforated plate segment 210 is integrally provided with an upstanding flange portion 218 as well as a horizontally extending flange portion 220 such that the two flanged portions together define an L-shaped shoulder or seat for engagement with the lower free end or peripheral edge portion 202 of the generator wrapper 146. The primary or main body portion 210 of each perforated plate segment is seen to be inclined with respect to the horizontal through means of an angle α of approximately 80°, and consequently, when the plate segments 210 are wedgingly interposed between the upper surface 204 of the tube sheet 122 and the lower free peripheral edge portion 202 of the generator wrapper 146 such that the wrapper edge portion 202 is seated within the plate shoulder region as defined by means of the plate segment flanged portions 218 and 220, the inclined plate segments 210 will be disposed within a stable erected mode relative to the generator wrapper 146 and the tube sheet 122, under the influence of the incoming infeed water 206, it being remembered that the perforated flow plate 100 of the present invention extends circumferentially about the entire lower end portion 202 of the wrapper.

In order to actually install the perforated flow distribution plate 100 of the present invention into existing steam generator facilities, an access must initially be made within the steam generator outer shell 116 so as to permit insertion of the individual plate segments 210 into the annular downcomer region 148 of the generator as well as to provide manipulative access to the segments 210 once the same are disposed within the down-

comer region 148. If the generator vessel or shell 116 is conventionally provided with manipulative access passageways, such as, for example, that shown at 222 in Figure 1, then such passageways may be employed for facilitating additional manipulation of the plate segments 210 within the downcomer region 148, provided that such access passageways are located at a suitable or proper elevational level with respect to the tube sheet 22 or 122, it being noted that such access passageways 222 are not conventionally large enough to permit the insertion of the plate segments 210 into the downcomer region 148. Once individual perforated flow distribution plate segments 210 are inserted through the access holes in the generator shell 116, adjacent segments may be securely fastened together either by means of welding techniques or be suitable brackets 224 provided upon the upper side edge of each plate segment, within or through which bolt fasteners 226 may be inserted. While such brackets 224 are illustrated as being employed only along the upper extent of each plate segment, it is understood that if such be desired, similar brackets and bolt fasteners may likewise be employed along the lower extent or edge of each of the segments 210 so as to maintain the abutting side edges of the segments 210 in close, sealed contact with each other. Upon completion of the welding or bolt fastening processing of, for example, the first two segments 210, the assembled plate segments 210 may be translated circumferentially within the transition zone 216 of the generator in order to accommodate the next plate segment 210 to be welded or bolt fastened to the preceding plate segments 210. It is to be understood that in view of the fact that the circumferential curvature of each of the plate segments 210 is similar to that of the generator wrapper 146, and in particular, the fact that the circumferential curvature of the plate flanged portions 218 and 220 are substantially identical to that of the wrapper so as to be operatively mated therewith, such circumferential translation of the segments within the transition zone 216 of the generator for accomplishing the installation of the entire plate 100 within the generator should not present any problems. Upon assembly together of all of the plate segments 210, and the disposition of the entire plate 100 about the lower periphery of the generator wrapper 146, the first and last two plate segments 210 may be welded or bolted together, however, it is noted that the segments 210 are not, and need not, be fixedly secured to the generator wrapper 146 within existing steam generator facilities. Such assembly processing or techniques not only permits the circumferential translation of the assembled segments about the transition zone 216 of the generator so as to accommodate additional segments for assembly thereof, but in addition, such foreshortens the requisite assembly time and any exposure of such assembly or maintenance personnel to radiation as a result of the core coolant having been conducted through the

heat exchanger tube bundle tubes 20. Upon completion of the entire assembly operation, it is simply necessary to close the access hole originally made within the generator shell 116 so as to preserve the structural integrity of the shell and the generator.

In accordance with an alternative mode of installing the perforated flow distribution plate 100 of the present invention within the steam generator facility, access to the interior of the steam generator shell may be accomplished through means of maintenance or inspection manways conventionally provided within the steam dome chamber region 80 of the upper steam generator shell section 14 as shown in Figure 1 at 228. The individual circumferentially curved or arcuate plate segments 210 may then be lowered vertically downwardly within the upper and transition zone sections 14 and 18 of the generator and ultimately passed downwardly into the downcomer region 148. The lower maintenance of personnel access or inspection manways 222 may then be utilized for performance of the actual installation, circumferential translation, and in-situ welding or bolt fastening operations in connection with the plate 100, if the manways 222 are suitably located elevationally with respect to the tube sheet 122. If the manways 222 are not suitably located, then access penetrations are again required to be made within the steam generator shell 116, however, these penetrations need not be as large as those required in accordance with the previous mode of installation for they do not have to provide for the insertion or introduction of the plate segments 210 into the generator. It is foreseeable that some difficulty might possibly be encountered in accordance with this mode of installation of the plate segments 210 into the generator in that the tapered transition zone annulus, as defined between the shell transition zone section 18 and the corresponding portion of the tube bundle wrapper, may not readily permit traversal therethrough of the circumferentially curved or arcuate-shaped plate segments 210, in which instance access penetrations, not shown, in the form of vertically extending grooves or the like, may have to be provided within the outer surface of the tube bundle wrapper. Lowering of the plate segments 210 from manways 228 to the tube sheet 122 or 22 may be accomplished by any suitable means, such as, for example, suspension cables, or the like.

In the instance of new steam generator facilities, the perforated flow distribution plate 100 of the present invention may simply be provided as an integral skirt portion of what otherwise would be the conventional tube bundle wrapper, and consequently, the foregoing installation requirements would not longer be required. It is noted that the tube bundle wrapper 146 is conventionally fabricated from a suitable carbon steel, however, in order to improve the erosive and corrosive resistivity of the perforated or foraminous flow distribution plate 100 of the

present invention, it might be best to fabricate the same from a suitable metal, such as, for example, INCONEL 600, a nickel-chromium alloy. This is particularly desirable in view of the fact that the plate 100 also serves to prevent the introduction of foreign particles, larger than the aforementioned predetermined size of 6.3 mm in diameter, into the tube bundle region 208 of the generator. Long term testing in reference water chemistry has shown that plates having such through-holes defined therein do not experience any substantial tendency for erosion, sludge deposition, or the like, and the fabrication of the plate segments 210 from INCONEL 600 would enhance these operative and service life characteristics or properties still further. In the instance that the plate segments 210 are therefore fabricated from a different material than that of the wrapper 146, the plate segments 210 may be welded to the wrapper 146 prior to the installation of the wrapper 146 within the generator, or still alternatively, a one-piece perforated flow distribution plate skirt, fabricated of INCONEL 600 may be welded or otherwise secured to the lower end of the wrapper 146 prior to installation of the same within the generator. It is of course to be understood that in connection with existing facilities, the plate segments 210 fabricated of INCONEL 600 would be installed in accordance with the aforementioned in-situ techniques, and not directly affixed or secured to the wrapper 146. The width of the individual plate segments 210 will be dictated by means of commercially available strip dimensions, and the thickness of the plate segments 210 may be specified by means of suitable stress analyses, anticipated transient flow loads under, for example, fluid line rupture conditions, and the like.

In the embodiment shown in Figure 4 a plurality of strong cylindrical members 124 constructed as either solid rods or thick-walled, hollow tubes, for example, having a wall thickness of greater than about 2.5 mm are provided.

The cylindrical members 124 generally have a length sufficient to span the opening 125 and are arranged around the lower peripheral portion of the tube bundle 108 in alignment with the longitudinal axis thereof. The cylindrical members 124 are dimensioned to have an outside diameter corresponding to the outside diameter of the heat transfer tubes 20 and are arranged in an array having a pitch corresponding to the pitch of the heat transfer tubes. In this regard, the cylindrical members 124, by having the same outside diameter and pitch as that of the heat transfer tubes 20, act like another row of heat transfer tubes 20 to the flowing fluid such that the pressure loss of the fluid flowing through the annular downcomer passage 106 and across the cylindrical members into the tube bundle 108 is almost negligible. Accordingly, the cylindrical members function as an almost indestructible screen against impacting pieces of metallic debris swept along by the fluid flowing within the annular downcomer passage 106.

The cylindrical members 124 can be secured at their lower ends to the tube sheet 122 within openings 126 provided about the periphery of the tube bundle. The openings 126 may be threaded so as to receive a corresponding threaded portion of the lower ends of the cylindrical members 124, or may provide for a slip or friction fit therebetween. In any event, the cylindrical members 124 can be spot-welded or permanently fastened in some other way to the tube sheet 122 if desired. The upper ends of the cylindrical members 124, extend through openings 128 provided within the first flow distribution support baffle 112 and are secured to the support baffle 112 by means of a collar 130 engaging a portion of the cylindrical members, as well as by welding them together. The cylindrical members 124 extend between the tube sheet 122 and the support baffle 112. However, it is not necessary that the cylindrical members 124 extend to the first support baffle 112. It is only require that the cylindrical members 124 extend generally across the extent of the opening 125, whereby the upper end of the cylindrical members may terminate freely under the first support baffle at a location indicated, for example, by the dotted lines 132. Protection above the support baffle 112 is not required, as this flow distribution plate support baffle prevents any debris from passing therebeyond.

Claims

1. A steam generator, comprising a plurality of heat exchange tubes (20) through which a heated fluid flows, said tubes (20) being mounted on a tube sheet (122); a wrapper (146) disposed about said heat exchange tubes (20) so as to define a heat exchange tube section (208) interiorly of said wrapper (146); an outer shell (116) disposed substantially concentrically about said heat exchange tube wrapper (146) so as to define a downcomer region (148) between said outer shell (116) and said heat exchange tube wrapper (146), and means (40) for introducing water (206) into said downcomer region (148) of said steam generator for flow into said heat exchange tube section (208) so as to permit said water to undergo a heat exchange process with said heat exchange tubes (20) and thereby be converted into steam, characterized in that a foraminous structure (100) is arranged at the bottom end of said heat exchange tube wrapper (146) so as to extend between the lower end of said wrapper (146) and said tube sheet (122) around the bottom end of said tubes for protecting said tubes from impacts of debris and for imparting to said water nonturbulent uniform flow conditions as said water flows from said downcomer region (148) of said steam generator into said heat exchange tube section (208) of said steam generator.

2. A steam generator according to claim 1, characterized in that said foraminous structure is a foraminous plate extending between the bottom end of said wrapper (146) and said tube sheet (112) and being inclined so as to extend

from said wrapper outwardly toward said shell (116), at an angle of about 80° with respect to a horizontal plane.

3. A steam generator according to claim 2, characterized in that said foraminous plate comprises a plurality of arcuate plate segments secured together so as to form an annular ring.

4. A steam generator according to claim 2 or 3, characterized in that the porosity factor of said foraminous plate is approximately fifty per cent (50%).

5. A steam generator according to any of claims 1 to 4, characterized in that said foraminous structure is fabricated from INCONEL 600 (nickel-chromium alloy).

6. A steam generator according to any of claims 1 to 5, characterized in that said foraminous structure has apertures of a predetermined size of approximately 6.3 mm in diameter thereby to prevent foreign particles having a size greater than said predetermined size from entering said tube bundle section of said steam generator.

7. A steam generator according to claim 1, characterized in that said foraminous structure comprises a plurality of cylindrical members (124) having an outside diameter corresponding to the outside diameter of said heat transfer tubes (20) and arranged in radial alignment with said heat transfer tubes (20).

8. A steam generator according to claim 7, characterized in that said cylindrical members are a plurality of solid rods (124).

Patentansprüche

1. Dampfgenerator, mit mehreren Wärmeaustauscherrohren (20), durch die eine erhitzte Flüssigkeit fließt und die auf eine Rohrplatte (122) aufgesetzt sind, einer Hülle (146), die zur Bildung eines Wärmeaustauscherrohrabschnitts (208) innerhalb der Hülle (146) um die Wärmeaustauscherrohre (20) herum angeordnet ist, einem äußeren Mantelgehäuse (116), das zur Bildung eines Fallbereiches (148) zwischen dem äußeren Mantelgehäuse (116) und der Wärmeaustauscherrohrhülle (146) im wesentlichen konzentrisch um die Wärmeaustauscherrohrhülle (146) herum angeordnet ist, und Mitteln (40), die in den Fallbereich (148) des Dampfgenerators Wasser (206) einführen, das in den Wärmeaustauscherrohrabschnitt (208) hineinfließt, so daß das Wasser mit den Wärmeaustauscherrohren (20) einem Wärmeaustauschvorgang unterziehbar und in Dampf umwandelbar ist, dadurch gekennzeichnet, daß zum Schutz der Rohre vor Trümmeraufprall und zum Herstellen nichtturbulenter, gleichmäßiger Strömungsbedingungen für das Wasser, während dieses von dem Fallbereich (148) des Dampfgenerators in den Wärmeaustauscherrohrabschnitt (208) des Dampfgenerators fließt, am unteren Ende der Wärmeaustauscherrohrhülle (146) ein foraminale Gebilde (100) angeordnet ist, das sich zwischen dem unteren Ende der Hülle (146) und der Rohrplatte (122) um das untere Ende der Rohre herum erstreckt.

2. Dampfgenerator nach Anspruch 1, dadurch gekennzeichnet, daß das foraminale Gebilde eine foraminale Platte ist, die sich zwischen dem unteren Ende der Hülle (146) und der Rohrplatte (122) erstreckt und in der Weise geneigt ist, daß sie sich im Winkel von etwa 80° zu einer waagrechten Ebene von der Hülle nach außen zum Mantelgehäuse hin erstreckt.

3. Dampfgenerator nach Anspruch 2, dadurch gekennzeichnet, daß die foraminale Platte mehrere bogenförmige Plattensegmente umfaßt, die zur Bildung eines Ringes aneinander befestigt sind.

4. Dampfgenerator nach Anspruch 2 oder 3, dadurch gekennzeichnet, daß der Porenanteil der foraminale Platte ungefähr fünfzig Prozent (50%) beträgt.

5. Dampfgenerator nach einem der Ansprüche 1 bis 4, dadurch gekennzeichnet, daß das foraminale Gebilde aus INCONEL 600 (Nickel-Chromlegierung) hergestellt ist.

6. Dampfgenerator nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß das foraminale Gebilde Öffnungen einer vorbestimmten Größe von ungefähr 6,3 mm Durchmesser aufweist, wodurch ein Eintreten von Fremdkörperteilen einer Größe, die größer als die vorbestimmte Größe ist, in den Rohrbündelabschnitt des Dampfgenerators verhindert wird.

7. Dampfgenerator nach Anspruch 1, dadurch gekennzeichnet, daß das foraminale Gebilde mehrere zylinderförmige Glieder (124) umfaßt, deren Außendurchmesser dem Außendurchmesser der Wärmeübergangsrohre (20) entsprechen und die in radialer Ausrichtung mit den Wärmeübertragungsrohren (20) angeordnet sind.

8. Dampfgenerator nach Anspruch 7, dadurch gekennzeichnet, daß die zylinderförmigen Glieder aus mehreren Massivstangen (124) bestehen.

Revendications

1. Générateur de vapeur comprenant une multiplicité de tubes (20) d'échange de chaleur à travers lesquels s'écoule un fluide chauffé, les tubes (20) étant montés sur une plaque tubulaire (122); une virole-enveloppe (146) disposée autour des tubes (20) d'échange de chaleur de manière à définir une section (208) de tubes d'échange de chaleur à l'intérieur de la virole-enveloppe (146); une enveloppe extérieure (116) disposée de façon sensiblement concentrique autour de la virole-enveloppe (146) de tubes d'échange de chaleur afin de former une région (148) de retour d'eau entre l'enveloppe extérieure (116) et la virole-enveloppe (146) de tubes d'échange de chaleur, et un moyen (40) pour introduire l'eau (206) dans la région (148) de retour d'eau pour qu'elle pénètre dans la section (208) de tubes d'échange de chaleur afin que cette eau subisse un processus d'échange de chaleur avec les tubes (20) d'échange de chaleur et soit, de ce fait, transformée en vapeur, caractérisé en ce qu'une structure perforée (100) est disposée à l'extrémité inférieure de la virole-enveloppe (146) de tubes

d'échange de chaleur de manière à s'étendre entre l'extrémité inférieure de la virole-enveloppe (146) et la plaque tubulaire (122) autour de l'extrémité inférieure des tubes pour protéger ces tubes contre les impacts des débris et pour soumettre cette eau à des conditions d'écoulement uniforme non turbulent lorsque ladite eau s'écoule de la région (148) de retour d'eau du générateur de vapeur pour pénétrer dans la section (208) de tubes d'échange de chaleur du générateur de vapeur.

2. Générateur de vapeur selon la revendication 1, caractérisé en ce que la structure perforée est une plaque perforée s'étendant entre l'extrémité inférieure de la virole-enveloppe (146) et la plaque tubulaire (122) et inclinée de manière à s'étendre depuis la virole-enveloppe vers l'extérieur en direction de l'enveloppe (116) suivant un angle d'environ 80° par rapport à un plan horizontal.

3. Générateur de vapeur selon la revendication 2, caractérisé en ce que la plaque perforée comprend une multiplicité de segments de plaque courbés, fixés les uns aux autres de manière à former une couronne

4. Générateur de vapeur selon la revendication 2 ou 3, caractérisé en ce que le facteur de porosité

de la plaque perforée est d'environ cinquante pour cent (50%).

5. Générateur de vapeur selon l'une quelconque des revendications 1 à 4, caractérisé en ce que la structure perforée est fabriquée en INCONEL 600 (alliage nickel-chrome).

6. Générateur de vapeur selon l'une quelconque des revendications 1 à 5, caractérisé en ce que la structure perforée comporte des ouvertures d'un diamètre prédéterminé d'environ 6,3 mm de manière à empêcher ainsi les particules étrangères ayant une taille plus grande que ce diamètre prédéterminé de pénétrer dans la section de faisceau tubulaire du générateur de vapeur.

7. Générateur de vapeur selon la revendication 1, caractérisé en ce que la structure perforée comprend une multiplicité d'éléments cylindriques (124) ayant un diamètre extérieur correspondant au diamètre extérieur des tubes (20) de transfert de chaleur et disposés en alignement radial avec ces tubes (20) de transfert de chaleur.

8. Générateurs de vapeur selon la revendication 7, caractérisé en ce que les éléments cylindriques sont formés par une multiplicité de barres pleines (124).

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FIG. 1.
(PRIOR ART)

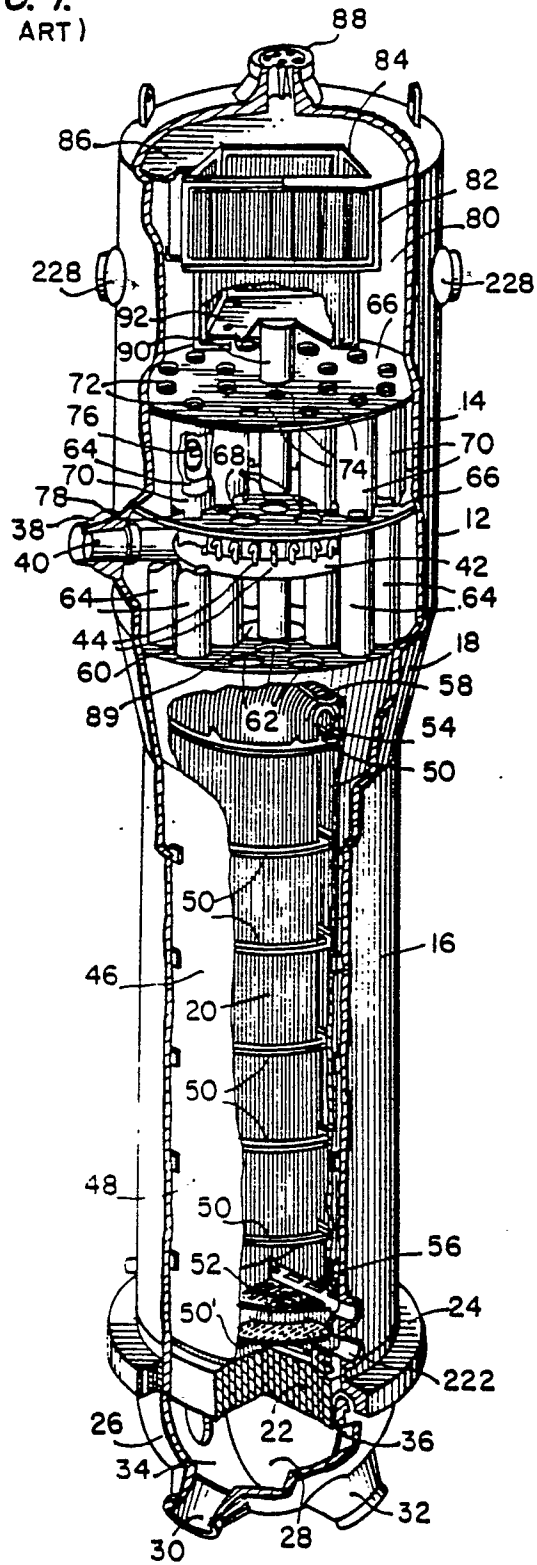


FIG. 2.

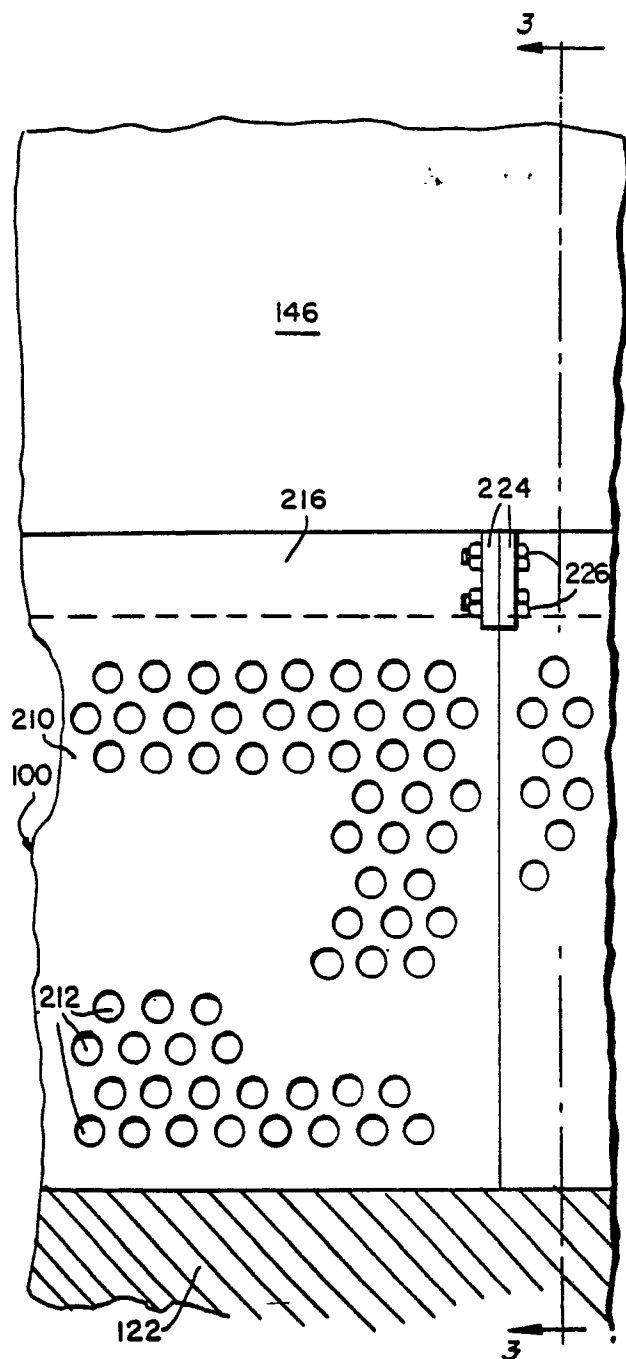


FIG. 3.

