May 13, 1969 J. G. RICH ET AL 3,443,548

HIGH TEMPERATURE AND HIGH PRESSURE STEAM GENERATOR

Filed Jan. 23, 1968 Sheet 1 of 2

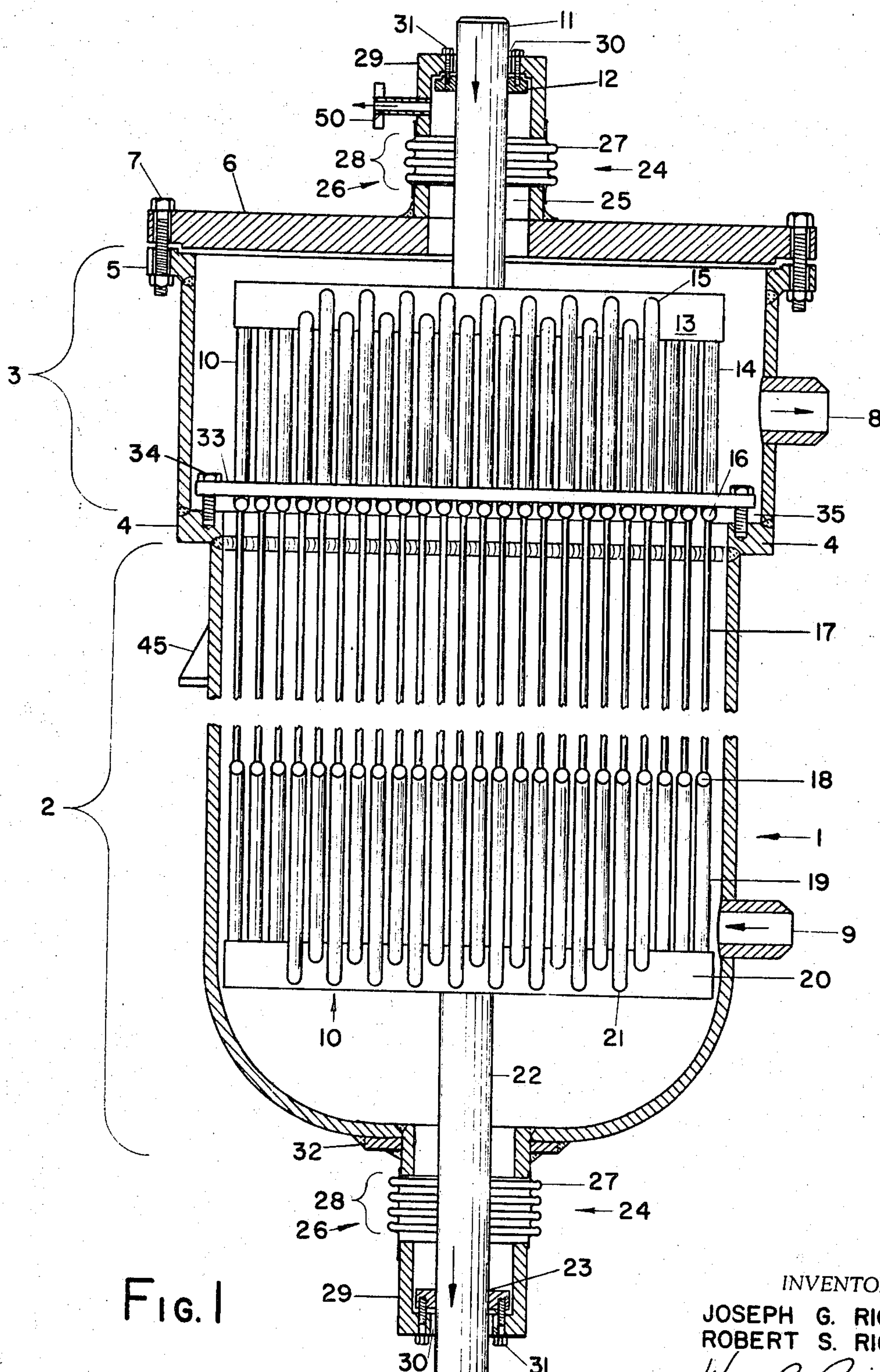

FIG. 1

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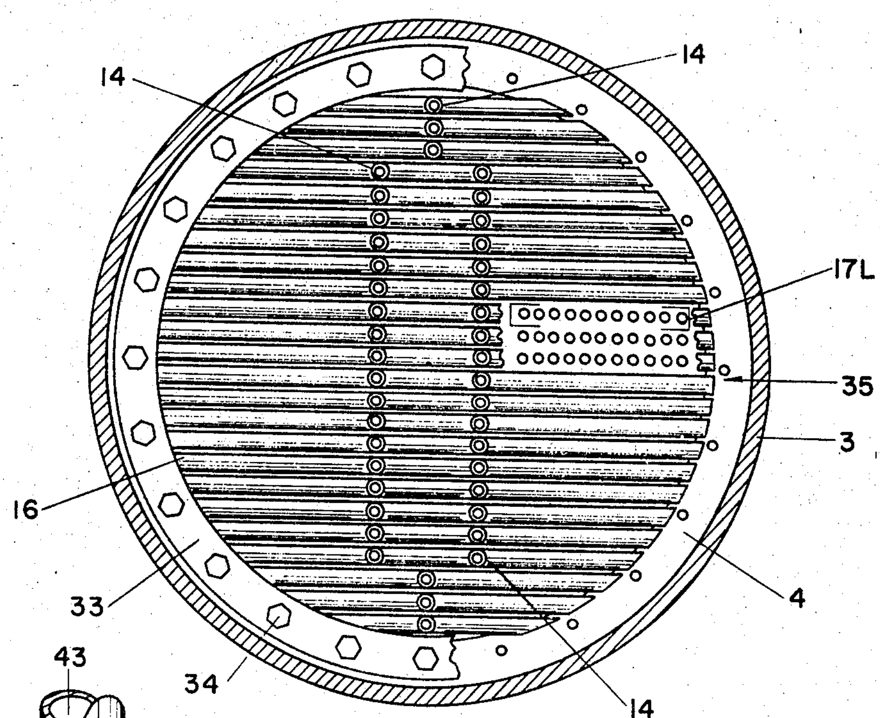

FIG. 2

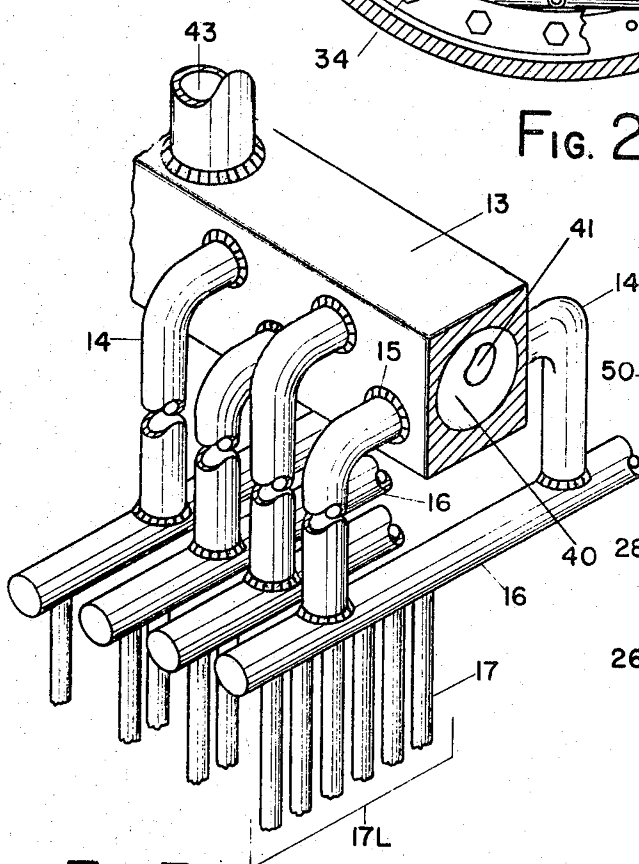

FIG. 3

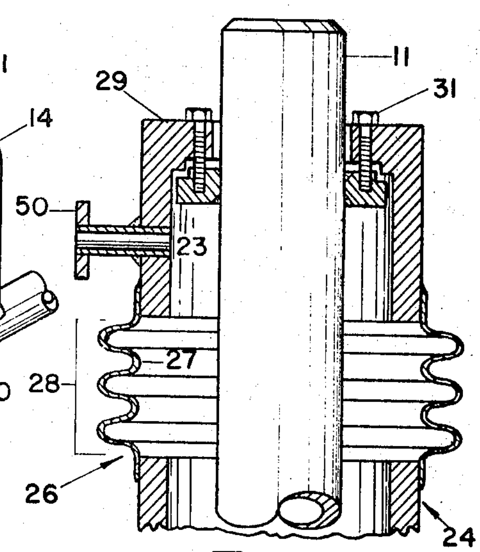

FIG. 4

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HIGH TEMPERATURE AND HIGH PRESSURE STEAM GENERATOR

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U.S. Cl. 122—32 8 Claims

ABSTRACT OF THE DISCLOSURE

Discloses an unfired, high pressure and high temperature fire tube steam generator including a removable tube bundle assembly fixedly attached at either end in an upright high pressure cylindrical shell. The tube bundle assembly consists of a series of layers of tubes in which each layer communicates at both ends with transverse tubular headers, which in turn, are connected to a high pressure manifold in communication with a tubular high pressure inlet and outlet, respectively. The high pressure cylindrical shell has tubular extensions of smaller diameter relative to the diamter of the shell, which contain a metallic packless expansion joint as an integral part of the wall, to compensate for thermal expansion and contraction of the tube bundle assembly relative to the shell.

Background of the invention

This invention relates to an unfired, high temperature and high pressure fire tube steam generator. This invention relates, more specifically, to a tube and shell type steam generator, capable of handling high temperature and high pressure heating media, as well as producing high temperature and high pressure steam. Process gases in the chemical processing industry are under increasingly higher pressures and increasingly higher temperatures so that it is not uncommon today to find many process gases at pressures of 700 p.s.i.g. or 45 atmospheres up to and exceeding 500 atmospheres. Additionally, many of these gases are at temperatures of from 700 to in excess of 1500 degrees F. Removal of the sensible heat from these gases allows the production of steam at pressures in excess of 300 p.s.i.g. or over 20 atmopheres. Due to the increasing competitiveness of the chemical processing industries, it is no longer possible to waste or dump considerable amounts of thermal energy as has often been done in the past. However, as the temperature and pressure of the gaseous media are increased, as well as the temperature and pressure of the steam produced in the steam generators, the concomitant problems of design of the unfired steam generators are also increased.

Description of the prior art

In the past, with large steam generators, it has been the practice to utilize a U tube type arrangement in which the open ends of the tubes are swaged into opposite sides of a tube sheet. (See, for example, U.S. 3,195,515, Blizard.) Thus, the hot gases were brought into a gas collection zone on one side of the tube sheet, passed into the tubes and brought out onto the other side of the tube sheet ino a gas collection zone separated by a partition from the inlet. Thermal expansion and contraction of the tubes was, therefore, possible since the tubes expanded inside of the body of the shell. Nevertheless, as the temperatures and pressures increased in the chemical processing industries, it became necessary to make an increasingly thicker tube sheet to withstand the stress of the high pressure heating media and steam.

The thickness of the tube sheet is a function of the ligament between the tubes, the diameter of the tube bundle, the pressure of the heating media, the pressure of the steam produced thereby and the temperature of both the heating media and the steam. The disproportionate size of the tube sheet thus became a problem as is illustrated in the patent to Blizard, 3,195,515. In some instances, the tube sheet was of from 12 to 18 inches in thickness. Thus, with a large steam generator containing several hundred tubes, it was necessary to bore two holes for each tube through 12 to 18 inches of steel, in perfect alignment. If one hole was out of alignment, the entire tube sheet was effectively ruined. Further, as the temperatures and pressures increased, the problems of thermal contraction and expansion became more exaggerated so that various expedients were proposed to allow one or the other end of the tube bundle to be free to expand or to utilize a floating head of some type. One expedient which has been proposed for high pressure gases but which is practical only for comparatively low pressure steam is disclosed in U.S. Patent 3,229,762 to Vollhardt. In this arrangement, the high pressure gases are brought into a solid manifold from which the gases are distributed to Y shaped tubular members connected to the heat exchange tubes. However, the manifold at either end is permanently welded to the pressure shell, thus necessitating a large expansion joint around the circumference of the shell, in order to compensate for thermal expansion and contraction. Since the necessary thickness of the shell wall is proportional to the diameter of the shell at a specified pressure, such an expedient could only be used at relatively low steam pressures or with relatively small diameter steam generators. Further, the tube assembly is non-removable so that it cannot be removed for retubing without dismantling the entire steam generator. Other non-removable steam generators make use of flexible tube sheets, in which the tube sheets are supported by the tubes which act as stays. In these generators, the spacing of the tubes govern the thickness of the tube sheet. These generators, however, are limited in the upper ranges of temperature and pressure.

Summary of the invention

According to our invention, a removable tube bundle assembly which is fixedly attached at either end in a cylindrical upright pressure shell is secured at the inlet and outlet to tubular extensions of the shell of relatively small diameter, as compared to the diameter of the main body of the shell, said tubular extensions having metallic packless expansion joints integrally incorporated in the walls so as to compensate for the thermal contraction and expansion of the tube bundle assembly relative to the shell. The tube bundle assembly itself consists of an inlet and outlet manifold at each end in communication with the high pressure tubular inlet and outlet which manifolds, in turn, are in communication with a series of transversely mounted tubular headers which are operatively connected to parallel layers of small diameter heat exchange tubes. The pressure shell has a steam riser outlet at the top and a water downcomer inlet near the bottom and an auxiliary steam riser at the top of the upper tubular extension to bleed off trapped steam with the result that the entire tube bundle assembly is completely water cooled. In one modification, the tube bundle assembly is mounted near the top to a transition ring of the cylindrical pressure shell so that the remaining portion of the tube bundle assembly is suspended from that point to provide for structural stability. While removable tube bundle assemblies have been known in the art, to our knowledge, they have not been applied to high pressure and high temperature steam generators in which both the heating media and the steam produced thereby are both in the high pressure and high temperature range.

Brief description of the drawings

FIG. 1 is a fragmentary view in elevation, with parts in section, of the entire unit;

FIG. 2 is a plan view of the holddown ring with parts broken away to illustrate the transition ring and the transverse headers;

FIG. 3 is a fragmentary view, in perspective, of the parallel layers of tubes, transverse headers, the connecting tubes and the inlet manifold;

FIG. 4 is an enlarged view, partially in section, of the upper tubular extension with the metallic packless expansion joint integrally incorporated in the walls of said extension and illustrating the relation of the high pressure tubular inlet thereto.

Detailed description of the preferred embodiment

Referring now to the drawings in detail, our high pressure, high temperature unfired steam generator consists of a cylindrical, upright pressure shell **1** having a lower portion **2** and an upper portion **3**. The upper portion **3** is of larger diameter than is the lower portion and is divided by a large annular transition ring **4** welded to the wall of the upper and lower portions. Welded to the top portion **3** of the shell is a cover flange **5** onto which the large cover plate **6** is attached by bolt **7**. Near the top in the upper portion **3** of the shell is a large steam riser outlet **8** and in the lower portion **2** of the shell is a water downcomer inlet **9**. The arrows illustrate the flow of the steam-water mixture from the steam riser outlet **8** to the steam drum (not shown) and the flow of water from the steam drum back to the water downcomer inlet **9**. The steam drum is located at some distance above the top of the shell **1** as is general practice and thus is not illustrated. The water level is maintained in the steam riser above the level of the shell so that the shell and upper tubular extension are completely filled with water.

The tube bundle assembly, which is mounted vertically in the vertically oriented shell **1** is designated generally by numeral **10** and consists of a high pressure tubular inlet **11** onto which is welded a closure flange ring **12** and which is in communication with an inlet manifold **13**. A series of tubular connecting members **14** are socket welded at point **15** into the inlet manifold **13** and are in communication with an upper set of transverse tubular headers **16**. As is better illustrated in FIG. 3, the transverse tubular headers **16** are in communication with heat exchange tubes **17** arranged in parallel layers **17L** so that each tubular header **16** lies in the same plane as its respective layer **17L** of heat exchange tubes **17**. At the other end of the steam generator, is a lower set of transverse tubular headers **18**, each tubular header of said set being in communication with a layer **17L** of the heat exchange tubes **17**. Connected to the transverse tubular headers **18** are a lower set of tubular connecting members **19** which are socket welded at point **21** into the lower manifold **20**. Further, in communication with the lower manifold is high pressure tubular outlet **22** having welded thereto a closure flange ring **23**. The arrows at the inlet and outlet illustrate the flow of hot gaseous media under high pressure through the apparatus. At either end of the cylindrical pressure shell **1** is a tubular extension **24** which at the inlet is welded to the large cover plate **6**. The tubular extension **24** has incorporated in its walls by welding, a metallic packless expansion joint **26** which consists of a series of metallic corrugations **27** forming a bellows **28**.

As is shown, the cover plate **6** contains an opening **25** through which the high pressure tubular inlet **11** projects. Welded to the tubular extension **24** is a closure cap **29** which is bolted by means of bolts **31** to the upper closure flange ring **12**. Due to opening **25**, the entire tubular extension **24** is filled with water. Thus, the high pressure tubular inlet **11** projects through the opening **30** of closure cap **29**. At the top of upper tubular extension **24** is a small auxiliary steam riser outlet **50** which bleeds off trapped steam to insure that the tubular extension **24** is filled with liquid water. Thus tubular extension **24** functions as a water jacket for inlet **11**.

The arrangement is essentially the same for the tubular extension **24** at the bottom except that the extension is welded to the shell and to reinforcing ring **32** and is attached to the closure flange ring **23** of the outlet **22** by means of bolts **31**.

Thus, it will be seen that the tube bundle assembly consists of an inlet **11** and an outlet **22**, upper and lower manifolds **13** and **20**, upper and lower sets of transverse tubular headers **16** and **18** in communication with the heat exchange tubes **17** of layers **17L**.

The entire tube bundle assembly **10** is fixedly attached at the inlet **11** and outlet **22** by means of bolts **31** secured through closure caps **29** into closure flange rings **12** and **23** respectively.

However, for better structural stability, the upper set of transverse tubular headers **16** rest on a large annular transition ring **4** as will be best seen in FIG. 2. In order to completely secure the upper set of transverse tubular headers **16** to the annular transition ring **4**, a large annular holddown ring **33** is attached thereto by means of bolts **34**. Thus, the entire tube bundle assembly is suspended from point **35** inside of cylindrical pressure shell **1** which is held in position through means of external lug **45** on a supporting structure (not shown). Thus, the tube bundle assembly is fixed at the inlet **11** and outlet **22** by means of closure caps **29** and at point **35** by means of holddown ring **33** attaching the ends of the upper set of tubular headers **16** to the annular transition ring **4**.

Positioning of the expansion joint **26** in the wall of the upper tubular extension **24** compensates for thermal expansion and contraction of the tube bundle assembly **10** between point **35** and the upper closure flange ring **12**, whereas the lower expansion joint **26** compensates for expansion and contraction of the tube bundle assembly **10** from point **35** to the lower closure flange ring **23**.

Referring now, more specifically to FIG. 3, which illustrates the relationship of the parallel tubular layers **17L** of heat exchange tubes **17** to the upper set of transverse tubular headers **16** and the inlet manifold **13**, it will be noted that the inlet manifold **13** is a solid block of steel having a center bore **40** which is in communication with an inlet bore **43** and a set of auxiliary bores **41** each in communication with its respective tubular connecting member **14**. As is shown in FIGS. 2 and 3, each of the larger transverse tubular headers **16** has two tubular connecting members **14** which are socket welded at point **15** into the manifold **13**. However, the short transverse tubular headers at the botom and top of the assembly have only one centrally disposed tubular connecting member which runs directly into the upper manifold **13**.

As previously set forth, the tube bundle of the present invention allows the individual heat exchange tubes **17** to be welded to the transverse tubular headers in layers **17L**. Thus, each layer can be built up as a modulator unit and tested as a unit prior to assembly of the complete tube bundle.

Furthermore, the entire tube bundle assembly including the inlet **11** and the outlet **22**, can be removed from the shell **1** by removing bolts **31** from the upper and lower closure flange rings **12** and **23** respectively, by removal of the bolts **7** from the cover plate **6** and by removal of bolts **34** from the annular holddown ring **33**. Thus, after the upper plate **6** and the upper tubular extension **24** are removed, the entire tube bundle assembly **10** can be removed for repair, for cleaning or for retubing. Further, it will be noted that the auxiliary steam riser outlet **50**, located in the upper portion of the tubular extension **24**, allows a water level over the complete tube bundle assembly, so that the entire tube bundle assembly is water cooled.

It will be apparent to those skilled in the art that we have proposed a high pressure and high temperature unfired steam generator which can use heating media of high pressures and temperatures and which can be manufactured in large size; which has a high level of efficiency and which has good structural stability. As many modifications will occur to those skilled in the art from the detailed description hereinabove given, it is intended that this description be exemplary in nature and nonlimiting except as to be commensurate in scope with the appended claims.

We claim:

1. An unfired, high temperature and high pressure steam generator comprising:
  (A) a cylindrical upright pressure shell, having a steam riser outlet near the top and a water downcomer inlet near the bottom;
  (B) a removable cylindrical tube bundle assembly, fixedly attached at each end in said shell with its longitudinal axis in parallel relation with the longitudinal axis of said shell, said tube bundle assembly including:
    (1) a bundle of tubes, arranged in spaced parallel layers, in which;
      (a) each tube is spaced, parallel and co-extensive with adjacent tubes in a layer, and,
      (b) each layer of tubes is spaced, parallel and co-extensive with adjacent layers;
    (2) an upper and lower set of tubular headers mounted transversely across said bundle of tubes at the top and bottom of said bundle, said upper and lower sets of tubular headers being in communication with the upper and lower open ends of the tubes of said layers;
    (3) an upper and lower manifold located at the top and bottom of said bundle, respectively and serving as conductors for high pressure and high temperature gaseous heating media to and from said bundle of tubes;
      (a) said manifold being of solid integral construction and containing a central bore for the inlet and outlet of said heating media and a series of auxiliary bores in communication with said central bore for conveying said heating media to and from said tubular headers;
    (4) tubular connecting members, connecting said upper and lower sets of tubular headers to said auxiliary bores of said upper and lower manifolds;
    (5) a high pressure tubular inlet for receiving said high temperature and high pressure heating media, and in communication with said central bore of one of said manifolds;
    (6) a high pressure tubular outlet for said heating media in communication with said central bore of the other of said manifolds;
  (C) said upright cylindrical presure shell comprising:
    (1) a removable upper end plate having a central opening for passage of said tubular inlet;
    (2) upper and lower tubular extensions of small diameter relative to the diameter of the main body of said shell, said upper and lower tubular extensions enveloping said tubular inlet and outlet;
    (3) closure means for closing said upper and lower extensions and attaching said extensions to said tubular inlet and outlet in gas tight connection;
    (4) a metallic packless expansion joint integrally incorporated in the wall of said tubular extensions to compensate for expansion and contraction of said tube bundle assembly relative to said shell;
    (5) an auxiliary steam riser outlet located at the top of said upper tubular extension to bleed off trapped steam so as to maintain liquid water in said tubular extension to water cool all of the tube bundle assembly.

2. An unfired, high temperature and high pressure steam generator, as defined in claim 1, in which:
  (A) said cylindrical pressure shell has an upper and lower portion, the lower portion having a smaller diameter than the upper portion;
  (B) an annular transition ring integrally incorporated in the wall of said shell to form a shelf at the point of transition between the upper and lower portions;
  (C) the combination therewith of anchoring means whereby the tube bundle assembly is anchored to said transition ring and the tube bundle assembly is suspended therefrom.

3. The unfired, high temperature and high pressure steam generator, as defined in claim 2, in which:
  (A) said transition ring is located at the level of the upper set of transverse headers of said tube bundle assembly, and,
  (B) the ends of said tubular headers are supported by the shelf formed by said transition ring.

4. The unfired, high temperature and high pressure steam generator as defined in claim 3, in which:
  (A) the anchoring means comprise an annular hold-down ring resting over the ends of said tubular header and secured to said transition ring by means of bolts.

5. An unfired, high temperature and high pressure steam generator as defined in claim 1, in which:
  (A) the number of tubular headers in each set is equal in number to the number of layers of said bundle of tubes and each header of each set is in the same plane as the plane of its respective layer of said bundle of tubes.

6. An unfired, high temperature and high pressure steam generator as defined in claim 1, in which:
  (A) each tubular header of each set has closed ends.

7. An unfired, high temperature and high pressure steam generator as defined in claim 1, in which:
  (A) the tubular connecting members connecting said upper and lower sets of tubular headers to said upper and lower manifolds are at least equal in number to the number of tubular headers.

8. An unfired, high temperature and high pressure steam generator of claim 1, in which said metallic expansion joint contains a series of corrugations forming a bellows.

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U.S. Cl. X.R.

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