April 25, 1961 F. M. BARTON 2,981,241

RADIANT WALL CONSTRUCTION FOR VAPOR GENERATOR

Filed Aug. 14, 1958

3 Sheets-Sheet 1

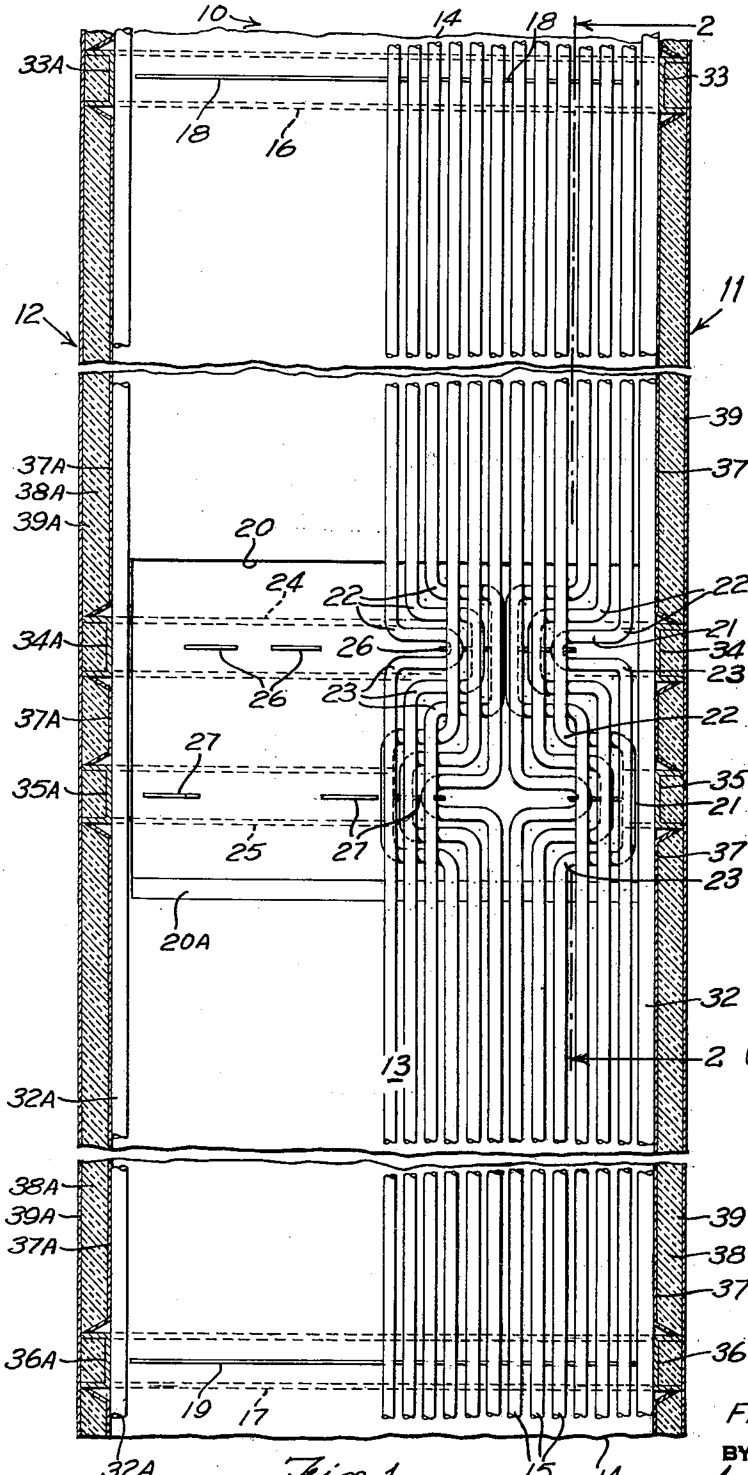

Fig. 1.

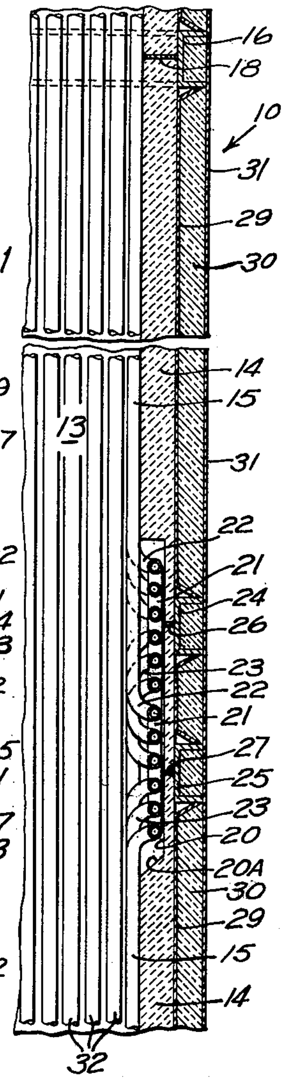

Fig. 2.

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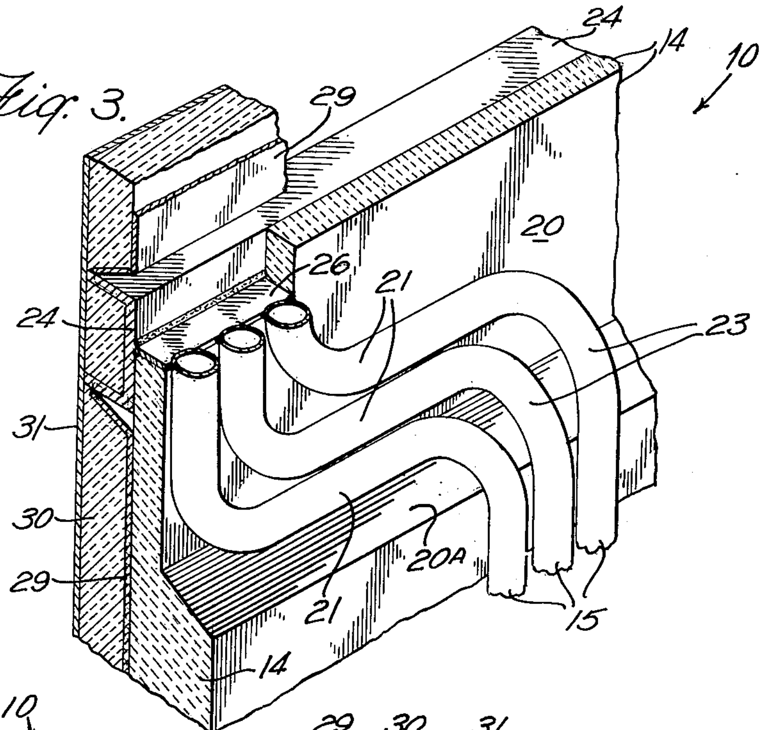
3 Sheets-Sheet 2

Fig. 3.



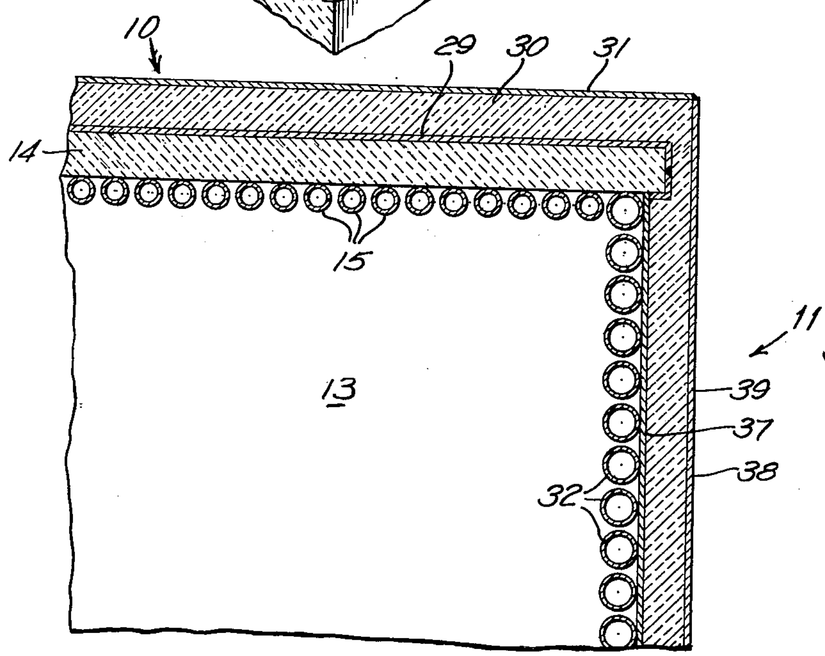


Fig. 4.

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3 Sheets-Sheet 3

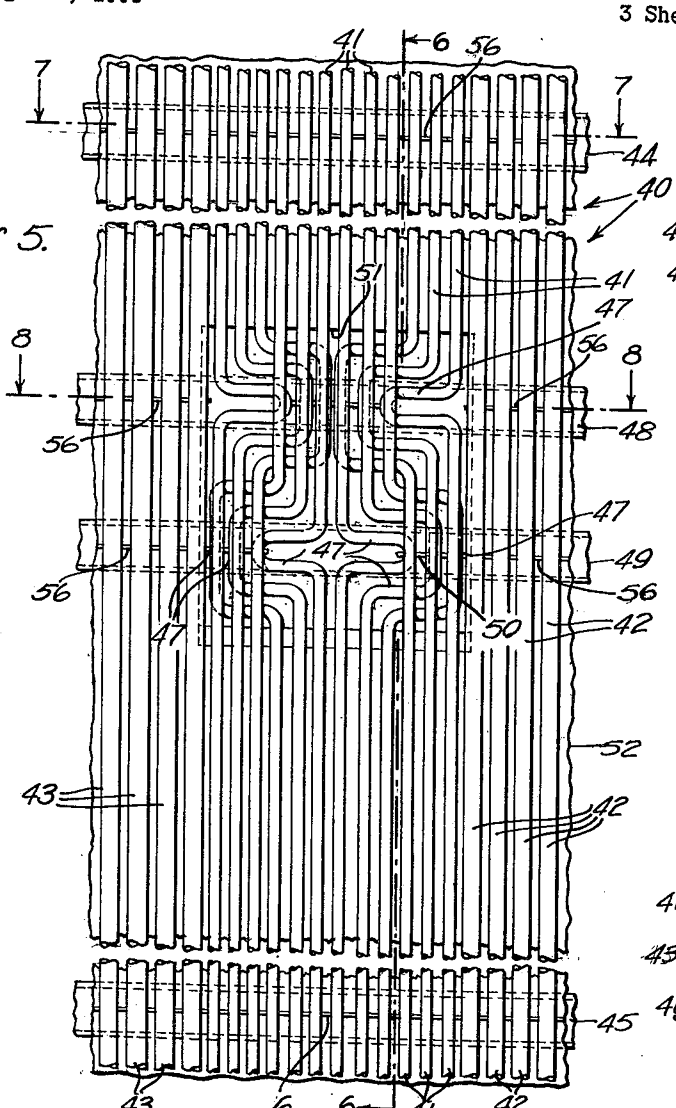

Fig. 5.

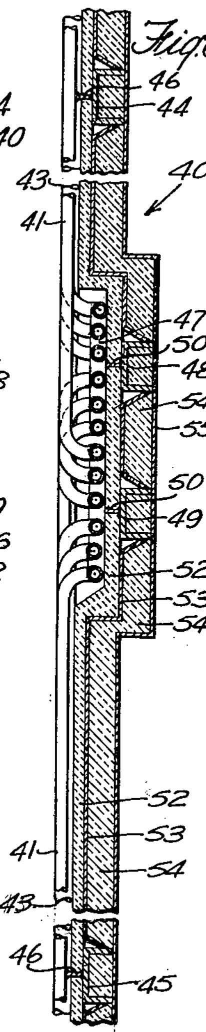

Fig. 6.

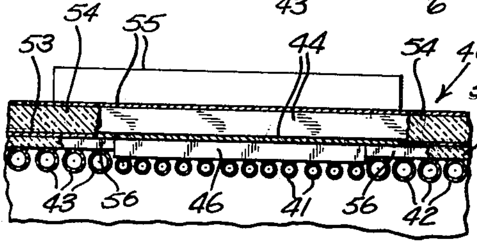

Fig. 7.

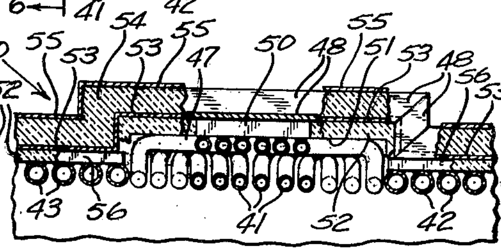

Fig. 8.

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2,981,241

RADIANT WALL CONSTRUCTION FOR VAPOR GENERATOR

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12 Claims. (Cl. 122—6)

This invention relates to vapor generators and more particularly to vapor-cooled walls of vapor generators.

In vapor generators having a combination of vapor-cooled and liquid-cooled furnace walls or vapor and liquid-cooled sections in the same furnace wall, the problem of differential expansion and contraction between the abutting vapor-cooled and liquid-cooled walls or the vapor and liquid-cooled wall sections is encountered. Heretofore, this differential linear expansion and contraction problem has been solved by rather elaborate and relatively complex spring and tie-back arrangements for securing the tubes to the furnace wall and seal slip joints for connecting the abutting liquid and vapor-cooled walls together whereby relative movement between the walls is permitted. In vapor generators where a wall comprises a combination of liquid and vapor-cooled sections, the wall has been provided with costly fluid seal slip joints between the abutting steam and water-cooled wall sections.

One of the disadvantages of the aforementioned means for connecting and supporting vapor and liquid-cooled walls or wall sections of a vapor generator to allow for differential linear expansion of the abutting walls or wall sections is that skin or skin and fin-tube type casings cannot be employed. A skin casing as used herein relates to a casing wherein the metal sheets or sections of the casing are disposed relatively close to the fluid conducting tubular members of the vapor generator walls and with little or no insulating refractory material between the tubular members and the casing so that the casing sections are at a temperature closely approximating the temperature of the tubular members. A casing of conventional type is insulated from the fluid conducting members so that it is at a temperature substantially equal to room or atmospheric temperature. A fin-tube casing, as used herein, relates to liquid-cooled tubular members which are provided with longitudinally extending ribs which are secured to the rib of an adjacent tubular member or to the surface of the next adjacent tubular member. Heretofore, a vapor generator having vapor-cooled and liquid-cooled walls was provided with a conventional casing which had to be supported independently of the walls and pressure parts of the vapor generator, and where the vapor generator had to be provided with separate buckstay systems for the vapor-cooled tubes and liquid-cooled tubes, thus resulting in a relatively complex and costly vapor generator structure.

Accordingly, it is an object of the present invention to provide in a vapor generator a novel vapor-cooled furnace wall which obviates the necessity for elaborate spring and tie-back assemblies or special sealing arrangements and/or other special means for allowing for differential linear expansion or contraction between vapor-cooled walls and liquid-cooled furnace walls.

Another object of this invention is to provide in a vapor generator a vapor-cooled furnace wall wherein a single buckstay system may be employed which is common to all furnace walls.

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A further object of the present invention is to provide in a vapor generator a novel vapor-cooled wall in combination with liquid-cooled walls which permits the use of skin or skin and fin-tube type casings.

The present invention contemplates a vapor-cooled wall, that is, a wall comprising vapor-cooled tubes or a combination of vapor-cooled and liquid-cooled tube bank sections, in which the vapor-cooled tubes are provided with at least one expansion bend or "loop" portion disposed between means for fixedly securing the tubes against movement relative to liquid-cooled tubes so that differential linear expansion or contraction between the vapor-cooled wall or section and the abutting liquid-cooled walls or sections is compensated for by said expansion bends of the vapor-cooled tubes.

In a first embodiment of the present invention a vapor-cooled furnace wall in combination with abutting liquid-cooled walls is disclosed wherein the vapor-cooled wall comprises a plurality of vapor-cooled tubes disposed in parallel relationship with each other. The vapor-cooled tubes are arranged in groups with a plurality of tubes in each group. Each tube of each group of tubes, at a point between the opposite ends of the tubes, is provided with at least one expansion "loop" portion. The "loop" portions of each tube of a group of tubes are dimensioned so that a "loop" portion of one tube lies within the "loop" portion of a next adjacent tube of the group of tubes. The vapor-cooled tubes adjacent their "loop" portions are so formed that the "loop" portions of each group of tubes lies in a plane adjacent the plane of the straight portions of the vapor-cooled tubes. The "loop" portions of the tubes of a group of tubes is offset from the "loop" portions of a next adjacent group of tubes so that the "loop" portions of one group of tubes is disposed in a plane adjacent the plane of the straight portions of the next adjacent group of tubes. Means are provided for securing each of the vapor-cooled tubes at the apex of the "loop" portion against movement relative to the liquid-cooled walls. Second means are provided for supporting and securing each tube of each group of tubes on each side of the "loop" portions against movement relative to the liquid-cooled walls so that the differential linear expansion or contraction between the vapor-cooled tubes and the liquid-cooled walls is compensated for by said "loop" portions of the vapor-cooled tubes. Said second means may also secure and support the liquid-cooled tubes.

In a second embodiment of this invention a vapor-cooled wall is disclosed which consists of at least one bank of vapor-cooled tubes disposed adjacent at least one bank of liquid-cooled tubes. The vapor-cooled tubes are arranged in parallel relationship with each other and the liquid-cooled tubes. The vapor-cooled tubes are arranged in two or more groups with each tube of each group provided with at least one expansion bend or "loop" portion disposed between the opposite ends of the tubes. The "loop" portions of the tubes in each group of tubes are dimensioned so that a "loop" portion of one tube lies within the "loop" portion of a next adjacent tube in the group. The tubes of each group of tubes are so formed adjacent the "loop" portions that the "loop" portions of a group of tubes lies in a plane adjacent to the plane of the straight portions of the vapor-cooled tubes. The "loop" portions of one group of vapor-cooled tubes is offset from the "loop" portions of another group of tubes so that the "loop" portions of the vapor-cooled tubes of one group lies under the straight portions of the adjacent group of tubes. Means are provided for securing each of the vapor-cooled tubes at the apex of the "loop" portion against movement relative to the liquid-cooled tubes. Second means are provided for securing the vapor-cooled tubes of each group at a point spaced from opposite sides of the "loop" portions against movement relative to the liquid-cooled tubes whereby differential linear expansion or contraction between the vapor-cooled tubes and the liquid-cooled tubes is compensated for by the "loop" portions of the vapor-cooled tubes. Said first and second means may be also employed to secure and support the liquid-cooled tubes.

In the aforedescribed embodiments, the vapor-cooled walls are provided with a layer of heat insulating refractory material disposed adjacent the tubes, with a skin casing portion disposed to cover the outer surface of the layer of heat insulating refractory material. The thickness of the layer of heat insulating refractory material is determined by that amount of insulation which is necessary to maintain the skin casing section adjacent the vapor-cooled tubes at substantially the same temperature as the skin casing section adjacent the liquid-cooled tubes. It is also contemplated that a layer of heat insulating refractory material may be provided between the liquid-cooled tubes and the casing section adjacent thereto, in which instance, the layer of refractory material adjacent the vapor-cooled tubes would be thicker than where no heat insulating refractory material is provided adjacent the liquid-cooled tubes. A skin or a skin and fin-tube type casing is feasible since expansion and contraction of the vapor-cooled wall or section is that of the liquid-cooled wall or section and the differential linear expansion or contraction between the vapor-cooled tubes and the liquid-cooled tubes is compensated for by the compression or expansion of the "loop" portions of the vapor-cooled tubes.

The invention will be more fully understood from the following detailed description thereof when considered in connection with the accompanying drawings wherein two embodiments of the invention are illustrated by way of example, and in which:

Fig. 1 is a fragmentary view in section of a vapor generator having a vapor-cooled wall according to a first embodiment of this invention;

Fig. 2 is a sectional view taken along line 2—2 of Fig. 1;

Fig. 3 is an enlarged fragmentary view in perspective of the vapor-cooled tubes and the means for securing them to a channel buckstay;

Fig. 4 is a fragmentary view of the corner construction between the vapor-cooled wall and an abutting water-cooled wall;

Fig. 5 is a fragmentary view in section of a vapor generator furnace having a vapor-cooled wall according to a second embodiment of this invention;

Fig. 6 is a sectional view taken along line 6—6 of Fig. 5;

Fig. 7 is a view, in section, taken substantially along line 7—7 of Fig. 5; and

Fig. 8 is a sectional view taken substantially along line 8—8 of Fig. 5.

Referring now to the drawings and more particularly to Figs. 1, 2, 3 and 4, the reference numeral **10** designates a vapor-cooled wall which abuts oppositely disposed liquid-cooled walls **11** and **12**. Vapor-cooled wall **10** defines with walls **11** and **12**, and another liquid-cooled wall (not shown) a furnace chamber **13** of a vapor generator. Vapor-cooled wall **10** comprises a layer of heat insulating refractory material **14** and a bank of vertically extending tubular members **15** which are disposed adjacent to the inner surface of the layer of heat insulating refractory material **14**. Tubular members **15** are arranged in parallel relationship with one another and are connected at one end to a source of vapor, such as a header (not shown), to receive vapor, as for example, such as a header (not shown), to receive vapor, as for example, steam or steam to be reheated, and pass the vapor in indirect heat exchange relationship with products of combustion in chamber **13** to heat said vapor. Tubular members **15** are connected at their opposite adjacent ends to a vapor receiver (not shown), such as an outlet header, to pass heated vapor thereto. Two vertically spaced horizontally extending channel buckstays **16** and **17** are disposed against the outer surface of refractory layer **14**. Each of the tubular members **15** is secured to channel buckstays **16** and **17** by plate members **18** and **19**, respectively, the tubular members **15** being secured, as by welding, to the inner edges of said plate members **18** and **19** while the opposite outer edges of plate members **18** and **19** are secured, as by welding, to the respective channel buckstays **16** and **17**. A recess **20** is provided in the inner surface of heat insulating refractory layer **14** at a point substantially midway between channel buckstays **16** and **17**, the purpose of recess **20** will be hereinafter described. The lower edge **20A** of recess **20** is downwardly inclined so that slag fly ash and soot will flow from the recess back in furnace chamber **13** and will not be trapped therein.

The banks of tubular members **15** are divided into a plurality of groups with each group comprising a plurality of adjacent tubular members. The number of groups of tubular members and the number of tubular members in each group is dependent upon the size of vapor-cooled wall **10**, size of the tubular members and other factors relative to a particular vapor generator design. However, for illustration purposes vapor-cooled wall **10** is divided into eight groups with three tubular members in each group, but only four groups are shown for reasons of clarity and because the arrangement of the tubular members for one half of wall **10** is identical with the tubular arrangement of the other half. Also for illustration purposes tubular members **15** are shown in close spaced relationship with each other while in actual practice the tubular members may be arranged in tangential abutment with each other.

As best shown in Figs. 1, 2 and 3, each tubular member **15** in each group has a horizontally extending expansion "loop" or U-bend portion **21** and is provided with a pair of compound bends **22** and **23** at the ends of the legs of U-bend portion **21** whereby U-bend portion **21** lies within recess **20** and in a plane offset from the plane of the straight portions of tubular members **15**. U-bend portion **21** of each tubular member of a group of tubular members is dimensioned so that a U-bend portion **21** of one tubular member is nested within the U-bend portion **21** of the next adjacent tubular member **15** of the group. As shown, the nested U-bend portions **21** of one group of tubular members **15** is arranged, with respect to the nested U-bend portions **21** of an adjacent group of tubular members **15**, so that the nested U-bend portions **21** of one group lie under or behind the straight portions of tubular members **15** of the next adjacent group of tubular members **15**.

As shown, another pair of vertically spaced, horizontally extending channel buckstays **24** and **25** are positioned against the outer surface of refractory layer **14** and adjacent to the U-bend portions **21** of tubular members **15**. Tubular members **15** in each group of tubular members are secured at the apices of their U-bend portions **21** to channel buckstays **24** and **25** by plate members **26** and **27**. Plate members **26** and **27** are secured along one edge, as by welding, to channel buckstays **24** and **25**, respectively, and are secured, as by welding, to tubular members **15** along their opposite edges (see Fig. 3). Tubular members **15** are slidably supported in a suitable manner (not shown) well known by those skilled in the art, as for example, by movable tie-bars, to one or more horizontal buckstays (not shown) disposed between channel buckstays **16** and **24** and between channel buckstays **17** and **25**.

Vapor-cooled wall **10** is provided with a skin-type casing **29** which is disposed against the outer surface of heat insulating refractory layer **14**. As best shown in Fig. 2, casing **29** may comprise a plurality of sections which are connected in a fluid-tight manner, as by welding, to channel buckstays **16**, **17**, **24** and **25** and the channel buckstays (not shown) disposed between channel buckstays 16 and 24, 17 and 25. Adjacent the outer surface of casing 29 is disposed a layer of insulating material 30 and an outer sheathing 31 of metal or hard finish cement. Heat insulating refractory layer 14 and heat insulating layer 30 may comprise a plurality of blocks or may be castable insulating material.

Liquid-cooled wall 11 comprises a bank of vertically extending liquid-cooled tubular members 32 which are arranged in parallel relationship with each other and may be disposed in tangential abutment with each other, although, for illustration purposes the tubular members are shown in close-spaced relationship. Each of the tubular members 32 is connected at one end to a source of liquid (not shown), as for example, an inlet header to receive liquid, such as water, from said inlet header and passes the liquid in indirect heat exchange relationship with combustion products in furnace chamber 13 to vaporize at least part of the liquid in said tubular members 32. The opposite end of each of the tubular members 32 is connected to a receiver of vapor and/or vapor-liquid mixture (not shown), as for example, an outlet header, to pass vapor and/or vapor-liquid mixture, such as steam and/or steam and water into said outlet header. Tubular members 32 are fixedly secured to and supported by horizontally extending channel buckstays 33, 34, 35 and 36 which are disposed to lie in the same horizontal planes as the respective channel buckstays 16, 24, 25 and 17. Each of the tubular members 32 are also fixedly secured as by welding, to one or more horizontal channel buckstays (not shown) disposed between channel buckstays 33 and 34 and between channel buckstays 35 and 36. Liquid-cooled wall 11 is provided with a skin casing 37 comprising a plurality of sections which are secured in a fluid-tight manner, as by welding, to channel buckstays 33, 34, 35 and 36 and the aforementioned channel buckstays (not shown) disposed between the latter. A layer of heat insulating material 38 is disposed adjacent the outer surface of skin casing 37 as well as an outer sheathing 39 of metal or hard finish cement disposed to cover the surface of heat insulating material 38.

Liquid-cooled wall 11, as well as the liquid-cooled wall (not shown) disposed opposite vapor-cooled wall 10, are identical in construction and, therefore, will not be described in detail. Accordingly, parts of wall 12 corresponding to like parts of wall 11 will be designated by the same reference numeral, but with the suffix A added thereto.

Channel buckstays 16, 17, 24 and 25 of vapor-cooled wall 10 are respectively secured at one end to channel buckstays 33, 34, 35 and 36 of liquid-cooled wall 11 (Fig. 4) and at their opposite ends are respectively secured to channel buckstays 33A, 34A, 35A and 36A of liquid-cooled wall 12. Skin casing 29 of wall 10 is connected in a fluid-tight manner, as by welding, to skin casing 37 of wall 11 and skin casing 37A of wall 12.

In the same manner aforedescribed, channel buckstays of the liquid-cooled wall (not shown) are secured to the ends of channel buckstays 33, 34, 35 and 36 of wall 11 and channel buckstays 33A, 34A, 35A and 36A of wall 12, thereby providing a channel buckstay system which is common to all the walls of the vapor generator. The casing of the liquid-cooled wall, not shown, is secured in a fluid-tight manner to casings 37 and 37A of walls 11 and 12, respectively. The heat insulating material 30, 38 and 38A of the respective walls 10, 11 and 12, including sheathing 31, 39 and 39A of the walls, as well as the heat insulating material and sheathing of the liquid-cooled wall, not shown, are integrally joined together to form a unitary wall structure defining chamber 13.

As can be seen from the foregoing description, the longitudinal expansion of tubular members 15 of vapor-cooled wall 10 between channel buckstays 16 and 17, which linear expansion is greater than the longitudinal or linear expansion of tubular members 32 and 32A of walls 11 and 12, including the liquid-cooled tubular members of the wall, not shown, will cause the legs of U-bend portions 21 of tubular members 15 to be compressed toward each other. Accordingly, the U-bend portions 21 of tubular members 15 are dimensioned so that the distance between the legs of the innermost U-bend portion 21 of each group of nested U-bend portions is at least equal to the calculated maximum differential expansion between the vapor-cooled wall 10 and the liquid-cooled walls of the vapor generator. If in a particular vapor generator design the calculated maximum differential longitudinal expansion between the vapor-cooled walls and liquid-cooled walls is greater than the flexure stress which may be safely imposed at the U-bend portions 21, it is within the contemplation of the present invention to provide tubular members 15 with one or more additional U-bend portions. For example, tubular member 15 may be fixedly secured to another channel buckstay spaced from channel buckstays 16 or 17 and provided with nested U-bend portions arranged as heretofore described and shown. The U-bend portions are disposed to extend within another recess formed in heat insulating refractory layer 14, which recess is disposed substantially midway between the aforementioned channel buckstay and channel buckstays 16 or 17. The U-bend portions are secured in the same manner as heretofore described, to two additional channel buckstays, similar to channel buckstays 24 and 25. In this manner, the total calculated differential linear expansion between the vapor-cooled wall and the liquid-cooled walls is divided between the two U-bend portions in each of the vapor-cooled tubular members 15 so that the total flexure of tubular members 15, at any U-bend is within allowable limits of stress.

The thickness of the layer of heat insulating refractory material 14 is determined by that amount of insulation necessary to maintain skin casing 29 of vapor-cooled wall 10 at substantially the same temperature as skin casing 37 and 37A of liquid-cooled walls 11 and 12 so that no differential expansion between casing 29 and the skin casings of the liquid-cooled walls exists, which differential expansion would cause buckling and/or fracture of the skin casings. The present invention also contemplates a construction wherein a layer of heat insulating refractory material is disposed between the skin casings of the liquid-cooled walls and the liquid-cooled tubular members associated with the walls. In this latter construction, the thickness of the heat insulating refractory layer 14 of vapor-cooled wall 10 would be greater than illustrated in the drawings, to maintain the skin casing of the vapor-cooled wall at substantial temperature as the casing adjacent the liquid-cooled tubes.

In Figures 5, 6, 7 and 8, a second embodiment of the present invention is shown wherein a vapor-cooled wall 40 of a vapor generator comprises one or more banks of vapor-cooled tubular members and one or more banks of liquid-cooled tubular members. As shown in Figs. 5, 6 and 7, vapor-cooled wall 40 comprises a bank of vapor-cooled tubular members 41 disposed between a bank of liquid-cooled tubular members 42 and a bank of liquid-cooled tubular members 43. Vapor-cooled tubular members 41 are arranged and supported in the same manner as vapor-cooled tubular members 15. Vapor-cooled tubular members 40 are secured to two spaced horizontally extending channel buckstays 44 and 45, similar to channel buckstays 16 and 17 by plates 46. Plates 46 are welded, or otherwise suitably secured, to channel buckstays 44 and 45 along one edge while tubular members 41 are secured, as by welding, to the opposite edge of plates 46. The U-bend portions 47 of each group of tubular members 41, similar to U-bend portions 21 of each group of tubular members 15, are secured at their apices to two spaced channel buckstays 48 and 49, similar to buckstays 24 and 25 of vapor-cooled wall 10, by means of plates 50 similar to plates 27. Plates 50 are secured along one edge, as by welding, to channel buckstays **48** and **49**, while tubular members **41** are secured, as by welding, to the opposite edge of plates **50** (see Fig. 7). As best shown in Fig. 8, channel buckstays **48** and **49** extend in a plane parallel with the plane of liquid-cooled tubular member **42** and **43** to a point adjacent the U-bend portions **47** of vapor-cooled tubular members **41**, at which point channel buckstays **48** and **49** extend away from the plane of liquid-cooled tubular members **42** and **43** and thence in a plane parallel to the plane of tubular members **42** and **43** to thereby provide space for a recess **51** in a heat insulating refractory layer **52** which forms a part of vapor-cooled wall **40**. The lower edge of recess **51** is downwardly inclined to permit slag, fly ash and soot to flow from recess **51**. U-bend portions **47** of tubular members **41** extend within recess **51**, in the same manner as U-bend portions **21** of tubular members **15** extend within recess **20** in heat insulating refractory layer **14** of vapor-cooled wall **10**.

A skin casing **53** is disposed against the outer surface of heat insulating refractory layer **52**, which casing **53** comprises a plurality of sections suitably secured in a fluid-tight manner, as by welding, to channel buckstays **44**, **45**, **48** and **49**, in the same manner as the casing sections of skin casing **29** of wall **10** are secured to channel buckstays **16**, **17**, **24** and **25** (see Fig. 6).

Tubular members **41** are slidably secured in a suitable manner (not shown) as by movable tie-bars, to one or more channel buckstays (not shown) disposed between channel buckstays **44** and **48** and between channel buckstays **45** and **49**. Liquid-cooled tubular members **42** and **43** are fixedly secured, as by welding, to the forementioned one or more channel buckstays (not shown), disposed between channel buckstays **44**, **45**, **48** and **49**.

As shown in Figs. 6 and 7, heat insulating refractory layer **52** extends between casing **53** and liquid-cooled tubular members **42** and **43**. The thickness of refractory layer **52**, adjacent liquid-cooled tubular members **42** and **43**, is less than its thickness adjacent vapor-cooled tubular members **41** so that the necessary amount of heat insulation is provided to maintain the sections of casing **53** adjacent vapor-cooled tubular members **41** at substantially the same temperature as the casing sections adjacent liquid-cooled tubular members **42** and **43**. Vapor-cooled wall **40**, adjacent the outer surface of casing **53**, is provided with a heat insulating layer **54** which is covered by a sheathing **55** of hard finish cement or metal. Heat insulating layer **54** adjacent the vapor-cooled and liquid tubular members is substantially uniform in thickness.

Liquid-cooled tubular members **42** and **43** are secured to and supported by channel buckstays **44**, **45**, **46** and **47** and one or more additional channel buckstays, not shown, by means of plates **56**. Each of the plates **56** are welded along one edge to the aforementioned channel buckstays and are welded to tubular members **42** and **43** along the opposite edge.

In the second embodiment hereindescribed, the differential linear expansion between vapor-cooled tubular members **41** and liquid-cooled tubular members **42** and **43** causes the legs of U-bend portions **47** of tubular members **41** to be compressed together so that expansion of vapor-cooled section of vapor-cooled wall **40** is that of the liquid-cooled tubular members **42** and **43**, thus permitting the use of a skin casing and eliminating the need for complicated and expensive slip joint connections between the vapor-cooled section and the liquid-cooled sections of wall **40**.

Vapor-cooled wall **40**, herein described, is integrally connected to abutting liquid-cooled walls which, with vapor-cooled wall **40**, defines a furnace chamber of a vapor generator.

It is contemplated in the present invention that instead of a skin casing adjacent liquid-cooled tubular members, the liquid-cooled tubular members may be provided with longitudinally extending fins which are welded to the next adjacent tubular member to thereby form a fin-tube type casing.

The present invention has application to a platen in a furnace chamber, which platen comprises vapor-cooled tubular members or a combination of vapor-cooled and liquid-cooled tubular members. In such application, fin or fin-tube type casings and layers of heat insulating refractory material, shown in the drawing are unnecessary. Any suitable means, other than channel buckstays, may be employed to secure the vapor-cooled tubes, at the U-bend portions and at points spaced on either side of the U-bend portions, against movement relative to the liquid-cooled tubes of the vapor geneartor. A platen constructed according to this invention eliminates the requirement for special support members to allow for differential expansion as in conventional platen structures.

From the foregoing description, a vapor-cooled wall for a vapor generator has been provided wherein differential linear expansion between the vapor-cooled tubes and the liquid-cooled tubes is effectively absorbed by the novel vapor-cooled tube form and arrangement thereby making skin and skin and fin-tube types of casings feasible. The vapor-cooled walls according to this invention obviates the necessity for complicated slip joints between vapor-cooled and liquid-cooled walls or wall sections. The invention also provides a vapor generator having a vapor-cooled wall wherein the tubular member support system is common to all the walls of the vapor generator.

Although but two embodiments of the invention have been illustrated and described in detail, it is to be expressly understood that the invention is not limited thereto. Various changes can be made in the arrangement of parts without departing from the spirit and scope of the invention, as the same will now be understood by those skilled in the art.

What is claimed is:

1. In a vapor generator having at least one vapor-cooled wall in combination with liquid-cooled walls, the vapor-cooled wall comprising at least one bank of vapor-cooled tubular members with the said tubular members thereof being arranged in parallel relationship to each other, each of said vapor-cooled tubular members having at least one loop portion disposed between the opposite ends of the tubular members, means for fixedly securing each of said tubular members at the loop portion against movement relative to said liquid-cooled walls, second means for fixedly securing each of said vapor-cooled tubular members at each side of the loop portion thereof against movement relative to said liquid-cooled walls whereby differential linear expansion between the vapor-cooled tubular members and the liquid-cooled walls compresses said loop portions of the vapor-cooled tubular members an amount equal to said differential linear expansion.

2. In the furnace of a vapor generator having at least one vapor-cooled wall in combination with liquid-cooled walls, the vapor-cooled wall comprising at least one bank of vapor-cooled tubes disposed in parallel relationship to each other, each of said vapor-cooled tubes having at least one integral U-bend portion disposed between the opposite ends of the tubes, means for fixedly securing each of said tubes at said U-bend portion against movement relative to said liquid-cooled walls, and second means for fixedly securing each of said tubes at each side of said U-bend portion against movement relative to said liquid-cooled walls whereby differential linear expansion or contraction between the vapor-cooled tubes is taken up by the U-bend portions, the spacing between the legs of said U-bend portions being of a dimension at least equal to the predetermined maximum differential expansion between the vapor-cooled tubes and liquid-cooled walls.

3. In the furnace of a vapor generator having at least one vapor-cooled wall in combination with liquid-cooled walls, the vapor-cooled wall comprising at least one bank

of vapor-cooled tubes disposed in parallel relationship to each other, each of said vapor-cooled tubes having at least one integral loop portion disposed between the opposite ends of the tube and extending normal to the longitudinal axes of the vapor-cooled tubes, means for fixedly securing and supporting each of said tubes at each of the loop portions against movement relative to said liquid-cooled walls, second means for fixedly securing and supporting each of said tubes at each side of the loop portion thereof against movement relative to said liquid-cooled walls whereby differential linear expansion or contraction between the vapor-cooled tubes and the liquid-cooled walls is taken up by the expansion or contraction of the loop portions.

4. In the furnace of a vapor generator having liquid-cooled and at least one vapor-cooled wall, the vapor-cooled wall comprising, a wall layer of heat insulating material, at least one bank of vapor-cooled tubular members disposed to extend parallel to said wall layer, said tubular members being arranged parallel to each other, each of said vapor-cooled tubular members being provided with at least one U-bend portion disposed between the opposite ends of the tubular members and extending normal to the longitudinal axes of the tubular members, means for fixedly securing and supporting each of said tubular members against movement at the apex of the U-bend portion of the tubular members, second means for fixedly securing and supporting each of said vapor-cooled tubular members against movement on each side of the U-bend portions whereby linear expansion of the vapor-cooled tubular members in excess of the linear expansion of the liquid-cooled walls compresses said U-bend portions.

5. The apparatus of claim 4 wherein the U-bend portions of each of the tubular members is dimensioned so that a U-bend portion of one tubular member lies within the U-bend portion of the adjacent tubular member.

6. In the furnace of a vapor generator having at least one vapor-cooled wall in combination with liquid-cooled walls, the vapor-cooled wall comprising a wall layer of heat insulating refractory material, at least one bank of vapor-cooled tubes disposed to extend vertically and parallel to said wall layer and with said tubes being arranged in parallel relationship to each other, each of said tubes being provided with at least one U-bend portion disposed between the opposite ends of the tubes and extending normal to the longitudinal axes of the tubes, means for fixedly securing and supporting each of said tubes at said U-bend portions against movement relative to said liquid-cooled walls, second means for fixedly securing each of said tubes at points spaced on either side of said U-bend portion against movement relative to said liquid-cooled walls, the spacing between the legs of said U-bend portion of each of the vapor-cooled tubes being of a dimension at least equal to the predetermined differential expansion between the vapor-cooled tubes and liquid-cooled walls.

7. In the furnace of a vapor generator having at least one vapor-cooled wall in combination with liquid-cooled walls, the vapor-cooled wall comprising a bank of vapor-cooled tubes disposed to extend vertically with the tubes being arranged in parallel relationship to each other, said bank of vapor-cooled tubes being divided into a first and second group of steam-cooled tubes, each tube of said first group of tubes being provided with at least one U-bend portion disposed between the opposite ends of the tubes and extending normal to the longitudinal axes of the tubes, said U-bend portions of each of the tubes of said first group of tubes being dimensioned so that a U-bend portion of one tube lies within the U-bend portion of the adjacent tube, each tube of said second group of tubes being provided with at least one U-bend portion disposed adjacent the U-bend portions of said first group of tubes, said U-bend portions of each of the tubes of said second group of tubes being dimensioned so that a U-bend portion of one tube lies within the U-bend portion of the adjacent tube, said U-bend portions of the tubes of said first and second group of tubes being offset from each other and disposed to extend in a plane parallel to the plane of the straight portions of the tubes of the other group of tubes, means for securing and supporting the tubes of said first and second groups of tubes at their respective U-bend portions against movement relative to the liquid-cooled walls, second means for securing the tubes of said first and second group of tubes at spaced points on either side of the U-bend portions against movement relative to the liquid-cooled walls, the space between the legs of the innermost U-bend of the tubes in the first and second group of tubes being of a dimension at least equal to the calculated differential linear expansion between the vapor-cooled tubes and the liquid-cooled walls.

8. In the furnace of a vapor generator having at least one steam-cooled wall in combination with water-cooled walls, the steam-cooled wall comprising a wall layer of heat insulating refractory material, said wall layer being secured to adjacent water-cooled walls, a bank of tubes disposed to extend vertically and parallel to said wall layer with the tubes arranged in parallel relationship with each other, said bank of steam-cooled tubes being divided into a plurality of groups of steam-cooled tubes, each tube of each group of tubes being provided with at least one U-bend portion disposed between the opposite ends of the tubes and extending normal to the longitudinal axes of the tubes, said U-bend portions of the tubes of each group of tubes being dimensioned so that a U-bend portion of one tube lies within the U-bend portion of the adjacent tube, a recess in the surface of said wall layer to provide a space between the straight portions of the tubes and the wall layer, the steam-cooled tubes being so formed that the U-bend portions thereof in each group of tubes lie within said recess between the surface of the recess and the straight portions of the next adjacent groups of tubes, means for securing and supporting the tubes of each group of tubes at the apex of their respective U-bend portions against movement relative to said water-cooled wall, and second means for securing and supporting the tubes of each group of tubes at points spaced from each side of their respective U-bend portions against movement relative to said water-cooled wall, the space between the legs of the innermost U-bend portion of each group of tubes being of a dimension substantially equal to the calculated maximum differential liner expansion between the steam-cooled tubes and the water-cooled walls.

9. The apparatus of claim 8 wherein a skin type casing is provided on the vapor-cooled and water-cooled walls.

10. In a furnace of a fluid heater, a vapor-cooled wall comprising at least one bank of vapor-cooled tubes and at least one bank of liquid-cooled tubes, said liquid-cooled and vapor-cooled tubes being arranged in parallel relationship to each other, said bank of vapor-cooled tubes being divided into at least two groups of vapor-cooled tubes, the tubes of each group of tubes being provided with at least one U-bend portion extending normal to the longitudinal axes of the vapor-cooled tubes, said U-bend portion of each tube in a group of tubes being dimensioned so that a U-bend portion of one tube lies within the U-bend portion of the next adjacent tube of the group of tubes, the tubes of each group of tubes being formed so that the U-bend portions of a group of vapor-cooled tubes lie in a plane adjacent to the plane of the straight portions of the vapor-cooled tubes, means for securing and supporting the liquid-cooled tubes, second means for securing the vapor-cooled tubes on each side of the U-bend portions of the vapor-cooled tubes against movement relative to said liquid-cooled tubes, and third means for securing the vapor cooled tubes at the U-bend portions against movement relative to the liquid-cooled tubes whereby differential linear expansion be-

tween the vapor-cooled tubes and liquid cooled tubes is taken up by compression of the U-bend portions of the vapor-cooled tubes.

11. In the furnace of a vapor generator having at least one vapor-cooled wall in combination with liquid-cooled walls, the vapor-cooled wall comprising a wall layer of heat insulating refractory material connected to the adjacent liquid-cooled walls, at least one bank of vapor-cooled tubes and at least one bank of liquid-cooled tubes disposed adjacent said wall layer, said liquid-cooled and vapor-cooled tubes being arranged in parallel relationship to each other, said bank of vapor-cooled tubes being divided into at least two groups with a plurality of tubes in each group, the tubes of each group of tubes being provided with at least one U-bend portion extending normal to the longitudinal axes of the tubes, said U-bend portion of each vapor-cooled tube in each group being dimensioned so that a U-bend portion of one tube lies within the U-bend portion of the next adjacent tube of the group of tubes, the tubes of each group of tubes being formed so the U-bend portions of a group of tubes lie in a plane between the surface of the wall layer and the straight portions of the tubes of the adjacent group of vapor-cooled tubes, means for securing and supporting the liquid-cooled tubes, second means for securing and supporting the vapor-cooled tubes of each group on each side of the U-bend portions of the vapor-cooled tubes, and third means for securing and supporting the vapor-cooled tubes at the U-bend portions against movement relative to said liquid-cooled tubes whereby differential linear expansion between the vapor-cooled tubes and liquid-cooled tubes is taken up by the compression of the U-bend portions of the vapor-cooled tubes.

12. The structure of claim 11 wherein said wall layer is provided with a recess in the inner surface thereof disposed adjacent the U-bend portions of said vapor-cooled tubes and adapted to receive said U-bend portions therein.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,981,241 April 25, 1961

Francis M. Barton

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, lines 69 and 70, strike out "such as a header (not shown), to receive vapor, as for example,"; column 7, line 5, for "member" read -- members --; line 33, for "44, 45, 48 and 49" read -- 44, 48, 45 and 49 --; column 8, line 13, for "geneartor" read -- generator --; column 10, line 39, for "groups" read -- group --.

Signed and sealed this 21st day of November 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

USCOMM-DC