May 8, 1962 W. F. C. SCHAAP 3,033,535

TUBULOUS HEAT EXCHANGERS

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Fig. 1.

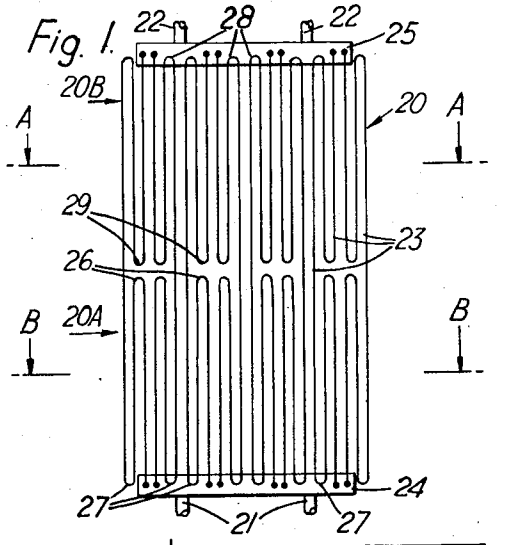


Fig. 2.

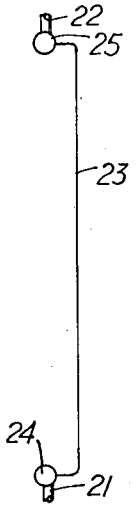
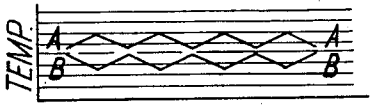


Fig. 3.



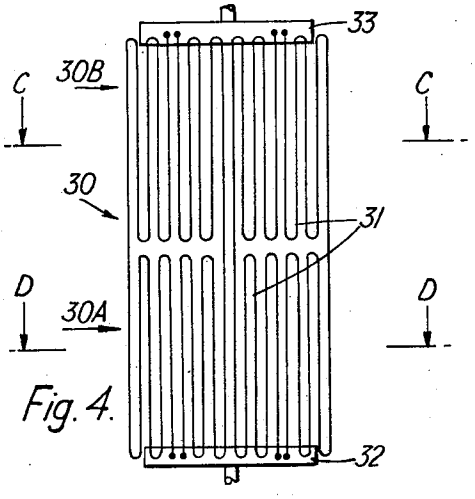


Fig. 4.

Fig. 5.

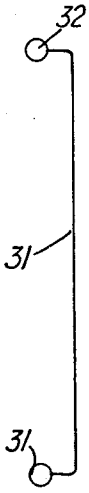
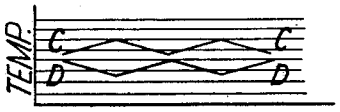


Fig. 6.



Inventor
Willem F.C. Schaap

By J. P. Moran
Attorney

May 8, 1962 W. F. C. SCHAAP 3,033,535

TUBULOUS HEAT EXCHANGERS

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Fig. 7.

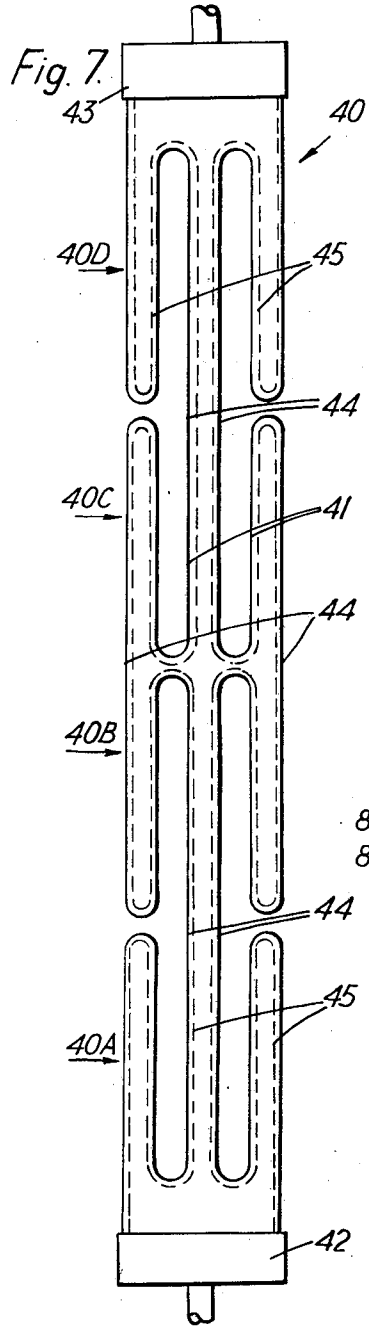


Fig. 13.

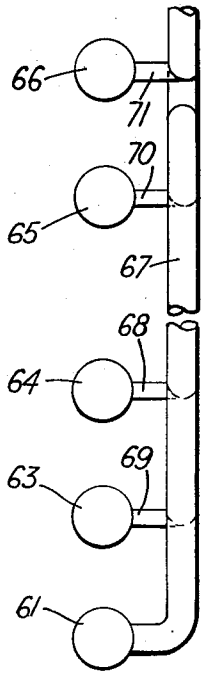


Fig. 16.

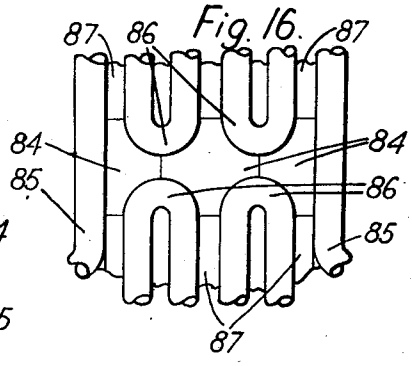


Fig. 15.

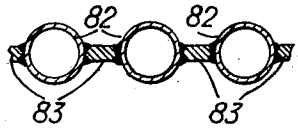
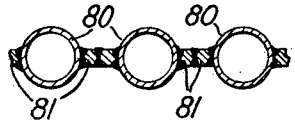


Fig. 14.



Inventor

Willem F.C. Schaap

By J. P. Moran

Attorney

May 8, 1962 W. F. C. SCHAAP 3,033,535

TUBULOUS HEAT EXCHANGERS

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Fig. 8.

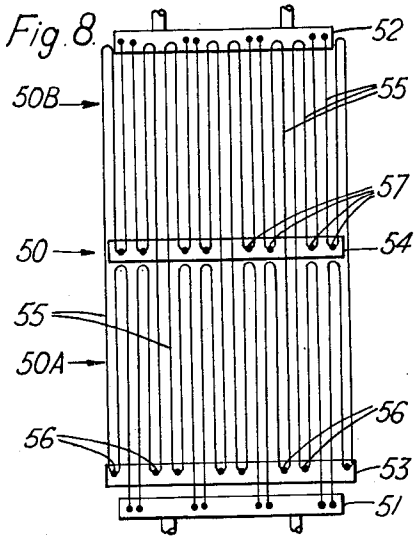


Fig. 9.

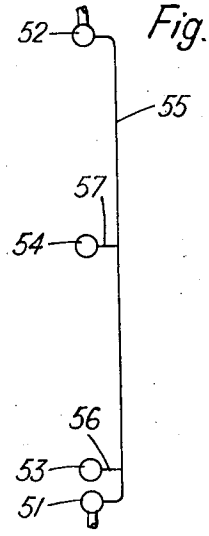


Fig. 10.

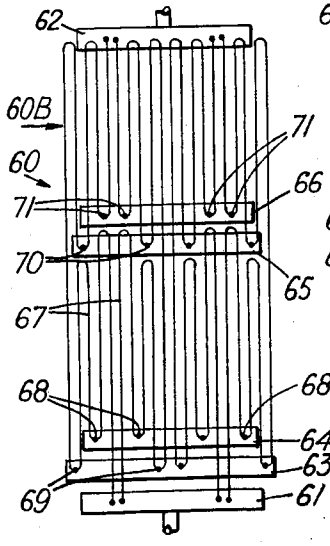


Fig. 11.

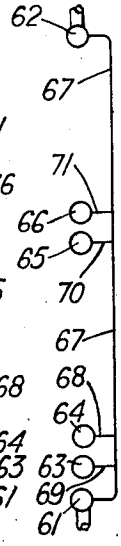
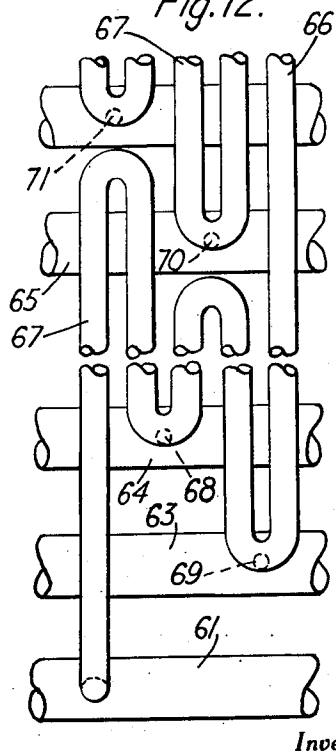


Fig. 12.



Inventor

Willem F. C. Schaap

By J. P. Moran

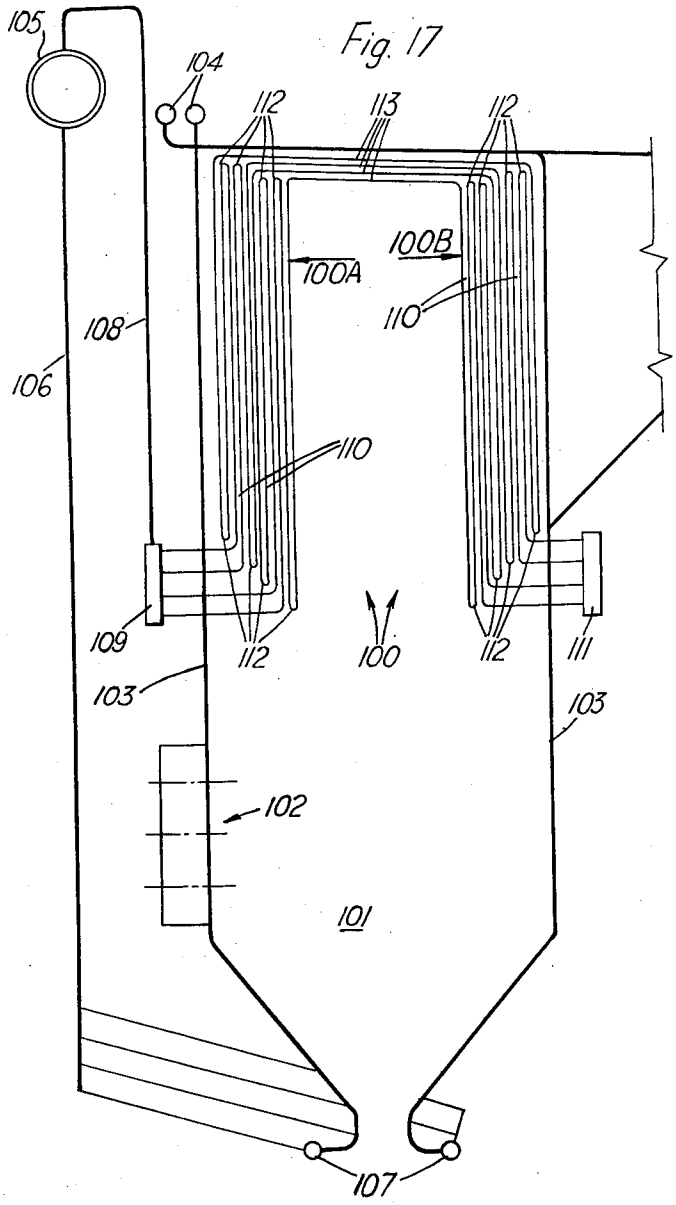
Attorney

May 8, 1962 W. F. C. SCHAAP 3,033,535

TUBULOUS HEAT EXCHANGERS

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Fig. 17



Inventor
Willem F.C. Schaap
By J. P. Moran
Attorney

United States Patent Office 3,033,535 Patented May 8, 1962

3,033,535

TUBULOUS HEAT EXCHANGERS

Willem F. C. Schaap, London, England, assignor to Babcock & Wilcox Limited, London, England, a British company

Filed June 25, 1958, Ser. No. 744,468
Claims priority, application Great Britain June 28, 1957
8 Claims. (Cl. 257—248)

This invention relates to tubulous heat exchangers.

In the art of steam generation for the purpose of supplying power from central electricity generating stations, modern developments have led to progressively higher steam pressures and temperatures and to steam generating and heating units of progressively greater size.

Frequently, in steam generating and heating units, a construction in which adjacent tube lengths are united by welding is advantageous, for example, for the purpose of increasing rigidity or facilitating positioning or in order to make a gas-tight wall. The difficulty then arises, however, that if the tube lengths are series connected differential expansions and contractions of the tube lengths may introduce stresses greater than can be tolerated.

A large part of the cost and time involved in the manufacture of a large modern central station boiler is due to site erection and any steps enabling reduction of work on site are of great practical value. This is particularly true of welding which can usually be accomplished more economically and effectively under shop conditions.

The present invention is concerned with the provision of an improved construction and arrangement of a tube wall comprising prefabricated tubular panel sections each of which is formed of tube portions, each tube portion having an odd number of limbs parallel to one another and connected by fluid return means so that each limb is connected to an adjacent limb by a return bend or to the adjacent limbs by respective return bends and the adjacent limbs are united by welding, and, at site, constructing the wall of panels each formed of tubular panel sections connected for series flow of fluid therethrough.

Advantageously in carrying out the invention, panels are connected for the parallel flow therethrough of the fluid to be heated and are arranged for the passage, through neighbouring limbs in adjacent panel sections of different panels, of fluid at approximately the same mean temperature and the said limbs are united by welding.

When the wall is required to be of gas-tight construction an external metal casing of gas-tight construction may be provided in suitable known manner but, advantageously, the adjacent limbs of each panel section, the adjacent ends of panel sections of each panel, and the adjacent limbs of panel sections of different panels are united by welding to form a gas-tight wall.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings in which:

FIGURE 1 is a diagrammatic view showing a tubulous panel of a furnace wall of a forced-flow once-through steam generator.

FIGURE 2 is a side view corresponding to FIGURE 1.

FIGURE 3 is a graph showing the temperatures along the lines A—A and B—B of FIGURE 1.

FIGURE 4 is a diagrammatic view showing an alternative form of furnace wall panel.

FIGURE 5 is an end elevation corresponding to FIGURE 4.

FIGURE 6 is a graph showing the temperatures along the lines C—C and D—D of FIGURE 4.

FIGURE 7 is a diagrammatic view showing an elongated form of furnace wall panel.

FIGURE 8 is a diagrammatic view showing another alternative form of furnace wall panel.

FIGURE 9 is an end elevation corresponding to FIGURE 8.

FIGURE 10 is a diagrammatic view showing a further alternative form of furnace wall panel.

FIGURE 11 is an end elevation corresponding to FIGURE 10.

FIGURE 12 is a fragmentary detail view of part of the furnace wall panel shown in FIGURES 10 and 11.

FIGURE 13 is an end elevation corresponding to FIGURE 12.

FIGURES 14, 15 and 16 are fragmentary views showing details of the gas-tight formation of furnace wall panels; and,

FIGURE 17 is a diagrammatic elevation of a steam generator incorporating superheater platens.

Referring to FIGURES 1 to 3 of the drawings, tubulous panel **20** is for incorporation in a furnace wall of a forced-flow steam generator. In such a wall a series of panels each of which extends the height of the furnace wall, lie in side-by-side relationship to occupy the wall length. The panels are fed from an economiser (not shown) through conduits **21** and deliver high temperature water or steam to a steam and water drum (not shown) through conduits **22**. Each wall panel comprises tubes **23** which extend between an inlet header **24** and an outlet header **25** to form lower and upper heat exchange sections **20A** and **20B**, respectively. Each tube **23** of the panel comprises three limbs in each section. The first or inlet limb in the lower panel section extends upwardly from inlet header **24** to an intermediate return bend **26**, the second or mid limb extends downwardly from return bend **26** to a lower return bend **27**, and the third limb extends upwardly from return bend **27** and is formed in one with or welded to the inlet limb of the upper panel section. This upper inlet limb extends upwardly to an upper return bend **28**, the second or mid limb of the upper panel section extending downwardly to an intermediate return bend **29** and the third limb extending from return bend **29** upwardly in line with the first limb of the lower panel section to outlet header **25**. Thus parallel flow of fluid takes place from header **24**, through tubes **23** to header **25**.

As can be seen from FIGURE 3, the temperatures of the outer tubes of the panel are similar. Thus, when adjacent panels are rigidly interconnected, no serious distortion due to temperature difference will occur at panel junctions. Also as the temperature variation across each panel is gradual, only slight stress due to temperature difference will occur between adjacent tubes of each panel which are also rigidly interconnected as hereinafter described.

Referring now to panel **30** shown in FIGURES 4 and 5, tubes **31** have five limbs in each of the lower and upper sections **30A** and **30B**, respectively. Each tube extends upwardly from inlet header **32**, then downwardly, then upwardly, then downwardly and again upwardly to meet or continue as the inlet limb of a tube of the upper section, which limb extends upwardly, then downwardly, then upwardly, then downwardly and again upwardly to outlet header **33**.

FIGURE 6 shows again that the temperature difference between adjacent tubes or between adjacent panels will not be sufficient to cause harmful distortion due to thermal expansion or contraction of rigidly interconnected adjacent tubes.

FIGURE 7 illustrates a wall panel **40** having four upright sections **40A**, **40B**, **40C** and **40D** connected in series one above another. The tubes **41** have three limbs in each section and the tubes may extend continuously from inlet header **42** to outlet header **43** or tube lengths may be welded together at the junctions **44** between the sections. A second pair of tubes **45** (shown in broken lines) may

be incorporated in the panel, tubes 41 and 45 being nested together, and if desired more than two tubes may be nested together.

FIGURES 8 and 9 illustrate a wall panel 50 having inlet and outlet headers 51 and 52, respectively, and also having draining and equalising headers 53 and 54. Tubes 55 are formed with three limbs in the lower section 50A and in the upper section 50B. Each lower return bend of the lower section has a connection 56 with header 53 and each lower return bend of the upper section has a connection 57 with header 54. Thus, for each tube of each panel there is a single return bend at the lower end of the lower panel section and a single return bend at the lower end of the upper panel section. The tubulous furnace wall, therefore, is provided with one draining and equalising header 53 extending horizontally adjacent the bottoms of the lower sections of the panels constituting the wall and a second draining and equalising header 54 extending horizontally adjacent the lower ends of the upper sections of the panels constituting the wall. Also the headers 53 and 54 rigidify the structure, and sets of headers may be used in the formation of buck stays.

FIGURES 10, 11, 12 and 13 illustrate a wall panel 60 having inlet and outlet headers 61 and 62, respectively, and also having draining and equalising headers 63, 64, 65 and 66. Tubes 67 of the five limb type extend upwardly in section 60A from header 61, then downwardly for connection through pipes 68 to header 64, then upwardly, then downwardly for connection to header 63 through pipes 69, then upwardly to upper section 60B and downwardly for connection through pipes 70 to header 65, then upwardly, then downwardly for connection through pipes 71 to header 66 and again upwardly for connection to header 62. The various connections can be clearly seen from FIGURES 12 and 13 which show a part of the right-hand end of the panel shown in FIGURE 10.

In many cases the panel sections will be similar as regards length and the number of limbs and the internal and external diameters thereof. However, the tube diameters in different sections of a panel may be varied in order to change the rate of flow of the fluid in passing through the panel. Alternatively, the number of tube limbs in the sections of a panel may be varied. For example, at a location where a tube panel is subjected to a reduced degree of radiation, a smaller number of tube limbs more widely spaced may be employed, and fins (hereinafter described) on the tube limbs will be of correspondingly increased width. Instead of or in addition to increasing the fin width, the diameters of the tubes may be increased. Moreover, the number of tubes in adjacent sections of a panel may be varied by the use of bifurcations.

The panels described above are used as gas-tight furnace walls and spaces between the tubes are filled by a web of metal welded between the tubes. In one form, as shown in FIGURE 14 each tube 80 has a pair of opposed radial fins 81 welded along its length and, in the panel, the fins of adjacent tubes are welded together. In another form, as shown in FIGURE 15, alternate tubes 82 across a section are formed with a pair of opposed radial fins 83 and, in the panel, the fins 83 are welded to adjacent tubes. In one convenient manner of manufacture of tubes for use in the fabricating panels in accordance with the invention, a tube (82) is formed with spaced lengths of opposed fins (83) so that when the tube is deformed to lie in a series of parallel lengths the fins fill the intertube regions.

At the return bends the opposed fins are interrupted and the intertube regions are filled by shaped webs. Thus, as shown in FIGURE 16, three shaped webs 84 are welded in position between tubes 85, return bends 86 and fins 87.

The invention has so far been described as embodied in a furnace wall panel. However, FIGURE 17 shows a

steam superheater 100 in accordance with the invention. In FIGURE 17 a natural circulation steam generator has a furnace chamber 101 fired by burners 102. The furnace walls comprise rows of upright tubes 103. Tubes 103 feed to headers 104, being themselves fed from steam and water drum 105 through downcomer 106 and headers 107. The mixture of water with steam generated in the wall tubes and/or other tubulous heat exchanger means of the generator, is fed to drum 105 through conduits (not shown). From drum 105 steam is fed through conduits 108 and header 109 to the superheater tubes 110 and superheated steam feeds to header 111 for delivery to a point of use or for further heating.

The superheater itself comprises two sections 100A and 100B and in each section tubes 110 each have three upright limbs interconnected by return bends 112, the tubes of one section extending in transverse lengths 113 to the other section. In each section the adjacent tube limbs of neighbouring tubes are "inlet" limbs or "outlet" limbs and conduct steam in the same direction. In the superheater, the adjacent limbs may be rigidly interconnected at the top and bottom of their upright lengths by welding or may be interconnected throughout a greater part of their lengths.

In manufacture, a great part of the welding associated with the tube panels or platens may be accomplished by automatic welding machinery in a factory under closely controlled conditions and the parts, after welding, may be subjected to suitable heat treatment. The panels or platens or parts thereof, provided their size is suitably limited, are readily transportable and the prefabrication of substantial areas of a tube wall or other part of a heat exchanger greatly facilitates and expedites the erection at site.

What is claimed is:

1. In a forced circulation fluid heating unit, a tube panel subject to high temperature heating gases comprising a pair of vertically contiguous tubular sections, each tubular section comprising groups of upright tubes secured to each other along at least a portion of the lengths thereof, with each group of tubes of one of said tubular sections connected for series flow of fluid to a corresponding vertically contiguous group of tubes in the other of said tubular sections, each group including an odd number of tubes connected for series flow of fluid and of which one tube is arranged for initial upflow of fluid and has a lower inlet end, another tube is arranged for final upflow of fluid and has an upper discharge end, and still another tube is arranged for downflow of fluid and positioned between said upflow tubes, with the initial upflow tubes of adjacent tube groups of said one tubular section disposed next adjacent each other and with the final upflow tubes of adjacent tube groups of said other tubular section disposed next adjacent each other, and means supplying fluid in parallel flow relation to the lower inlet ends of the initial upflow tubes of the tube groups of said one tubular section.

2. In a forced circulation fluid heating unit, a tube panel subject to high temperature heating gases comprising a pair of vertically contiguous coplanar tubular sections, each tubular section comprising laterally adjacent groups of upright closely spaced parallel tubes secured to each other along at least a portion of the lengths thereof, with each group of tubes of one of said tubular sections connected for series flow of fluid to a corresponding vertically contiguous group of tubes in the other of said tubular sections, each group including an initial upflow leg having a lower inlet end, a second upflow leg having an upper discharge end, and a downflow leg positioned between said upflow legs and connected by return bend tube portions for series flow of fluid from said initial upflow leg and to said second upflow leg, with the initial upflow legs of adjacent tube groups of said one tubular section disposed next adjacent each other and with the

second upflow legs of adjacent tube groups of said other tubular section disposed next adjacent each other, and means supplying fluid in parallel flow relation to the lower inlet ends of the initial upflow legs of the tube groups of said one tubular section.

3. In a forced circulation fluid heating unit, a tube panel subject to high temperature heating gases comprising a pair of vertically contiguous coplanar tubular sections, each tubular section comprising laterally adjacent groups of tubes secured to each other along at least a portion of the lengths thereof, with each group of tubes of one of said tubular sections connected for series flow of fluid to a corresponding vertically contiguous group of tubes in the other of said tubular sections, each group including an odd number of tubes connected by return bend tube portions for series flow of fluid and of which one tube is arranged for initial upflow of fluid and has a lower inlet end, another tube is arranged for final upflow of fluid and has an upper discharge end, and still another tube is arranged for downflow of fluid and positioned between said upflow tubes, with the initial upflow tubes of adjacent tube groups of said one tubular section disposed next adjacent each other and with the final upflow tubes of adjacent tube groups of said other tubular section disposed next adjacent each other, means supplying fluid in parallel flow relation to the lower inlet ends of the initial upflow tubes of the tube groups of said one tubular section, header means at the lower end of each of said tubular sections, and means connecting the return bend tube portions at the lower end of each of said tubular sections to the corresponding header means.

4. In a forced circulation once-through fluid heating unit, a tube panel subject to high temperature heating gases comprising a pair of vertically spaced coplanar tubular sections, each tubular section comprising laterally adjacent groups of upright closely spaced parallel tubes secured to each other along at least a portion of the lengths thereof, each group including an odd number of tubes connected for series flow of fluid and of which one tube is arranged for initial upflow of fluid and has a lower inlet end, another tube is arranged for final upflow of fluid and has an upper discharge end, and still another tube is arranged for downflow of fluid and positioned between said upflow tubes, with the initial upflow tubes of adjacent tube groups of one of said tubular sections disposed next adjacent each other and with the final upflow tubes of corresponding vertically adjacent tube groups of the vertically adjacent tubular section disposed next adjacent each other, the final upflow tube of each group of said one tubular section being connected for series flow of fluid to the initial upflow tube of the corresponding vertically adjacent group in the next vertically adjacent tubular section, and means supplying a vaporizable fluid in parallel flow relation to the lower inlet ends of the initial upflow tubes of the tube groups of said one tubular section.

5. In a forced circulation fluid heating unit, a tube panel subject to high temperature heating gases including a pair of vertically adjacent tubular sections; each tubular section comprising laterally adjacent groups of upwardly extending tubes which are rigidly secured to each other along at least a portion of the lengths thereof; each group of tubes including an initial upflow tube, a second upflow tube, and a downflow tube positioned between said upflow tubes and connected by return bend tube portions for series flow of fluid from said initial upflow tube and to said second upflow tube; means for interconnecting the second upflow tubes of said one tubular section to the initial upflow tubes of the other tubular section; and means for supplying a vaporizable fluid in parallel flow relation to the initial upflow tubes of said one tubular section.

6. In a forced circulation fluid heating unit, a tube panel subject to high temperature heating gases including a pair of vertically adjacent tubular sections; each tubular section comprising laterally adjacent groups of upwardly extending tubes which are rigidly secured to each other along at least a portion of the lengths thereof; each group of tubes including an initial upflow tube, a final upflow tube, and a downflow tube positioned between said upflow tubes and connected by return bend tube portions for series flow of fluid from said initial upflow tube and to said final upflow tube, with the initial upflow tubes of laterally adjacent tube groups of one tubular section disposed next adjacent each other and with the final upflow tubes of laterally adjacent tube groups of the other tubular section disposed next adjacent each other; means for interconnecting the final upflow tubes of said one tubular section to the initial upflow tubes of the other tubular section; and means for supplying a vaporizable fluid in parallel flow relation to the initial upflow tubes of said one tubular section.

7. In a forced circulation fluid heating unit, a tube panel subject to high temperature heating gases including upper and lower vertically adjacent tubular sections; each tubular section comprising laterally adjacent groups of upwardly extending closely spaced parallel tubes which are rigidly secured to each other along at least a portion of the lengths thereof; each group of tubes including an initial upflow tube, a second upflow tube, and a downflow tube positioned between and next adjacent to said upflow tubes and connected by return bend tube portions for series flow of fluid from said initial upflow tube and to said second upflow tube; means for interconnecting the second upflow tubes of the lower tubular section to the initial upflow tubes of the upper tubular section; means for supplying a vaporizable fluid in parallel flow relation to the initial upflow tubes of the lower tubular section; header means at the lower end of each of said tubular sections; and tubular fluid conducting means connecting the return bend tube portions at the lower end of each of said tubular sections to the corresponding header means.

8. In a forced circulation fluid heating unit, a tube panel subject to high temperature heating gases including upper and lower vertically adjacent tubular sections; each tubular section comprising laterally adjacent groups of upright closely spaced parallel tubes which are rigidly secured to each other along at least a portion of the lengths thereof; each group of tubes including an initial upflow tube, a final upflow tube, and a downflow tube positioned between and next adjacent said upflow tubes and connected by return bend tube portions for series flow of fluid from said initial upflow tube and to said final upflow tube, with the initial upflow tubes of laterally adjacent tube groups of the lower tubular section disposed next adjacent each other and with the second upflow tubes of laterally adjacent tube groups of the upper tubular section disposed next adjacent each other; means for interconnecting the final upflow tube of each tube group of the lower tubular section to the initial upflow tube of the overlying tube group of the upper tubular section; means for supplying a vaporizable fluid in parallel flow relation to the initial upflow tubes of the lower tubular section; header means at the lower end of each of said tubular sections; and tubular fluid conducting means connecting the return bend tube portions at the lower end of each of said tubular sections to the corresponding header means.

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