Sept. 10, 1968 R. BAGLEY ETAL 3,400,689

VAPOUR GENERATORS

Filed Aug. 25, 1966 6 Sheets-Sheet 1

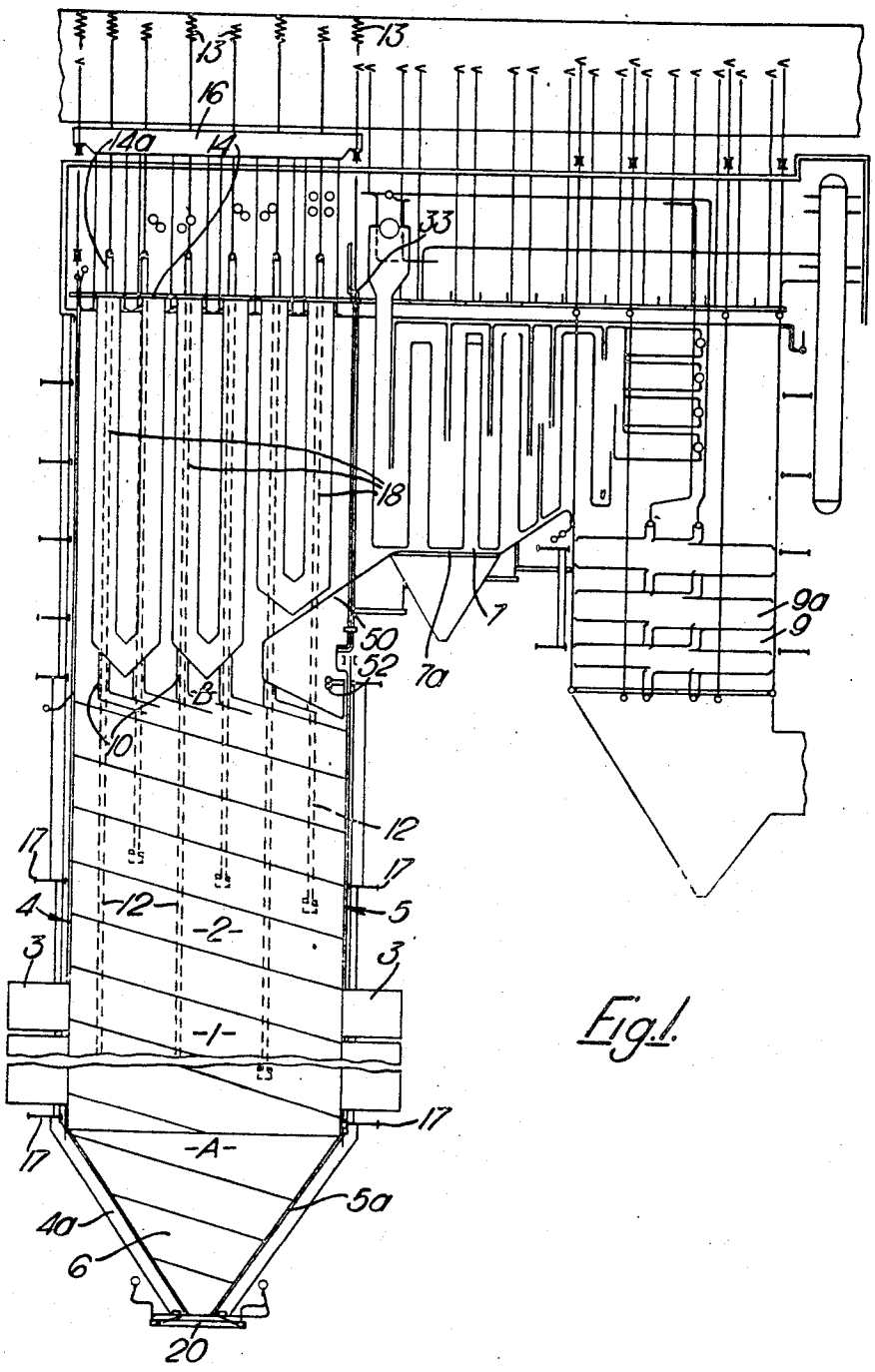


Fig.1.

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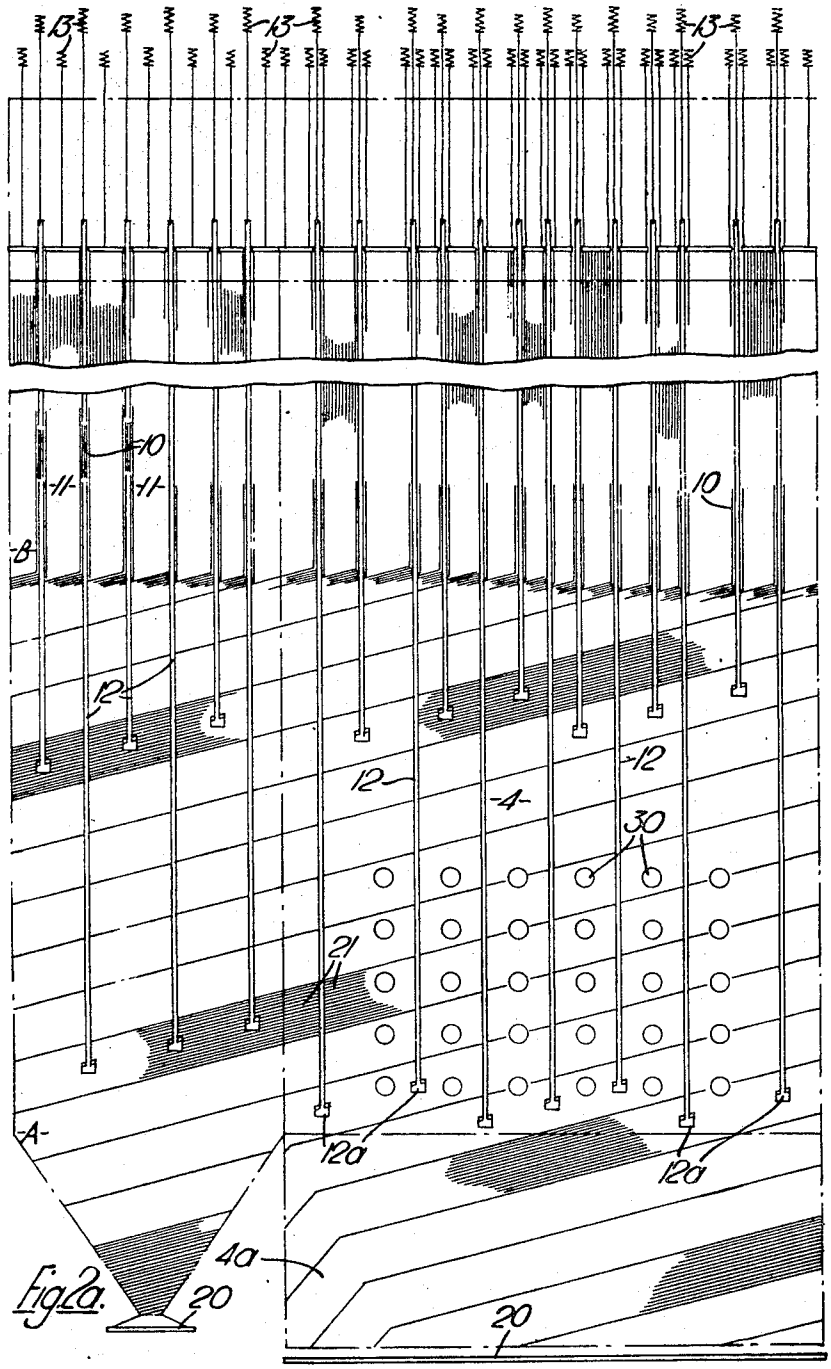


Fig 2a.

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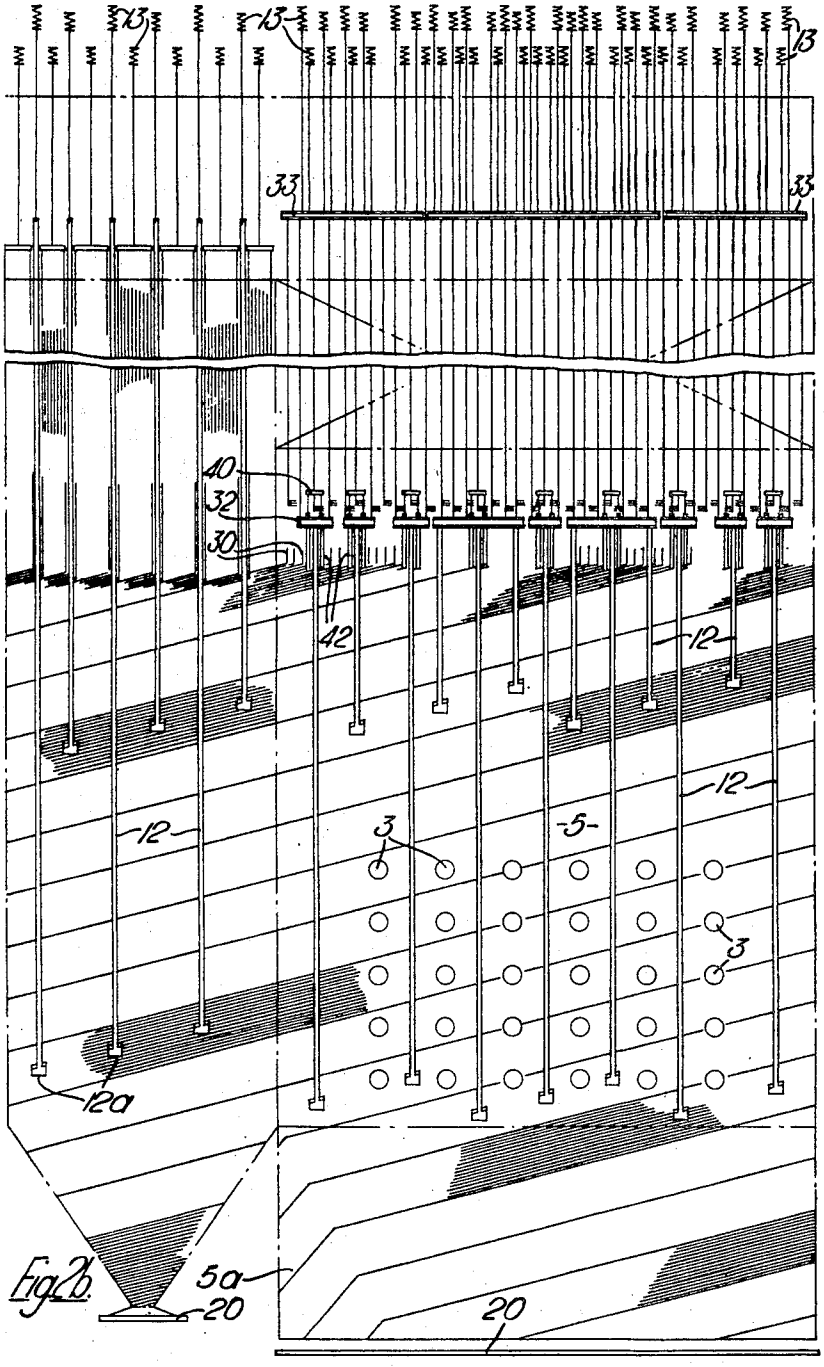


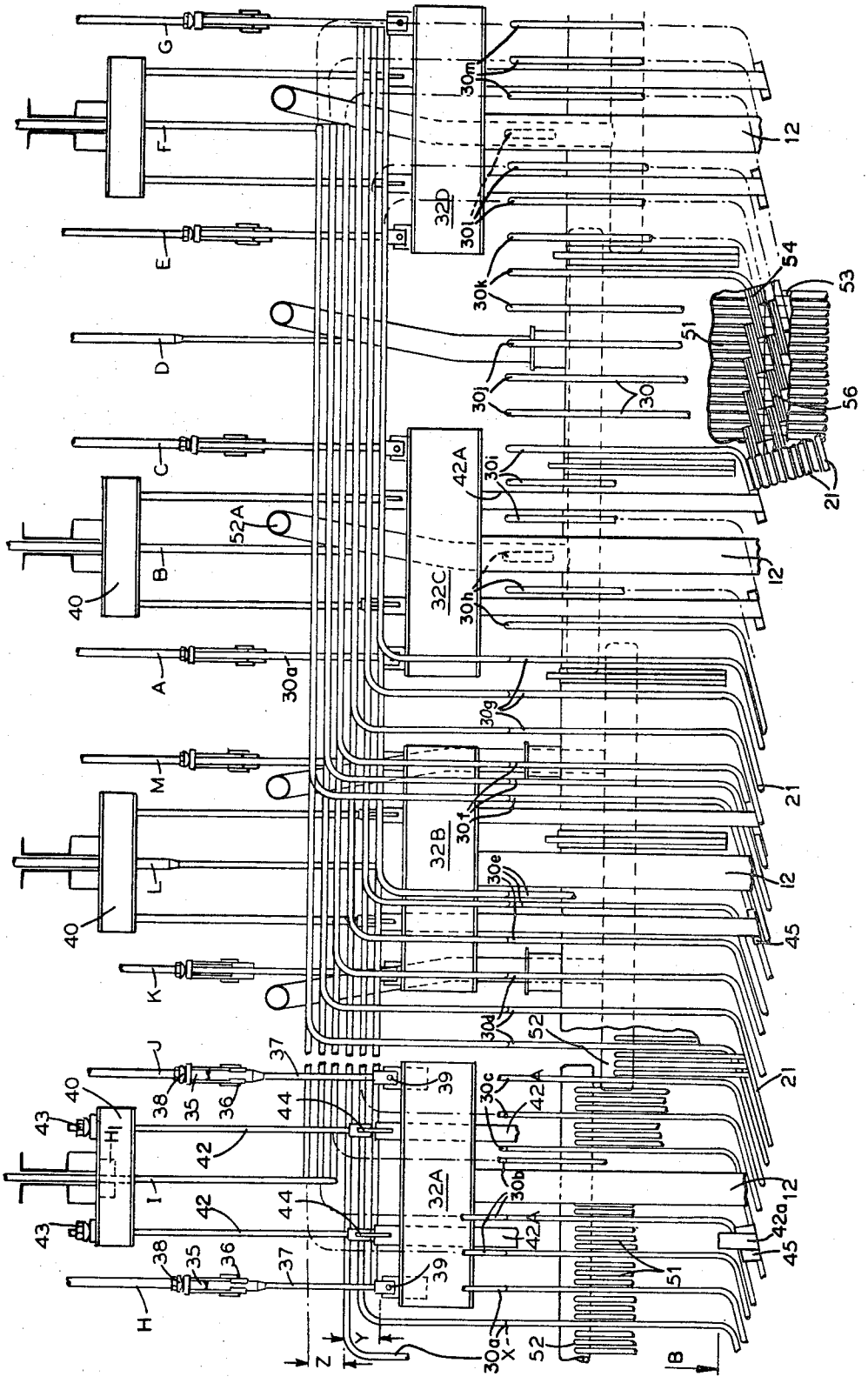
Fig. 2b.

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FIG.3

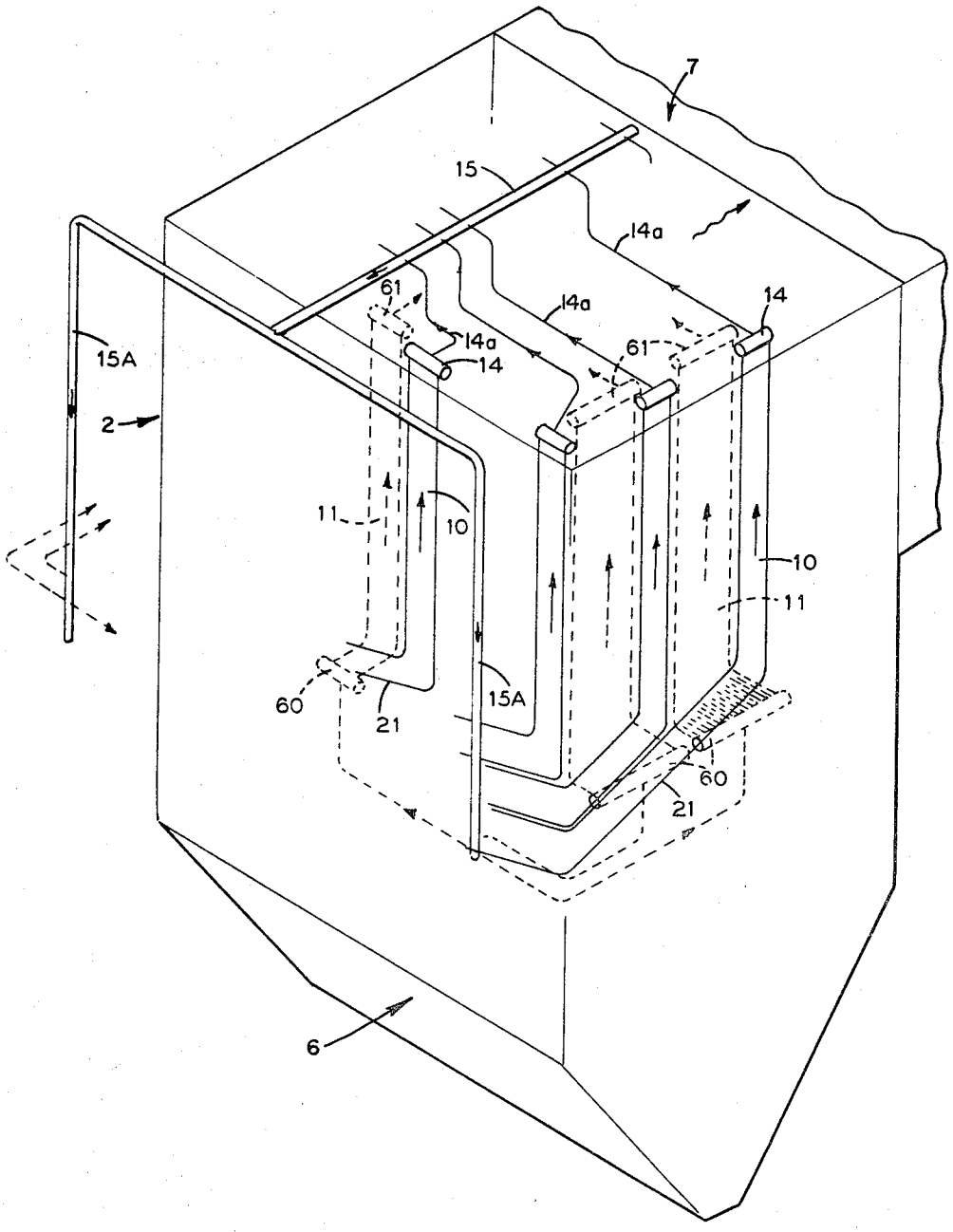


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FIG. 4



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FIG. 5

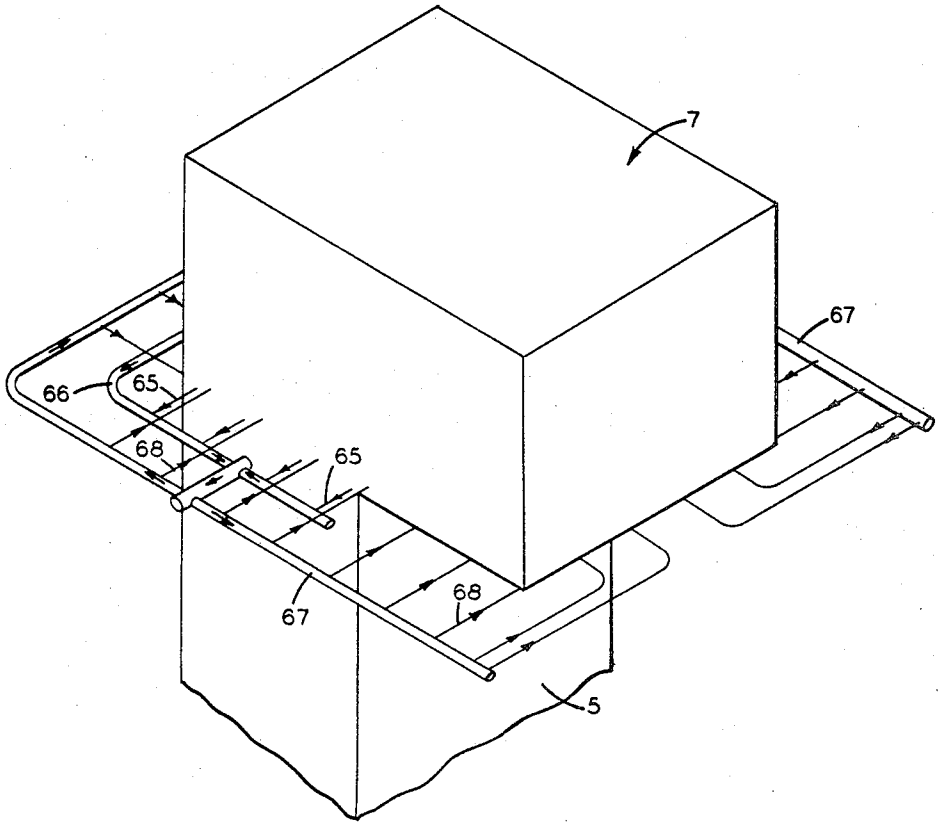
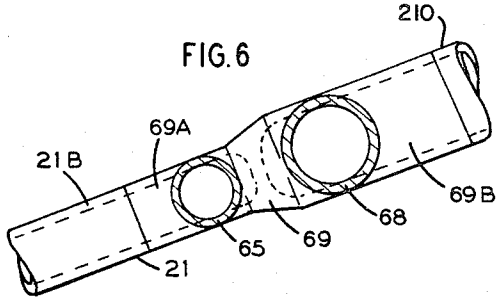


FIG. 6



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3,400,689

VAPOUR GENERATORS

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12 Claims. (Cl. 122—510)

ABSTRACT OF THE DISCLOSURE

A forced flow vapour generator having upwardly inclined tubes in the lower portion and upright tubes in the upper portion with the tubes supported by straps from above. The real wall of the furnace is provided with inclined tubes terminating adjacent the level of the lower boundary of a gas outlet with the upright tube extensions arranged in groups arranged axially of gas flow through the gas outlet and supported from above.

This invention relates to once-through, forced flow boilers and is especially concerned with boilers of this sort in which a gas pass is lined by a membrane wall, i.e., a wall in which tubes are connected together side-by-side to provide a gas tight membrane.

One of the problems arising in the design of such walls is to ensure that the tubes are adequately cooled, even at low loads and several proposals have been made for dealing with this problem.

In one proposal, a wall is formed by vertical tubes connected in parallel to form a single pass. In order to ensure that even at low loads the mass flow is sufficient to cool the tubes adequately, the internal diameter of the tubes must be small. Not only is it expensive to manufacture such tubes to sufficiently close tolerances but even a thin internal deposit would significantly increase the pressure drops occurring in them.

In an attempt to enable tubes of large diameter to be used it has been proposed that, to ensure adequate cooling of the tubes, at lower loads, say below 70% MCR, some of the fluid that has passed through the tubes should be recirculated through them. However, the lower mass flow at MCR leads to higher metal temperatures in the furnace; the tubes therefore operate at temperatures close to oxidation limits so that better quality tubes are necessary.

In a further attempt to enable tubes of larger diameter to be used, it has been proposed that they should form three passes, the tubes of one pass alternating with the tubes of the second pass and the tubes of both passes lying below the tubes of the third pass. In this arrangement, however, provision, which is expensive, must be made for mixing and this provision requires that the furnace should be operated at supercritical pressure with the consequent need for the feed pumps to operate against closed valves and for a flash tube to which the fluid flow can be diverted during start-up through reducing valves.

A disadvantage common to all these arrangements lies in the fact that the tubes are not all uniformly heated since the tubes at the corners of a gas-pass of rectangular cross-section will tend to be less highly heated than tubes extending along the middles of the sides of the gas pass.

According to the present invention, there is provided a once-through, forced-flow vapour generator having a length of upright gas pass bounded by a membrane lining formed from tubes connected for parallel flow and having the spaces between the tubes closed, wherein each tube extends generally laterally of the length of gas pass and rises generally continuously.

In such a generator, the length of the tubes is not dictated by the upright gas pass in which they are contained.

Some degree of freedom in the choice of tube size is thus possible, by variation of tube angle and membrane width, so that the tube size can be chosen to reconcile heat pick-up requirements with economic factors. Moreover, the fluid rises continuously in its passage through the lining tubes.

By way of example, an embodiment of the invention will now be described with reference to the accompanying drawings in which—

FIGURE 1 shows somewhat diagrammatically a vertical section through a once-through, forced-flow vapour generator and superheater;

FIGURES 2*a* and 2*b* form a diagram showing the walls of the upright furnace chamber of this generator developed into a single plane;

FIGURE 3 is a detail on an enlarged scale seen from the rear, of a typical tube arrangement of the upper end of the rear wall of the furnace chamber.

FIGURE 4 is a perspective diagram illustrating certain details of the front and one of the side walls of the vapour generator;

FIGURE 5 is a perspective diagram illustrating certain details of the rear wall, lateral gas pass and one of the side walls of a modified form of the vapour generator; and

FIGURE 6 illustrates a tube connection included in the modification shown in FIGURE 5.

The once-through, forced-flow vapour generator and superheating unit illustrated in FIGURES 1 and 2 includes a furnace chamber **1** forming the lower end of an upright gas pass **2** and fired by thirty circular burners, such as **3**, in each of the front and rear walls, **4** and **5**, of the gas pass **2**. The lower end of the gas pass **2** ends in a hopper bottom **6**, the front and rear walls **4***a* and **5***a* of which are convergent whilst the side walls are parallel.

A lateral gas pass **7** containing reheater tubes **7***a* extends from the upper end of the rear wall **5** and discharges combustion gases into the downpass **9** containing economiser tubes **9***a*. The walls of the gas pass **2** are lined, in a manner that will be described in more detail later, up to the level of the inlet to the lateral gas pass **7** by finned tubes that extend generally laterally but rise generally continuously. At the level of the inlet to the lateral gas pass **7** each of these tubes is connected to a vertical tube, the vertical tubes in the front and side walls being arranged side-by-side in groups **10**. Each group **10** of tubes discharges into a header **14** (see FIGURE 4) and each header **14** is connected by means of a conduit **14***a* to a collector **15** extending centrally across the top of the gas pass. Conduits **14***a* extending towards each other from opposite sides of the gas pass are tied together, as is more clearly described in our co-pending application S.N. 575,157, and in this way they serve to withstand the pressures within the gas pass. The spaces between the groups **10** are filled by further groups **11** (see FIGURES 2 and 4) of vertical tubes, the tubes of the group **11** being supplied with fluid from the collector **15**.

The front and side walls are suspended by means including vertical tension members **12** lying outside the boundary walls of the gas pass **2**, being connected at their lower ends to the walls and supported by springs **13** at their upper ends. Each support strap or tension member **12** associated with the front and side walls lies alongside one of the groups **10** of vertical tubes. Similar tension members are associated with the rear wall in a manner that will be described in more detail later.

The support straps extend alongside the tube lining. internally of lagging, and are supported by a system of buckstays outside the lagging. The system includes horizontal buckstays **17** connected to the transversely extend-

ing tubes of the tube lining so that the tubes themselves withstand the forces urging opposed buckstays apart.

Platens of U-shaped superheater tubes **18** are suspended in the upper end of the pass, depending from beams **16** connected to certain of the springs **13**.

Inlet headers **20** are arranged around the lower end of the hopper **6**, a space being left at the lower end through which gases may be recirculated. Tubes rise from the headers **20** to line the hopper **6** and each of these tubes leads to a tube **21** extending from the level A to the level B. The tubes **21** are controlled-bore tubes of 1½" outer diameter on a 2 inch pitch, the spaces between the tubes being closed by fins welded together along their edges. Between the levels A and B, each tube **21** encircles the gas pass more than once and rises continuously, at an angle of 15° to the horizontal, except where the routes of the tubes must be modified to accommodate the burners **3**.

At the level B, each of the inclined tubes **21** leads to a generally vertically extending tube. These vertically extending tubes discharge into a common collector and then flows in a second pass through the further tubes, disposed in groups **11** between the vertical tubes in the front and side walls, as will be described with reference to FIGURE 4. A typical arrangement of the vertically extending tubes in the rear wall will now be described in more detail with especial reference to FIGURE 3.

At the level B, each of the tubes **21** that terminates in the rear wall is connected to an upright tube **30** (see FIGURE 3), the lower ends of which are uniformly spaced. The tubes **30** are then shaped and arranged to accommodate means for supporting the inclined tubes below them.

In the particular form shown in FIGURE 3, thirty-nine adjacent tubes **21** form a group, each set of three adjacent tubes **30** being shaped in a similar way. Thus tubes **30***a* rise to the levels Y, with a C-shaped deflection away from the furnace between level X and levels Y to skirt the beam **32**. The tubes **30***a* then extend horizontally along the levels Y to the central position A where they extend in a plane parallel to the direction of flow of combustion gases through the gas pass **7** to a collector **33** connected at the top of the furnace setting to the collector **15**.

The next set of three tubes, **30***b*, rise to the levels Z, being also provided with a C-shaped deflection away from the furnace between level X and levels **2** to skirt the beam **32**. They then extend horizontally along the levels X to the position B where they extend in a fashion similar to the tubes **30***a* at position A.

Similarly, tubes **30***c* extend to position C, and tubes **30***d*, **30***e* and **30***g* to positions D, E, F and G respectively. The horizontal portions of tubes **30***a*, **30***c*, **30***e* and **30***g* lie side-by-side at the levels Y and the horizontal portions of tubes **30***b*, **30***d*, **30***f* lie side-by-side at the levels Z.

The tubes **30** that lie to the right of the centre line extend in a generally similar manner to positions lying to the left of the centre line. Thus, tubes **30***h*, **30***j* and **30***l* extend to the positions H, J and C, having horizontal portions extending along the levels Y whilst tubes **30**, **30***b* and **30***m* extend to the positions I, K and M having horizontal portions extending along the levels Z. To skirt the beams **32**, the tubes **30***h*–**30***m* are provided between the levels X and Y and Z with C-shaped deflections extending towards the furnace chamber and the horizontal portions of tubes **30***h*–**30***m* lie furnace-wards of the horizontal portions of tubes **30***a*–**30***j*.

Each of the beams **32**A, **32**B, **32**C and **32**D, is in the form of a box beam and acts as a support for a strap **12**. The lower ends of the straps **12** are connected to the lining of the lower part of the rear wall. As is indicated in FIGURE 3, certain of the tubes **30** are deflected to accommodate the straps **12**. Beam **32**A is supported from the portions of tubes **30** that extend along positions H and J. Beams **32**B, **32**C and **32**D are similarly associated with the portions of tubes **30** that extend along positions K and M; A and C; and E and G, respectively. The tube portions at positions D are not used in supporting the wall. The tubes at positions I, L, B and F provide other support for the rear wall.

The tubes **30** at positions H and J are each provided with a stirrup **35** extending across the three tubes and resting on lugs **36** welded across the three tubes. Bars **37**, attached to the stirrups **35** by a rocking mounting **38**, extend down to the ends of the beam **32**A and are attached thereto by connections **39** which permit a limited pivotal movement between the bar **37** and the beam **32**A.

The straps **12** depending from the beams **32**A and **32**C provide support for the rear wall in the region of the bottom of the burners and beams **32**B and **32**D provide support for the rear wall in the region just above this. Support is also provided at the upper end of the rear wall of the length of gas pass that is lined by inclined tubes. This support is associated with the tubes at positions I, L, B and F. At position I, for instances, the tubes **30** are provided with a further stirrup **40** resting on lugs indicated at **41**, welded across the tubes. Bars **42** extend downwardly from rocking connections **43** to the stirrup **40**, each being pivotally connected at **44** to a strap **42***a* welded at its lower end to a block **45** welded between adjacent tubes **21**.

As is apparent from FIGURE 1, the tubes **30** are cranked at their upper ends to join the collectors **33** and the springs by which the tubes are suspended are connected to the tubes rather than the collector; the cranking of the tubes accommodates the relative movement of the tubes that will occur in operation. The springs by which the tubes at positions H, J, K, M, A, C, E and G. are supported are similar but the springs by which the tubes at positions I, L, B and F are supported are, whilst similar to each other, adapted to carry a smaller load than the spring by which the tubes at positions M, J, etc., are supported.

As is apparent from FIGURE 1, the groups of tubes at locations A to M extend upwardly through the nose arch **50** and across the entrance to the lateral gas pass, the separation between the groups of tubes being sufficient to permit the free flow of gases between them. Thus, forming the tubes **30** in a manner such described not only enables support to be provided for the rear wall without interfering with the free flow of combustion gases, but the horizontal components of the tubes enable relative expansions and contractions to be readily accommodated. It will be realised that the particular arrangement shown in FIGURE 3 may be modified to suit more, or less, than thirty-nine tubes. It will also be realised that since the beams **32** lie in what is, effectively, a tunnel their lengths need not be the same so that instead of one strap **12** being associated with each beam, any beam may carry two or more straps. Such longer beams are indicated in FIGURE 2.

The tubes **51** forming the nose arch **50** extend in parallel from the horizontal headers **52**, supplied by conduits **52***a*, and a seal is provided between these tubes and the tube **21** in the same manner shown in the detail in FIGURE 3. Vertical blocks **53** are welded to the outer surfaces of the tubes **51** to provide a plane continuous surface whilst blocks **54** parallel to the tubes **21** are welded to the inner surface of the tubes **21** to provide a plane continuous surface in rubbing contact with that provided by the blocks **51**. The other blocks, **56**, that are connected to the tubes **21** provide a flush surface to which the casing for the wall may be connected.

As is shown in FIGURE 4, the vertically upwardly extending tube lengths to which the inclined tubes **21** in the front and side walls are connected are arranged in groups **10**. Each group **10** discharges into header **14** connected by means of a duct **14***a* to a collector **15** extending centrally across the gas pass. The collector **15** discharges into two downcomers **15***a* and the downcomers **15***a* supply a group of inlet headers **60**. Each header **60** lies outwardly of the corresponding wall of the gas pass and to it is con-

nected a group **11** of vertically upwardly extending tube lengths, the outlet headers **61** of which lead eventually to the superheating platens. The spacers between the tube lengths in the groups **10** and **11** are closed by webs so that the lengths form a membrane wall.

The tube lengths in the groups **10** and **11** may be of the same diameter but, to take account of the greater volume of the fluid flowing through the tubes in the groups **11**, the tube lengths in these groups may have a diameter larger than the tube lengths in the groups **10**.

By the arrangement that has been illustrated in FIGURE 4, mixing is achieved in a simple fashion and a second pass is conveniently introduced. Moreover, the headers **60** by which the tubes of the second pass are supplied may be disposed outside the gas pass where they are accessible and not exposed directly to the heat of the furnace chamber.

In the modification indicated in FIGURE 5, inclined tubes are used to line the entire upright gas pass and the lateral gas pass. At the level B, the tubes **21** that terminate in the rear wall are connected to tube lengths (not shown in FIGURE 5) that extend upwardly across the lateral gas pass **7** in the manner already described. Each of the tubes **21** that terminates in the front and side wall is connected by an extension **65** to a collector **66** extending alongside, and outwardly of, these walls. The collector **66** discharges into a distributor **67**, parallel to the collector **66** which feeds tubes **210** via ducts **68**.

As is illustrated in FIGURE 6 each tube **21** is connected at its outlet end to a connector **69** in the form of two thimbles arranged back to back so that there is no pasasge between them. One thimble has a recess **69A** of the same diameter as the tube **21** and discharges into the extension **65** extending laterally from it. The other thimble **69B** has a recess of a larger diameter, the same as that of the tube **210** and is fed by the duct **68** extending laterally of the thimble **69B**. Immediately before its connection to the connector **69**, each tube **21** is bent slightly, at **21B** so that the inclination of the tube **210** is greater than that of the major part of the tube **21** to which it is connected. By virtue of this greater inclination, the spacing between tubes **210** is the same as that between the tubes **21** although the diameter of the former is greater than that of the latter. The use of connectors in the form shown at **69** enable a smooth surface to be presented to the interior of the gas pass.

In the embodiment that has been described, the tubes **21** are formed into a membrane by means of fins projecting from the tubes and welded together. It is, however, envisaged that spacers may be welded along their edges to adjacent tubes or that a tangent tube arrangement might be used.

We claim:

1. A once-through forced flow vapour generator comprising walls defining an upright gas pass of rectangular cross-section, means forming a gas outlet in a rear wall of said upright gas pass, said walls including parallel tube lengths, means for passing fluid in parallel flow relationship through said tube lengths, means filling the intertube spaces of said tubes to form a substantially gas tight gas pass wall structure, said rear wall tubes being inclined laterally and upwardly to rise generally continuously upwardly of said gas pass to terminate at the lower boundary of the gas outlet from said gas pass, a lateral gas pass extending from the gas outlet means of said upright gas pass, and each of the inclined tubes terminating at the lower boundary of said rear wall gas outlet means is connected at its upper end to a vertically upwardly extending tube length which traverses said gas outlet, said upwardly extending tube lengths being arranged in groups, the tube lengths in each group being aligned in the direction of gas flow through said lateral gas pass.

2. A forced-flow vapour generator as claimed in claim **1**, in which the groups of tube lengths are incorporated in means supporting the upright gas pass rear wall that extends below the lateral gas pass.

3. A forced-flow vapour generator as claimed in claim **2**, in which each upwardly extending tube length is in an upper and a lower part, the parts are displaced axially from each other across the width of the wall, and means for supporting the wall including tension members carried from said upper parts.

4. A forced-flow vapour generator as claimed in claim **3**, in which each tension member is carried by a beam suspended from some of said tube length upper parts and the beams lie between tube lengths connecting upper and lower parts of the upwardly extending tube lengths.

5. A forced-flow vapour generator as claimed in claim **1**, in which immediately below the entrance to the lateral gas pass, the tubes of said length of gas pass are provided, in the region at which they are connected to upright tube lengths, with filler blocks to which a casing for the length of gas pass is welded.

6. A forced-flow vapour generator as claimed in claim **5**, in which tubes of said length of gas pass are provided, in the region at which they are connected to upwardly extending tube lengths that traverse the lateral gas pass with filler blocks to provide a generally flush surface, parts of tube lengths included in an arch extend past said filler blocks and are themselves provided with filler blocks forming a generally flush surface, the flush surfaces bearing against each other.

7. A forced flow vapour generator as claimed in claim **1** wherein the inclination of said inclined tubes in the front and side walls of said gas pass ends substantially at the level of the lower boundary of said gas outlet means, each of said side and front wall tubes at said level being connected at its upper end to one of a first set of vertically extending tube lengths extending to the upper end of the gas pass, tube lengths of a second set of vertically upwardly extending tube lengths are disposed between tube lengths of the first set, and means arranged for said second set of tubes to be cooled by fluid that has flowed through the tube lengths of said first set of tubes.

8. A forced flow vapour generator as claimed in claim **7**, in which the vertically upwardly extending tube lengths are connected together to form a membrane wall.

9. A forced-flow vapour generator as claimed in claim **8**, in which collector means receive fluid discharged from said first set of tube lengths, and conduit means connect said collector means with said second set of tube lengths for discharge thereto.

10. A forced flow vapour generator as claimed in claim **9**, in which the tube lengths of the first set lie contiguously in groups and the tube lengths of the second set lie contiguously in groups alternating with the groups containing tube lengths of the first set.

11. A forced flow vapour generator as claimed in claim **10**, in which each of the groups in which tube lengths of the second set lie is provided with an inlet header lying externally of the wall.

12. A forced-flow vapour generator as claimed in claim **11**, in which the tube lengths of the second set have the same diameter, the tube lengths of the first set have the same diameter and the latter is less than the former.

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