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A. W. AMBROSE

3,301,224

STEAM GENERATOR ORGANIZATION

Filed Dec. 13, 1965

3 Sheets-Sheet 1

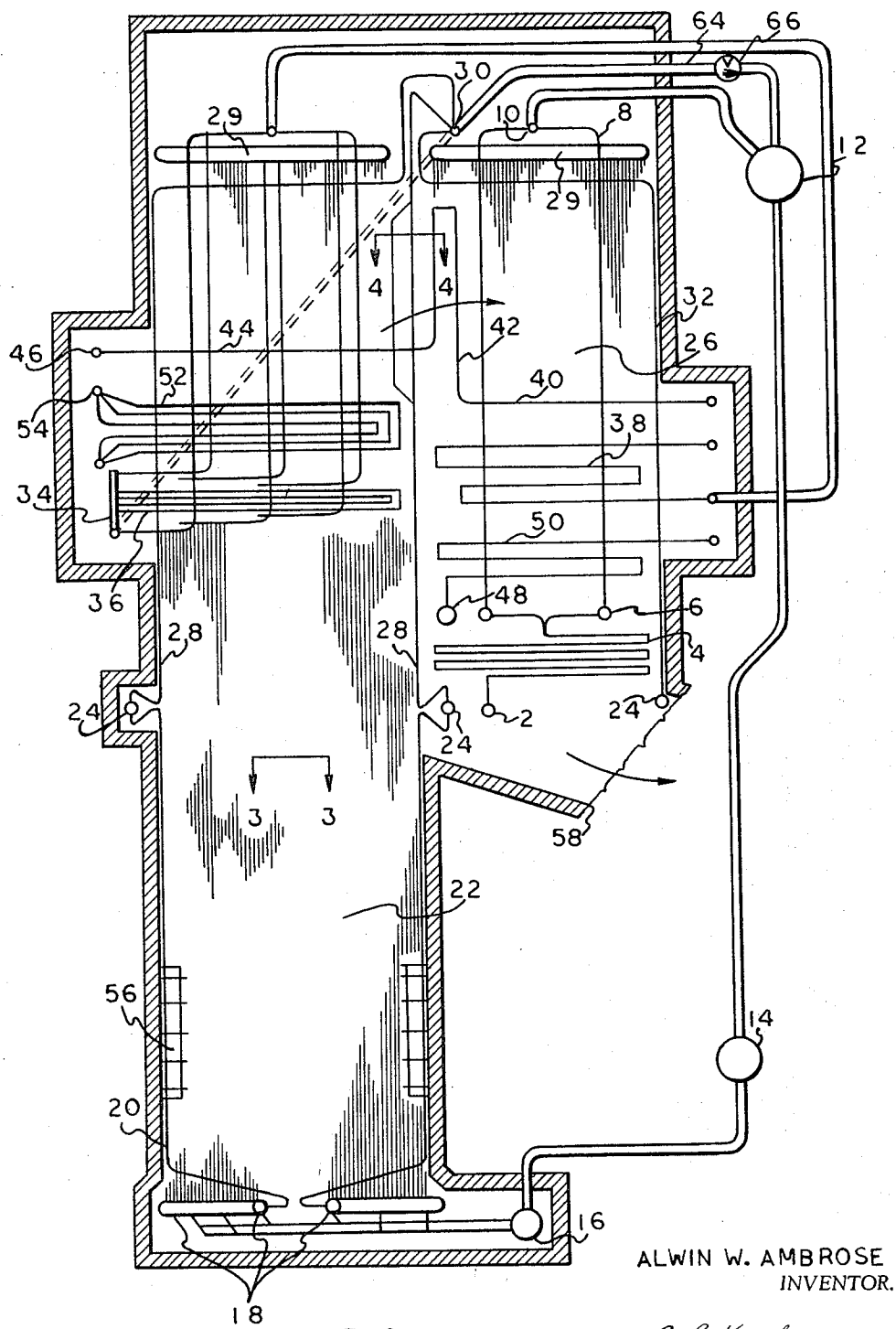


FIG. 1

BY *E L Kocher*
Agent

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3 Sheets-Sheet 2

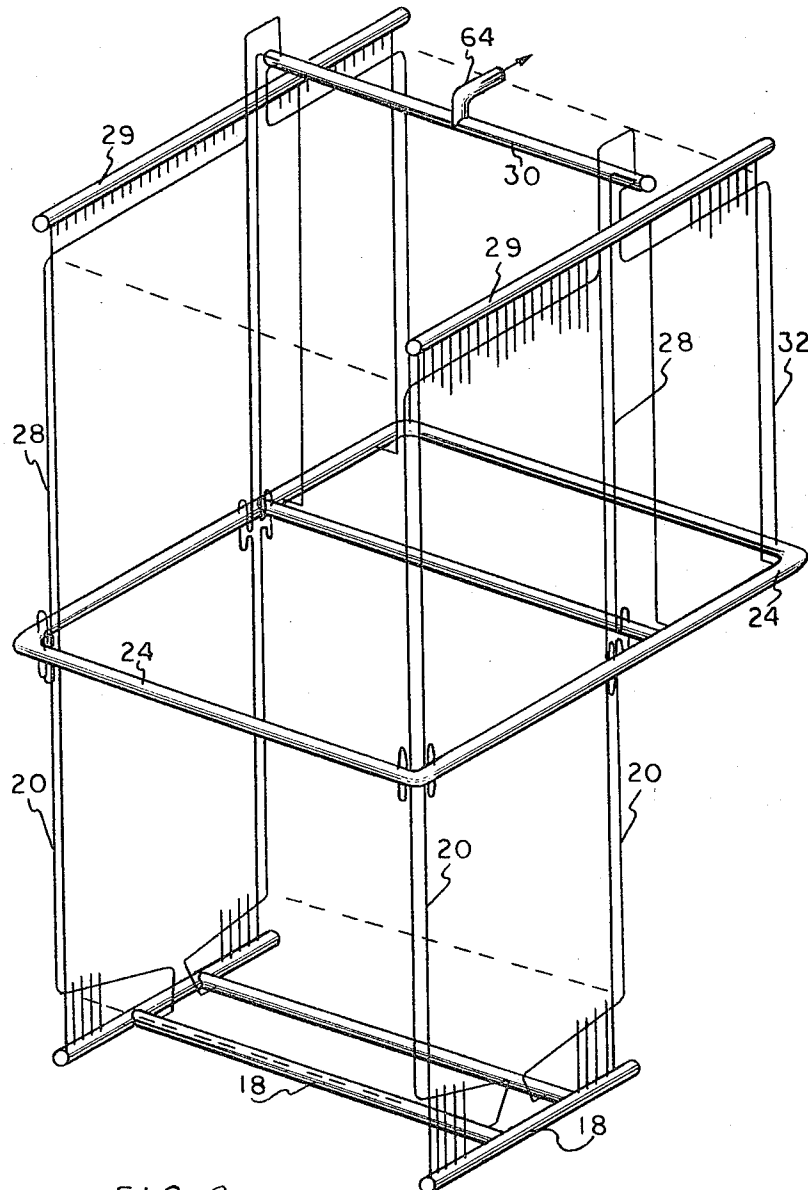


FIG. 2

ALVIN W. AMBROSE
INVENTOR

BY *E. L. Koeber*
agent

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A. W. AMBROSE

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3 Sheets-Sheet 3

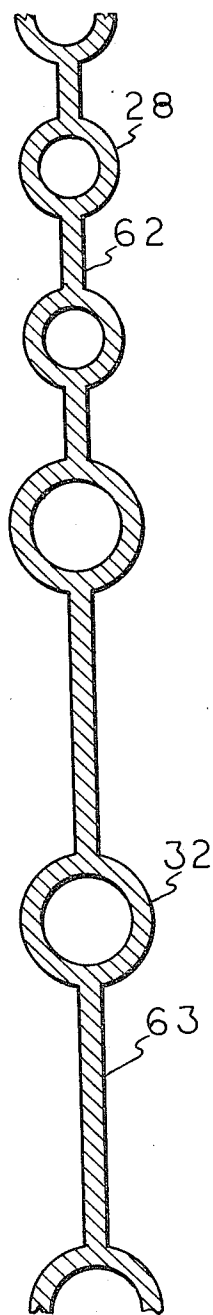


FIG. 4

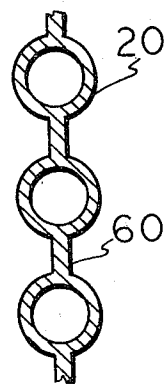


FIG. 3

ALWIN W. AMBROSE
INVENTOR.

BY *E. L. Kockuy*
Agent

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3,301,224

STEAM GENERATOR ORGANIZATION

Alwin W. Ambrose, Hazardville, Conn., assignor to Combustion Engineering, Inc., Windsor, Conn., a corporation of Delaware

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8 Claims. (Cl. 122-406)

This invention relates to once-through steam generators and in particular to an improved organization of the tubing thereof.

In the operation of a subcritical vapor generator the water is generally evaporated in the tubes lining the furnace walls and, accordingly, each of these tubes remains at saturation temperature. There is, therefore, no temperature difference between the fluid passing through the various parallel tubes, and only slight temperature difference in the actual metal temperatures of these tubes. In the operation of a supercritical vapor generator there is no saturation temperature and thus the fluid does not absorb heat at constant temperature. Therefore, as the fluid is heated, the temperature of the fluid continuously rises.

As this fluid is passed through the multiplicity of parallel tubes lining the walls of the furnace, certain temperature unbalances inherently accrue due to differential flow in the various tubes and due to unequal heat absorption from the furnace. As a result some of the tubes operate at temperatures significantly higher than other tubes. This can produce extremely high stresses when welded panel wall construction is used wherein the adjacent parallel tubes are welded to one another. This type of construction is very desirable since it forms a gas-tight structure of a high degree of confidence and simplifies erection of the steam generator.

Since it is not possible to tell which of the parallel tubes will be operating at the high temperature, all of the tubes must be designed so as to be safe at this high temperature. In other words, where an unbalanced temperature condition can exist in the parallel furnace wall tubes, all these tubes must be designed for this maximum unbalanced temperature condition. This, of course, results in the use of high alloy material and/or thick wall tubing. Where there is significant heat absorption in these tubes, the metal temperature is further increased by the use of thicker wall material due to the metal rise through the walls. This is also true with most of the high alloy materials since although the walls may not increase in thickness, the thermal conductivity tends to be less for the higher alloy materials.

The pressure drop through the steam generator affects the cycle efficiency, and it is therefore desirable to design the steam generator with the minimum pressure drop consistent with other design considerations. One of these design considerations is the protection of a furnace wall tubing in the lower furnace or burner zone. In order to achieve satisfactory cooling of the tubing materials in this area, minimum safe mass flow rates must be maintained. In other areas of the steam generator, however, the heat absorption rates are considerably lower and, accordingly, lower mass flow rates are tolerable for safe conditions. When tubes covering the furnace walls pass upwardly throughout the length of the furnace, the mass flow rate throughout the length is the same if the tube maintains the same inside diameter. Since the fluid increases in temperature as it passes upwardly through these tubes, the portion of the tubes near the top generally operates at higher temperature, and therefore the material is at lower strength. This requires thicker walled tubing and since it is inconvenient to change the outside diameter of the tube as it extends longitudinally, this

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results in a decreased inside diameter. Therefore, the mass flow in these upper portions will tend to be higher than it was in the lower furnace. This is true in spite of the fact that we have lower heat absorption rates near this upper portion and, accordingly, require a lower mass flow.

This unnecessarily high mass flow rate at this portion of the unit is, of course, connected with high velocities and, therefore, results in an unnecessarily high pressure drop. Various approaches have been attempted to solve this problem generally involving the use of two passes of the fluid through the lower portion of the furnace with the final pass through the upper portion. These two passes in the lower portion of the furnace being intermeshed, result in localized temperature differences and resultant high stress levels. Also since the temperature at the upper end of this dual pass is the average of the temperatures leaving the lower portion, this temperature at the upper extremity of the lower portion is clearly less than the temperature of the lower portion of the upper section of the furnace. This temperature difference causes stresses at this junction. Since the entire load of the lower furnace including the burners is generally carried through these furnace wall tubes, these stresses are imposed on structure load carrying members.

It is an object of this invention to provide an improved once-through flow supercritical vapor generator.

Another object of the invention is to provide an improved once-through flow vapor generator operating at supercritical pressures and provided with tubular panel wall type furnace wall construction in which the stresses within the panel are maintained at a relatively low value.

A further object is to provide an improved once-through flow supercritical vapor generator having decreased temperature unbalance in the tubes leaving the furnace wall structure and, accordingly, permitting the furnace walls to be designed for lower temperatures at this outlet position.

It is a further object to provide an improved once-through flow supercritical vapor generator which maintains satisfactorily high mass flow rates in the furnace tubes at the burner zone while obtaining a low pressure drop throughout the furnace wall section.

It is a further object to provide an improved once-through flow supercritical vapor generator in which external piping sections between various tubular sections of the furnace walls is minimized.

Other and further objects of my invention will become apparent to those skilled in the art as the description proceeds.

With the aforementioned objects in view, the invention comprises an arrangement, construction and combination of the elements of the inventive organization in such a manner as to attain the results desired, as hereinafter more particularly set forth in the following detailed description of an illustrative embodiment, said embodiment being shown by the accompanying drawings wherein:

FIG. 1 is a side elevation of a vapor generator employing the instant invention;

FIG. 2 is an isometric view of the tubing headers and piping of relevant portions of the vapor generator;

FIG. 3 is a sectional view through the tubes lining the lower portion of the furnace taken at section 3-3; and

FIG. 4 is a sectional view through the tubes lining the upper walls of the furnace and the tubes lining the walls of the flue taken through section 4-4.

In this through-flow supercritical vapor generator feed-water enters the unit at supercritical pressure through economizer inlet header 2 passing through tubular economizer heating surface 4 to the economizer intermediate header 6. The water thus heated passes through the sup-

port tubes 8 to the economizer outlet header 10 from which it passes to the mixing vessel 12.

From the mixing vessel the fluid passes through the circulating pump 14 and distribution sphere 16 to the lower furnace wall headers 18. Parallel tubes 20 pass upwardly covering the walls of the furnace 22 in conveying the fluid from the lower furnace wall headers to the ring header 24. This header passes parallel to each of the furnace walls and also passes parallel to each of the walls of the vertical flue 26. Tubes 28 lining the walls of the upper portion of the furnace 22 are arranged to receive fluid from the ring header 24 conveying it upwardly along the walls to the furnace wall outlet header 30. To simplify piping flow from the side walls is collected in collecting headers 29 before being conveyed to the outlet header 30 through jumper lines (not shown).

In parallel flow relation with these tubes 28, tubes 32 lining the walls of the flue 26 also receive fluid from the ring header 24 and convey it to the furnace wall outlet header 30. From this point the through-flow is conveyed to the panel inlet header 34 passing through the superheater panel 36 for initial superheating. This through-flow is then serially passed through superheater sections 38, 40, 42 and 44 reaching its full degree of superheat as it enters superheater outlet header 46. From this point the steam is conveyed to a steam turbine (not shown) which is used for the generation of electric power.

Steam from this turbine is returned at lower pressure to reheater inlet header 48, from which this low pressure steam passes through low temperature reheater section 50 and high temperature reheater section 52 attaining its full degree of reheat. From reheat outlet header 54 the steam is delivered to the reheat turbine which is also employed in driving an electric generator.

Fuel is fired tangentially into the furnace 22 through burners 56 with the combustion gases passing upwardly through the furnace over panels 36 and heating surfaces 52 and 44. These gases pass through the furnace outlet formed in the rear wall where the tubes at the upper portion are offset to permit the gas egress. These combustion gases then pass downwardly through the flue 26 over heating surfaces 40, 38, 50 and 4 with these gases passing out through exhaust duct 58 to an air heater (not shown).

As the water passes upwardly through the tubes 20 lining the walls of the lower furnace, it absorbs heat from the combustion occurring within the furnace. Due to the various tolerances of the tubing and the erratic pattern of hot absorption from the furnace, the temperature of each of these tubes will vary as it delivers fluid to the header 24. In this header the fluid is generally mixed before delivering it to the upper furnace tubes 28. This mixing is improved in this header system since the ring header 24 receives fluid only in that portion adjacent the furnace 22 while it delivers fluid to the area of both the furnace and the vertical flue 26. Accordingly, a cross flow is developed in this header which improves the mixing of the various streams which are entering the header. Due to this mixing the temperature unbalance entering the tubes 28 is decreased and, accordingly, the temperature unbalance leaving these tubes is decreased. Therefore, the design temperature of these tubes may be lower than it would be without the mixing.

The tube sizing of the tubes lining the lower furnace wall as indicated in FIG. 3 is selected to supply adequate mass flow rates in this burner zone where heat absorption rates are extremely high. The tubes are $1\frac{1}{4}$ inches in diameter with $\frac{1}{2}$ inch webs 60 welded to adjacent tubes. Such mass flow rates are not required in either the upper furnace portion or the flue 26. FIG. 4 illustrates the tubing selection employed in these low heat absorption rate locations. The upper furnace walls are covered with $1\frac{1}{2}$ inch tubes 28 having 1 inch webs 62 welded therebetween. In the flue 26 the wall tubes are of 2 inch diameter tubing with 4 inch webs 63 welded between ad-

jacent tubes. The total flow area of all the tubes lining the walls of the flue plus those lining the walls of the upper furnace is greater than the flow area of the tubes lining the lower furnace wall. This results in lower mass flow rates and, accordingly, lower pressure drop. Since the perimeter supplied from header 24 is substantially greater than the perimeter of the lower furnace, increased tube spacing may be employed in the upper sections. The spacing between the tubes is covered by an increased length of fin between the adjacent tubes. Fin length is also limited as a function of the heat exchange rate of any particular section since excessive fin lengths will result in high fin temperatures with their ultimate destruction. Since lower heat absorption rates occur in these upper zones, increased fin lengths can be tolerated. It should be noted that the upper furnace wall tubes as compared to those of the lower furnace provide an increased spacing between the outer edges of adjacent tubes. This facilitates the passage of the superheater tubes going to and from the superheater sections 38 and 44 as well as reheater section 52 as they pass through the furnace wall since it reduces the amount of offsetting of the furnace wall tubes required to pass the tubes through.

The tubes 20 and 28 lining the lower and upper portions respectively of the furnace 22 are formed into welded panels by welding web 60 between adjacent tubes 20 in the lower furnace and welding web 62 between the adjacent tubes 28 in the upper furnace. This welded wall construction is well known as well as its advantages of simplified erection with good gas-tight construction. Obviously, when temperature differences exist between welded tubes in such a construction, stresses are set up within the structure. These stresses are minimized on this construction because of the mixing achieved and, accordingly, reduction of temperature difference between parallel tubes.

The rear wall of the furnace is formed at its upper section by tubes 28 with these tubes also comprising the front wall of the flue 26. With such a structure the side walls of each section, that is, the upper portion of the furnace 22 and the flue 26, are welded together. Any temperature difference existing between the walls of these sections would result in extremely high stresses throughout the longitudinal line separating these two sections. In this design, with the fluid to both of these sections being supplied by the ring header 24 after mixing, the same temperature fluid is supplied to each of these sections. Therefore, no temperature difference with its resultant stress formation exists.

Because of the construction used wherein the ring header 24 is also the supply to the tubes 32 lining the walls of the flue 26, no additional external piping is required to supply this section.

Recirculating line 64 including stop check valve 66 is operative to recirculate a portion of the flow entering the furnace wall outlet header 30 through line 64 in parallel with tubing sections 20, 28 and 32 so that this amount of flow may be passed through these tubes in supplement to the through-flow. Such a system is described in U.S. Patent No. 3,135,252, issued June 2, 1964 to W. W. Schroedter. This recirculation system further decrease the temperature unbalance between tubes, thereby further decreasing any stresses incurred by that temperature difference.

While I have illustrated and described a preferred embodiment of my invention it is to be understood that such is merely illustrative and not restricted and that variations and modifications may be made therein without departing from the spirit and scope of the invention. I therefore do not wish to be limited to the precise details set forth but desire to avail myself of such changes as fall within the purview of my invention.

What I claim is:

1. A vapor generator of the once-through type for operation at supercritical pressure and having a through-

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flow system through which the working medium is forced; said generator including a vertically disposed furnace; burner means for firing a fuel and generating combustion gases that pass through the furnace with the furnace being provided with an outlet remote from said burner means; said furnace being defined by vertically elongated walls which are lined with separate generally vertically extending tubes in side-by-side relation across the width of each wall member, said tubes being in parallel flow relation with adjacent tubes on each wall and forming part of said through-flow system; a flue extending from said furnace outlet at least a portion of said flue extending downwardly parallel to the upper portion of the furnace; said downwardly extending portion of said flue being defined by vertically elongated walls which are lined with separate generally vertically extending tubes in side-by-side relation across the width of each wall, said tubes being in parallel flow relation; said tubes lining the furnace wall comprising a lower section and an upper section, said upper and lower sections being connected in series flow relation; a mixing header arranged to receive fluid from said lower section and to discharge fluid to both said upper section and said tubes lining the walls of the flue in parallel flow relation.

2. An apparatus as in claim 1 wherein the total flow area of the tubes comprising the upper section plus the total flow area of the tubes lining the walls of the flue is greater than the total flow area of the lower section of tubes lining the walls of the furnace.

3. An apparatus as in claim 2 wherein the upper section tubes lining the walls of one wall of the furnace forms one wall of said flue.

4. An apparatus as in claim 2 wherein the centerline-to-centerline distance of the tubes lining the walls of the flue is greater than the centerline-to-centerline distance of the tubes of the upper section tubes lining the furnace walls.

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5. An apparatus as in claim 1 wherein the spacing between adjacent edges of adjacent tubes lining the upper furnace walls is greater than the spacing between adjacent edges of adjacent tubes lining the lower furnace wall.

6. An apparatus as in claim 1 wherein the tubes lining the furnace wall are bonded together generally throughout the height of the furnace forming a rigid imperforate structure.

7. An apparatus as in claim 1 wherein said mixing header arranged to receive fluid from said lower section and to discharge fluid to both said upper section and said tubes lining the walls of the flue in parallel flow relation comprises: a header passing horizontally parallel to each of the furnace walls and horizontally parallel to the flue walls; said header receiving fluid from the lower furnace walls at locations where it is immediately adjacent said furnace walls and delivering fluid to the flue walls where it is immediately adjacent to the flue walls, and having cross flow through said header so that the portion of flow which is being delivered to the flue walls passes through said header from the lower furnace supply section of the header to the rear flue walls.

8. An apparatus as in claim 3 having also a circulating system superimposed on the through-flow system in parallel flow relation with the tubes lining the furnace walls and the tubes lining the flue walls and effective to recirculate working medium through these portions of the through-flow system in supplement to the through-flow.

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KENNETH W. SPRAGUE, *Primary Examiner*.