Sept. 22, 1959 H. SCHROEDER ET AL 2,905,157

SEPARATELY FIRED RADIANT SUPERHEATER

Filed April 23, 1956 3 Sheets-Sheet 1

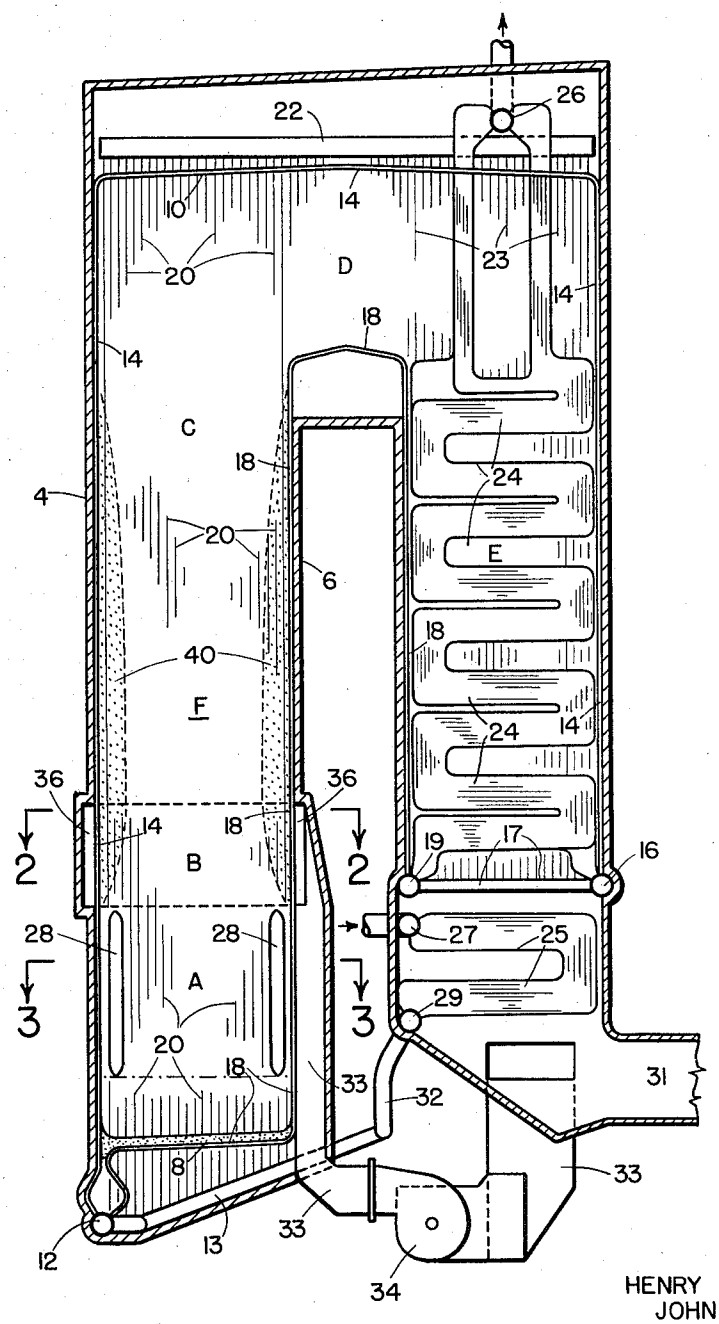


FIG. 1

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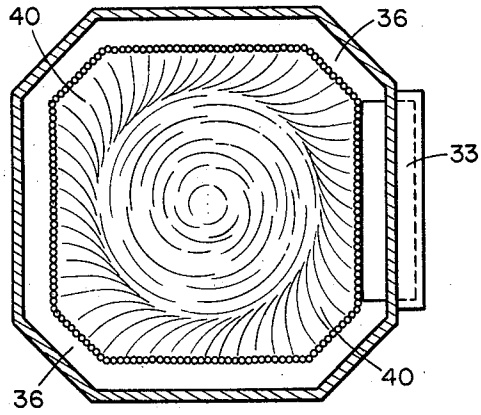


FIG. 2.

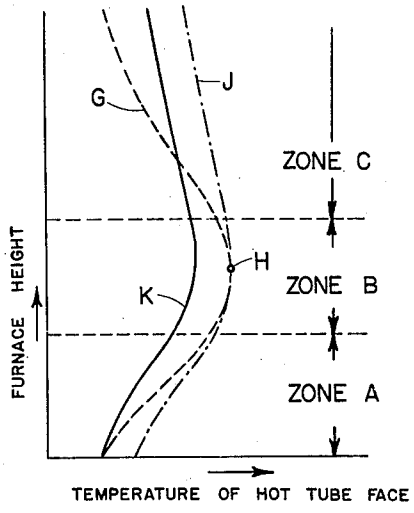


FIG. 7.

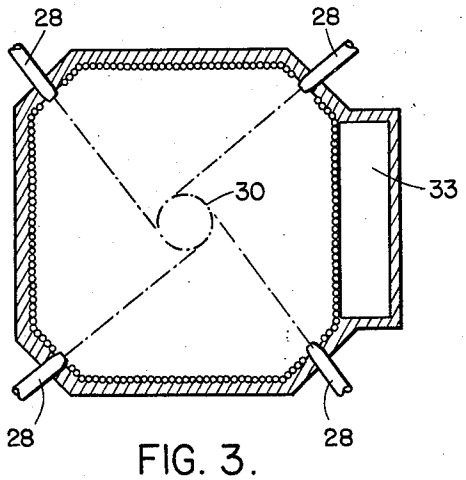


FIG. 3.

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Filed April 23, 1956 3 Sheets-Sheet 3

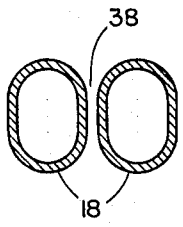


FIG. 6.

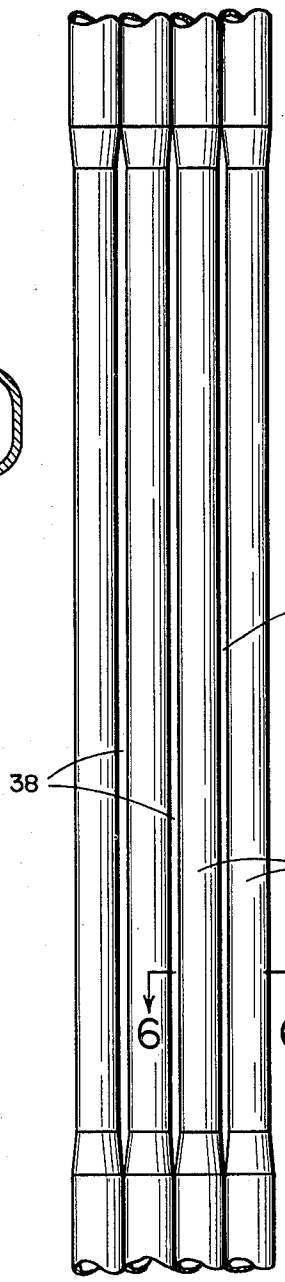


FIG. 5.

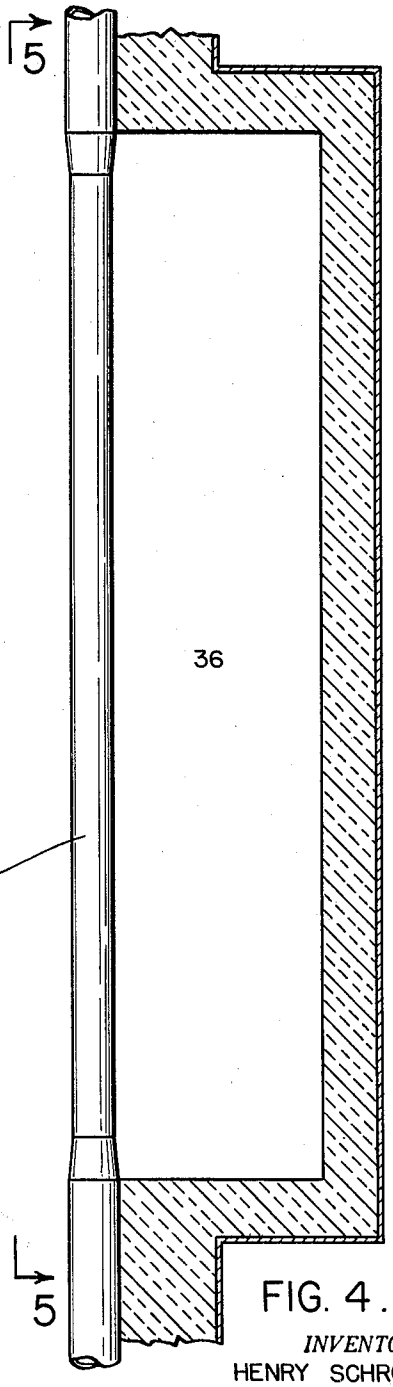


FIG. 4.

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2,905,157

SEPARATELY FIRED RADIANT SUPERHEATER

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Application April 23, 1956, Serial No. 580,070

3 Claims. (Cl. 122—485)

This invention relates to a method and apparatus for heating vapors, air or other gases, and is more particularly concerned with a separately fired superheater having a tangentially fired furnace including walls that are lined with closely spaced superheating tubes.

In furnaces of this type the vapor, for instance steam, is superheated to a relatively high temperature such as 1100° F. and at high pressures such as 2000 lbs. p.s.i. or more. Also in tangentially fired furnaces the heat release is very rapid so that flame temperatures in excess of 3000° F. may be encountered in the hotter portions thereof. As a result the rate of heat absorption by radiation of the furnace walls is very high. This sometimes causes the metal temperature of certain portions of the tubes to exceed the allowable limit of the material resulting in failure of the tubes.

It is accordingly a primary object of the invention to provide an apparatus and method of superheating vapor by radiation in a furnace, which permits the attainment of unusually high vapor temperatures without unduly endangering the operating safety of the apparatus.

It is a further object of the invention to greatly reduce the use of expensive alloy steel tubing in the lining of the furnace walls of a separately fired superheater or vapor heater.

Other objects and advantages of the invention will become apparent from the following description of an illustrative embodiment of the invention when read in conjunction with the accompanying drawings wherein:

Figure 1 is a vertical section through a separately fired superheater constructed in accordance with the invention.

Figure 2 is a horizontal section through a central portion of the furnace chamber taken along line 2—2 of Fig. 1.

Figure 3 is another horizontal section through a lower portion of the furnace chamber and taken along line 3—3 of Fig. 1.

Figure 4 is an enlarged section of a specific portion of the furnace wall.

Figure 5 is an elevational view of the furnace tubes taken on line 5—5 of Fig. 4.

Figure 6 is an enlarged horizontal cross section through the furnace tubes taken on line 6—6 of Fig. 5.

Figure 7 is a graph which illustrates the metal temperature of the furnace wall tubes when plotted against various furnace levels and for three different operating conditions.

The preferred embodiment of the invention illustrated in Figs. 1, 2 and 3 shows a separately fired superheater which comprises a vertical furnace chamber F having a lower or burner zone A, an intermediate or gas recirculation zone B and an upper zone C. From the upper zone C a gas offtake passage D leads into a vertical down flow gas pass E.

The furnace chamber F is bounded by two opposing side walls 2, a front wall 4, a rear wall 6, a bottom 8 and a roof 10.

Substantially all of the interior surfaces of chamber F, offtake D and gas pass E are lined with closely spaced superheating tubes originating in lower front header 12 or side wall headers 13. Thus tubes 14 line the furnace front wall 4, the roof 10, the rear wall of down pass E, and terminate in header 16 arranged across the lower rear wall of down pass E. Tubes 18 line the furnace bottom 8, rear wall 6, the bottom of offtake passage D and the front wall of down pass E and terminate in header 19. Tubes 20 originating in headers 13 cover the side walls 2 and enter the forward end of upper header 22. Other tubes 23 originating in the rearward portion of header 22 line the side walls of offtake passage D and down flow pass E and connect to header 17. There are two headers 17, each spanning one side wall of gas pass E, and connected at their ends to headers 16 and 19. A convection steam heater 24 is arranged in down flow pass E. This heater 24 comprises tubes having their lower ends connected to headers 16 and 19, and their upper ends to steam outlet header 26. Following heater 24 in the gas flow sense there is provided a second steam heater 25, comprising tubes which are connected to headers 27 and 29.

Fuel and air is introduced into the furnace chamber F by way of burners 28 which are mounted in or near the corners of furnace chamber F, as shown in Fig. 3, and which introduce streams of fuel and air into the furnace in directions tangential to a firing circle 30. These burners are located adjacent the lower or burning zone A (see Fig. 1). The combustion gases form a rotating mass which, following a spiral path, rises through the intermediate and upper furnace portions B and C respectively and passes through offtake duct D into down flow pass E. Heat is absorbed from these gases by the tubes 14, 18, 20 and 23 lining the furnace walls, offtake duct D, and gas pass E. Additional heat is given off by the gases to the convection steam heaters 24 and 25 while flowing through gas pass E. The gases then leave by way of outlet duct 31, and after passing over additional heat absorbing surfaces such as an air heater (not shown) are discharged to the atmosphere by way of an induced draft fan and stack (not shown).

During operation saturated steam from a source not shown enters inlet header 27, passes through convection steam heater 25, pipe 32, headers 13 and 12, radiant superheater tubes 14, 18, 20, header 22, tubes 23 into headers 16 and 19. The steam thereupon flows through convection steam heater 24 where it is heated to the final temperature before it enters outlet header 26 to be conducted to a point of use such as a steam turbine (not shown).

Some of the gases after having passed over the heating surface of steam heaters 24 and 25 are returned to the furnace F by way of recirculating duct 33 and fan 34. Surrounding the furnace walls, a peripheral duct 36 is provided adjacent and directly above the intermediate or burner zone A. Referring now to Fig. 4 this duct which is connected to the gas recirculating duct 33 is bounded on the furnace side by the bare furnace wall tubes 14, 18 and 20 having intertube openings or interstices 38 between them (see Fig. 5). These openings permit the recirculated gas to enter the furnace in a plurality of streams which issue throughout the perimeter and height of zone B, and are of such width as to allow the gas to filter into the furnace chamber at a relatively low velocity, thereby forming a gas layer 40 (see Fig. 1).

As earlier stated herein modern separately fired superheaters may require that the steam be heated to extremely high temperatures such as 1100° F. and at very high pressures. This is so, because the efficiency of a steam power plant increases with an increase in steam temperature and steam pressure. Since the tubes lining the walls

of the furnace chamber are not only exposed to extremely high radiant heat, especially in the burner zone such as zone A of the illustrative embodiment, but also to high internal pressure, the material of which these tubes are made must be of the very best heat resisting alloy. Such alloy material is quite costly and represents a considerable item in the original cost of the unit.

In a separately fired superheater of the type shown in Fig. 1, but without the inventive improvement herein disclosed, the temperature of the tube surface facing the furnace and exposed to the sweeping burning combustion gases reaches a high peak value H in the furnace zone B as illustrated in Fig. 7. This temperature tapers off both toward zone A and zone C to considerably lower values as indicated by curve G. The high peak temperature H determines the quality of the heat resisting alloy material which must be used. On the other hand, if the high peak temperature H could be reduced and the lower temperatures in zone C be raised a corresponding degree, either a greater amount of heat could be absorbed by the tubes over the furnace length thereof as shown by curve J, or less expensive alloy material could be used while maintaining the same total heat absorption. This latter condition is shown by curve K.

The present invention accomplishes the above desirable results in a novel manner by infiltration of relatively cool recirculated gases through spaces between all furnace wall tubes into zone B located at a level directly above the burning zone A. These cool gases are distributed equally throughout the perimeter of furnace zone B by way of duct **36**, and also by the rotating scrubbing action of the gases in a tangentially fired furnace. Infiltration of the gases at relatively low velocity through the intertube spaces **38** between the wall tubes **14**, **18** and **20** produces a solid layer of cool gases **40** hugging the entire inner surface of the furnace walls above the burners that are lined with tubes which otherwise would be exposed to the hot sweeping furnace gases.

In a tangentially fired, or cyclonically fired furnace chamber of the type herein considered, centrifugal forces acting on the rotating gas mass cause movement of these gases away from the center of rotation and toward the furnace wall. Consequently the cool gases entering the furnace through peripheral duct **36** are pushed against and drawn upwardly along the face of the tube lined walls at a velocity which, because of the higher density of the cooler gases is lower than that of the centrally located hot combustion gas mass. Due to the whirling and rotating action of these burning combustion gases passing in a spiral path upwardly through zones B and C, the thickness of the recirculated gas layer **40** is gradually reduced by diffusion into the hot combustion gases in their upward sweep. This as well as the lower heat absorption in zone B due to gas infiltration results in a flattening of the tube metal temperature curve G by a lowering of the peak temperature in zone B and a raising of the low temperature in zone C, as indicated by curve K, Fig. 7.

Consequently when designing a separately fired superheater in accordance with the herein disclosed invention, the selection of heat resisting alloy material for the furnace wall tubes can be governed by a much lower maximum metal temperature as indicated by curve K. This is in contrast to the peak temperature H of curve G which would govern in an apparatus designed without the benefit of the invention.

Or, if operating conditions should make it desirable, such as when operating at higher steam heating loads, the temperature level throughout the length of the wall tubes can be raised in the low temperature portions thereof by gas recirculation in the manner disclosed herein, resulting not only in absorption of heat more evenly distributed throughout the length of the tube but also in a higher overall heat absorption. This condition is illustrated by curve J in Fig. 7.

In the design shown in Figs. 4 and 5 the interstices **38** between the tubes are formed by reducing the diameter of the tubes through swaging. There are other ways whereby the desired intertube spaces **38** can be produced. One alternate method would be by flattening the tubes somewhat to a slightly elongated cross sectional form as illustrated in Fig. 6. Or the desired intertube spaces can be produced by staggering of the tubes locally.

While the preferred embodiment of the invention has been here shown and described as applying to a separately fired steam superheater, our inventive method and apparatus can with equally beneficial results be utilized for heating other vapors or gases such as air, for example. Also it is understood that changes in construction, combination, and arrangement of parts may be made without departing from the spirit and scope of the invention as claimed.

We claim:

1. In a steam heating apparatus having an elongated vertical single combustion chamber defined by four upright side walls lined with closely spaced steam heating tubes; a gas passage including a steam heater disposed therein, said gas passage operatively connected to said furnace for flow of combustion gases through said passage and said steam heater; the combination therewith of a set of burners mounted in the chamber walls in the lower portion thereof to introduce fuel and air into the chamber in directions tangential to an imaginary firing circle to produce a rising rotating mass of hot combustion gases; a peripheral gas recirculation duct surrounding said four tubular steam heating walls and connected with said passage at a point beyond said steam heater in direction of gas flow for recirculating relatively cool gases back into the furnace; a substantially continuous and horizontally endless peripheral zone flanking the inner heating surface of the walls of said chamber that is located above and immediately adjacent said burners and extending throughout a major portion of said combustion chamber above said burners; conduit means for communication between said duct and said peripheral zone including a plurality of vertically elongated interstices between said tubes, said interstices being substantially coextensive with the periphery of said zone; means for infiltrating recirculated gases from said duct through said interstices and for flooding said peripheral zone with recirculated gases; said rising and rotating combustion gases producing an outwardly directed pressure upon said infiltrated cool gases together with an upwardly spiralling motion causing said infiltrated gases to hug the walls of said chamber while rising to the upper part thereof, whereby a continuous relatively cool zone is established directly above said burners and between said rotating hot gas mass and the steam heating tubes lining said four walls.

2. A separately fired superheater having in combination four side walls forming a single elongated vertical combustion chamber, an upper exit passage for the products of combustion and communicating with the combustion chamber, said passage containing a convection steam heater; a peripheral gas recirculation duct completely girthing the outside of said chamber walls and connected with said passage at a point beyond said steam heater in direction of gas flow; a continuous horizontally peripheral zone flanking the inner surface of the walls of said chamber in the general elevational region of said duct, said zone extending throughout a major portion of said chamber above said elevational region; a set of horizontally spaced tangentially firing burners disposed at a level below and immediately adjacent said zone to introduce fuel and air into said combustion chamber in directions tangential to an imaginary firing circle to produce a rising rotating mass of hot combustion gases; closely spaced vertically disposed steam heating tubes lining the inside of the four walls of said chamber, said tubes within the area of said peripheral zone being arranged to form elon-

gated narrow interstices between adjoining tubes; flow communicating means between said duct and said peripheral zone via said interstices; means for causing infiltration of recirculated gases from said peripheral duct through said interstices into said combustion chamber over an area which is substantially coextensive with the periphery of said zone; means for flooding said zone with recirculated gases; said rising and rotating combustion gases producing an outwardly directed pressure upon said infiltrated cool gases together with an upwardly spiralling motion causing said infiltrated gases to hug the walls of said chamber while rising to the upper part thereof whereby a continuous relatively cool zone is created between said rotating hot gas mass and the steam heating tubes lining said four walls.

3. In a separately fired vapor heating apparatus provided with a single combustion chamber having a chamber bottom at one end thereof, a gas passage disposed remotely from said end and operatively connected to said chamber for flow of gases therethrough, said chamber being enclosed by four upright boundary walls lined with closely spaced vertical vapor heating tubes absorbing heat primarily by radiation; the combination of tangentially firing burner means discharging streams of fuel and air into said tube lined chamber in directions tangential to an imaginary circle for burning in a burner zone, and producing a rising rotating stream of combustion gases passing through said combustion chamber in contact with said tubes and through said gas passage; a body of vapor heating tubes exposed to said gas stream for heat absorption

therefrom and arranged within said passage beyond said burner zone in direction of gas flow; means forming a plurality of parallel interstices between said closely spaced wall tubes throughout a peripheral generally horizontal region of each chamber wall, said region being located above and immediately adjacent said burner means and forming a continuous band girthing said chamber and extending throughout a major portion of said combustion chamber above said burners; means for conducting recirculated gases from the downstream side of said body of tubes in the gas flow sense to said interstices; means for causing infiltration of said recirculated gases into said region via said interstices, and means for flooding said region with said recirculated gases; said rising and rotating combustion gases producing an outwardly directed pressure upon said infiltrated cool gases together with an upwardly spiralling motion causing said infiltrated gases to hug the walls of said chamber while rising to the upper part thereof.

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