Oct. 30, 1962 P. M. BRISTER ET AL 3,060,908

FLUID HEATING UNIT

Filed May 13, 1958

FIG. 1

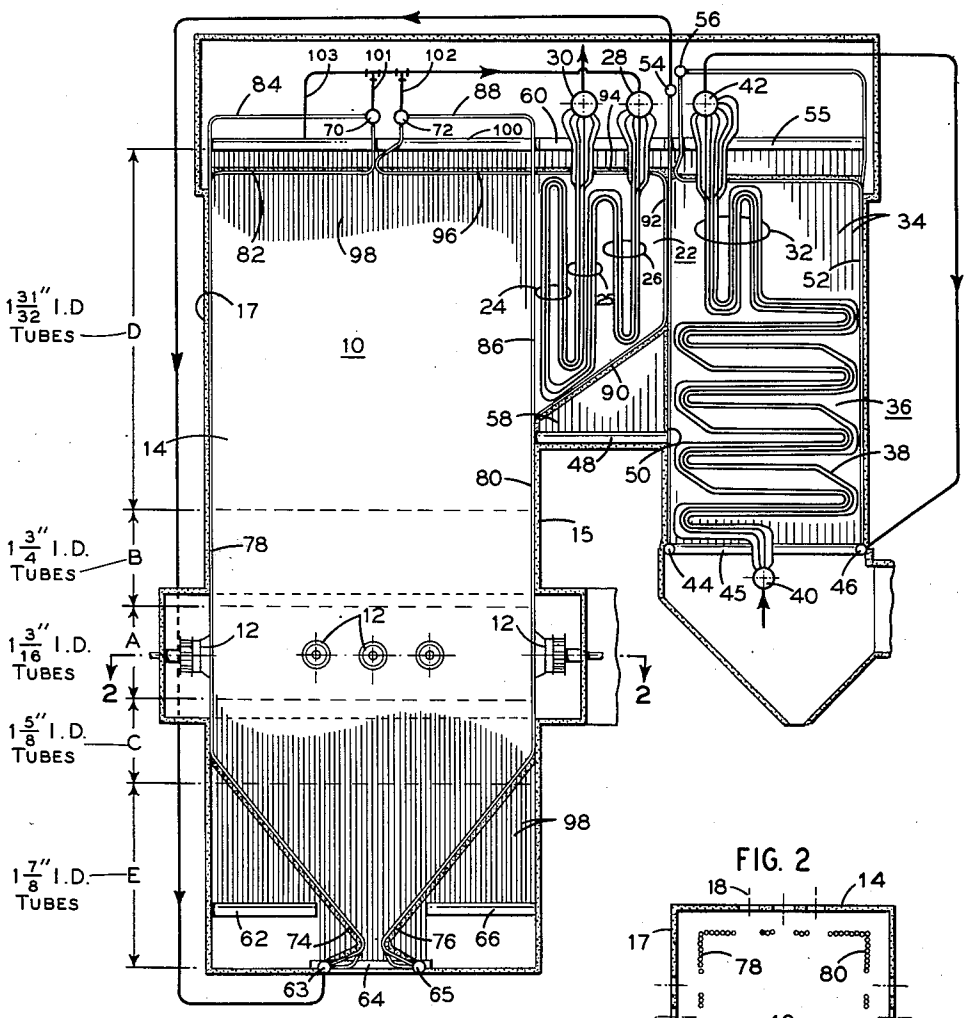
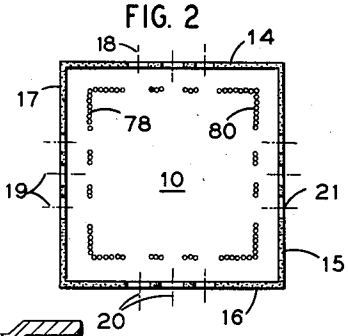


FIG. 2



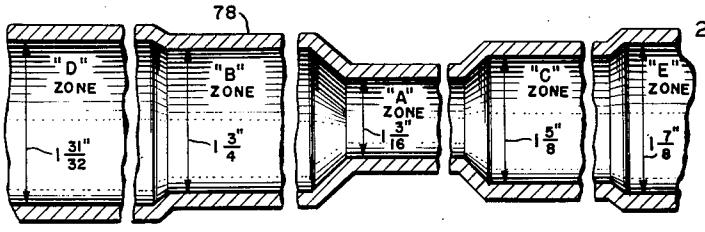


FIG. 3

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United States Patent Office 3,060,908 Patented Oct. 30, 1962

3,060,908

FLUID HEATING UNIT

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Filed May 13, 1958, Ser. No. 734,957
2 Claims. (Cl. 122—481)

This invention relates in general to the construction and operation of fluid heat exchange apparatus, and more particularly to a method of and apparatus for heating steam or other gases or vapors to high temperatures.

In separately fired steam superheaters, for example, having steam superheating tubes lining the walls of a fluid fuel fired furnace, there is a tendency for the steam-carrying tubes exposed in zones of high furnace radiant heat inputs to attain extremely high tube metal temperatures at normal steam velocities within the tubes, due primarily to the comparatively low heat conduction characteristic of the steam film on the inside surface of the tubes. Thus it has been necessary to fabricate such tubes of costly alloy materials in order to attain satisfactory life of the tube sections. Increasing the velocity of the steam flowing within the tubes, and thereby producing a higher rate of heat extraction from the metal of the tube wall, obviates to some extent the necessity for costly alloy materials in the zones of high radiant heat absorption. Advantageously this can be accomplished by the use of steam conducting tubes of smaller inside diameter in the higher heat absorbing zones than customarily are used in zones of lesser radiant heat intensity. Any decrease in inside tube diameter however results in an increased steam pressure drop.

In accordance with the invention, the overall increase in steam pressure drop and the extent of the high radiant heat absorbing zone are minimized by arranging the fuel burning means within a limited zone relative to the length of steam travel in the furnace walls. For example, in one separately fired steam superheating unit embodying the invention, a vertically elongated furnace of rectangular horizontal cross-section is defined by vertical walls lined with upright steam heating tubes receiving steam from header means at their lower ends and discharging superheated steam from their upper ends. The fuel burning provisions for the furnace advantageously consist of an equal number of fuel burners symmetrically spaced in each of the vertical walls, with the horizontal centerlines of all of the burners in the same plane. This plane is preferably at a level substantially above that of the lower ends of the steam heating tubes, and the zone of highest furnace temperature is thus correspondingly disposed within the furnace, said zone extending between levels above and below the horizontal plane containing the centerlines of the burners and disposed intermediate the height of the furnace. The highest furnace radiant heat transfer to the superheater tubes, and to the steam flowing therein, occurs in this zone with the rate of heat input decreasing in the successive zones downstream of the burner zone. In this arrangement the invention provides for maintaining the temperature of the superheater tube metal within allowable safe limits by varying the velocity of the steam as it flows from zone to zone, by means of successive changes in the inside diameter of the steam carrying tubes, with the smallest diameter, i.e. highest velocity of the steam, occurring within the burner zone. In the zoned areas preceding and following the burner zone, wherein the heat inputs are successively lower than that normally prevailing in the burner zone, the inside tube diameters are proportionately increased, thereby maintaining a reasonable pressure loss through the system. The invention

achieves the above indicated results while, at the same time, providing for relatively uniform heat absorption by the different vertical wall sections at any level in the furnace.

The invention also involves in combination with radiant heated superheater surface of the character described, convection superheater surface heated by the gases from the furnace and preferably including primary and secondary superheater sections at a downstream position in the flow of furnace gases toward a stack.

The various features of novelty which characterize this invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which we have illustrated and described a preferred embodiment.

Of the drawings:

FIG. 1 is a partly diagrammatic sectional elevation of a steam superheating unit embodying the invention; FIG. 2 is a partly diagrammatic horizontal section taken on the line 2—2 of FIG. 1, and FIG. 3 is a cross-section through one of the furnace wall tubes, showing the variations in inside diameter.

The separately fired steam superheater illustrated comprises a vertically elongated furnace 10 of rectangular horizontal cross-section defined by side walls 14 and 16, a rear wall 15, and front wall 17, and a multiplicity of short flame fluid fuel burners 12. As shown in FIG. 2, three fuel burners are positioned in each of the four furnace vertical walls, the center lines of the burners being disposed in the same horizontal plane indicated by the line 2—2 in FIG. 1, the burner center lines in the walls 14, 15, 16 and 17 being indicated at 18, 21, 20 and 19 respectively.

Heating gases, as will be more fully discussed later, pass from the furnace 10 through a laterally directed gas pass 22 opening through the upper part of the furnace rear wall 15. In this gas pass there are disposed banks of tubes indicated by circles 24–26 and formed by a plurality of multi-looped nested return bend vertically arranged tubes having their opposite ends connected to an inlet header 28 and outlet header 30 and constituting the convection heated secondary superheater section.

The furnace gases flow from the gas pass 22 across a vertically arranged bank of multi-looped nested tubes indicated by the circle which form part of the convection heated primary superheater section. The tube bank 32 is positioned in the upper end of a vertical downflow gas pass 36 in which are arranged successive vertically spaced banks of horizontally extending multi-looped nested tubes 38 serially connected to the tubes of the primary convection superheater section 32 and their lower ends to a transverse horizontal inlet header 40. The upper ends of the tubes 32 are connected to an external header 42 arranged adjacent to the headers 28 and 30. The outlet header 42 is connected through external piping to header sections 44–46 embracing the lower end of the downflow gas pass 36. Other appropriate external connections (not shown) conduct steam from the header 42 to side wall headers 48 at a level below the lateral gas pass 22. From the header sections 44–46, and a fourth header section (not shown) along the fourth side of the downflow gas pass 36, the steam passes upwardly through tubes lining the walls of the downflow gas pass to corresponding external headers 54–56. Such tubes are indicated at 34, 50 and 52, some of the rear wall tubes 52 extending forwardly along the corresponding roof section.

The side wall headers 48 are connected by upright wall tubes 58 to corresponding upper side wall headers 60,

and thence through appropriate external connections (not shown) to one or more of the headers **62–66** arranged at the lower end of the furnace, as shown in FIG. 1. Similar external connections **61** conduct steam from the headers **54–56** also to one or more of the headers **62–66**. The lower side wall headers **62**, **64** and **66** are indicated for the furnace wall **14**, and it is to be understood that the opposite wall **16** has similar headers.

The furnace shown in FIG. 1 is a hopper bottom furnace with rows of superheater tubes lining the opposite walls **17** and **15** leading from the transverse bottom headers **63** and **65** to the upper headers **70** and **72** respectively. The initial sections **74** and **76** of these tubes are oppositely inclined and the intertube spaces closed, to form the hopper front and rear sides. Successive upright tube sections **78** and **80** are disposed along the furnace walls **17** and **15**. Succeeding sections of some of the wall tubes **78** are bent rearwardly to form a furnace roof portion **82**, and connect to the external header **70**. The remaining tubes **78** have rearwardly bent sections **84** above the furnace roof which also connect to the header **70**.

Alternate wall tube sections **80** disposed along the furnace wall **15** have vertically extending tube portions **86** providing a screened gas outlet to the lateral gas pass **22**. The tube portions **86**, after passing between furnace roof defining tubes **96**, have forwardly bent portions **88** disposed above the roof communicating with the header **72**. The remaining wall tube sections **80** have rearwardly inclined portions **90** extending along the floor of the lateral gas pass **22**, and thence vertically to provide a gas outlet screen **92** for pass **22**. These tube sections are then bent forwardly to form the roof **94** of the gas pass **22** and a roof portion **96** of furnace **10**, and terminate in the header **72**.

Each of the opposite furnace side walls **14** and **16** has three lower headers **62**, **64** and **66** from which upright wall tubes **98** extend, with their upper ends connected to a header **100**.

The headers **70**, **72** and **100** at the top of the furnace have outlet connections **101**, **102** and **103** to the inlet header **28** of the convection heated secondary superheater. The steam flows from the header **28** countercurrent to the direction of gas flow successively through the tube group **26** and portions of the tube groups **25** and **24**, and then concurrently relative to gas flow through the remaining portions of the tube groups **24** and **25** to the header **30**, from which it passes to a point of use.

In accordance with the invention, heat is supplied to the described radiantly and convection heated steam superheating surface by a special symmetrical arrangement of short flame fluid fuel burners **12** in all of the vertical furnace walls. As shown in FIGS. 1 and 2, the burners **12** are of the multi-fuel circular type, being adapted for firing pulverized fuel, oil and/or gas, and horizontally arranged normal to the corresponding vertical wall. The horizontal center lines **18–21** of all of the burners **12** are positioned in the same horizontal plane at an elevation above the furnace hopper corresponding to the lower vertical portions of the walls **15** and **17**. As shown, the burners are arranged in similarly spaced groups of three, with the centerline of each burner directly in line with an oppositely arranged burner in the opposite furnace wall. The streams of heating gases generated meet in the furnace chamber, forming a high temperature combustion zone at the burner level, and then flow upwardly in the furnace and then rearwardly into the gas pass **22**.

In such separately fired superheaters, the steam supplied to the unit may be either in the saturated or superheated state. For example, saturated steam may be supplied at a temperature of, for example, 375° F., or superheated steam at a temperature up to 700 F. In any event, the heat absorbing surfaces can be proportioned so that the steam during its passage through the unit will attain a final steam temperature of the order of say 1000 F. to 1100 F. The major part of the heat absorption which effects this superheating is produced by radiant emission from the high temperature combustion gases to the superheater wall tubes of the furnace **10**.

The use of fuel burners symmetrically positioned in all four furnace walls result in a distinctive zone of high temperature gases, with correspondingly high radiation capability substantially uniformly disposed within this zone. Moreover, locating the burners at the same horizontal elevation in all four furnace walls confines this high radiation zone to a relatively small proportion of the total furnace volume. By way of general illustration, and not of limitation, such a zone would correspond to the portion of the furnace volume having the vertical dimension A in FIG. 1. Heat absorption by the furnace wall tube portions lying within this zone of high radiation thus may be in the order of 100,000 B.t.u. per square foot of surface per hour.

In similar manner sections B and C, FIG. 1, designate furnace volumes which are contiguously disposed immediately above and below zone A and which may be considered as generally indicative of zones of prevailing lower gas temperature and therefore susceptible to somewhat less radiation capability than zone A, since these zones are vertically spaced from the fuel burners and their associated zone of characteristically high radiation intensity. By way of comparative illustration, the absorption rate within zones B and C may be of the order of one-half of that prevailing in zone A.

Similarly lines D and E, FIG. 1, adjoining and disposed immediately above and below zones B and C, respectively, indicate additional representations of furnace enclosures farther spaced from zone A than either zone B or C. The radiation capability within these zones D and E will be still less than the potential within zones B and C, and the rate of heat absorption by the furnace wall tubes lying within zones D and E may be but half of that occurring in the zones B and C.

Under the above conditions the furnace temperatures and the associated rates of heat absorption within the zone A, and also in the zones B and C, might be sufficient to overheat and damage furnace wall tube sections carrying superheated steam as they are customarily constructed. Such overheating is avoided in the presen unit by increasing the velocity of the steam in the tube sections located in the higher heat absorbing zones, thereby maintaining the tube metal temperatures of these sections within the safe allowable use limits dictated by practice. This velocity increase is accomplished by varying the inside diameters of the wall tube sections in the furnace zones A, B, C, D and E. For example, as shown in FIG. 3, the inside diameter of the wall tube sections within zone E may be 1⅞". In that event, the succeeding tube sections within the zone C may have, for example, an inside diameter of 1⅝" and in the next succeeding tube sections, i.e., within the zone of highest heat release and absorption rate, zone A, the inside diameter of the tube sections may be 1⅜". Similarly the tube sections in zones B and D may have inside diameters of 1¾" and 1$^{31}/_{32}$", respectively. Continuity of flow from zone to zone within a particular furnace wall tube is effected by securing, in pressure tight relation, the adjacent ends of the tube sections, so that steam entering a furnace wall lower header, as header **62**, will flow uninterruptedly upward through wall tubes **98** and discharge into furnace upper wall header **100**. This provision of differential tube inside diameters thus provides for an increase in the velocity of steam in the wall tube sections in zone C over and above the velocity in the wall tube sections in zone E. It also provides a further increase in the steam velocity in the wall tube sections of zone A over and above the velocity of the steam in the wall tube sections of zone C. In this latter zone, the highest heat absorption rate zone, the steam velocity will be at a maximum. In the zones B and D, the velocity of the steam in the wall tube sections will be successively reduced

from that prevailing in the zone A. It is recognized that the heat absorbed by the steam in its passage through the furnace wall tubes will result in some increase in the steam velocity independent of the change in tube inside diameter due to the thermodynamic relationship existing between temperature and specific volume for a given pressure; however, the tube inside diameters indicated produce an effect which substantially augments this natural characteristic.

While in accordance with the provisions of the statutes we have illustrated and described herein the best forms of the invention now known to us, those skilled in the art will understand that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by our claims, and that certain features of the invention may sometimes be used to advantage without a corresponding use of other features.

What is claimed is:

1. In a fuel fired fluid heater, walls forming a vertically elongated furnace having a row of contiguous parallel uniflow upright unbifurcated fluid heating wall tubes extending substantially the full height and width of said furnace walls and arranged to receive heat mainly by radiation, a plurality of fluid fuel burners arranged to produce a combustion zone having a high heat release rate at a location intermediate the height of said furnace wall tubes and disposed in a single relatively narrow zone transversely of the furnace and normal to the general path of gas flow through the furnace, and each of said radiantly heated fluid heating wall tubes having differential inside diameters corresponding to zones of different radiation intensities, with the inside diameters of each tube proportionally increased within zones successively more remote from and above and below the zone of highest radiation intensity in proximity to said fuel burners.

2. In a separately fired steam superheater, walls defining a vertically elongated furnace of rectangular horizontal cross-section having a gas outlet at its upper end and a row of contiguous parallel uniflow upright unbifurcated steam superheating tubes lining the vertical furnace walls substantially throughout the height and width of said furnace walls, a plurality of fluid fuel burners mounted in opposite vertical walls and arranged to produce a combustion zone having a high heat release rate at a location intermediate the height of said furnace, each of said steam superheating tubes having differential inside diameters corresponding to zones of different radiation intensities, with the inside diameters of each tube proportionally increased within zones successively remote from and above and below said combustion zone.

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