

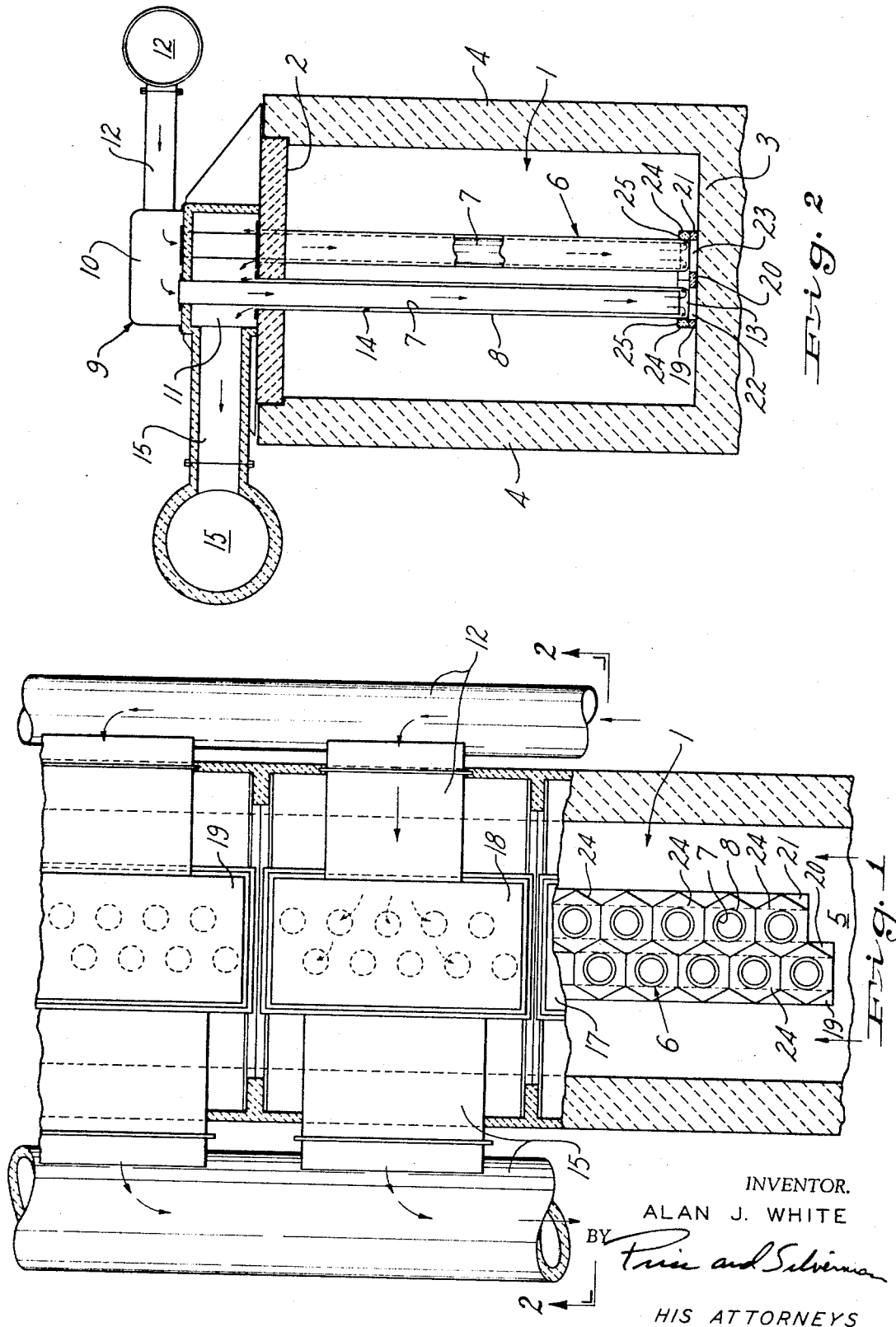
May 27, 1969

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3,446,277

SPINE RECUPERATOR

Filed Aug. 30, 1967



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3,446,277

SPINE RECUPERATOR

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Filed Aug. 30, 1967, Ser. No. 664,345

Int. Cl. F28f 13/18; F28d 7/12

U.S. Cl. 165-136

11 Claims

ABSTRACT OF THE DISCLOSURE

A multi-stage heat exchanger recuperator having a multiplicity of recuperator tubes suspended in an elongate heat exchanger chamber. The recuperator tubes, each of which has an inner and outer tube, are disposed in two lines which are parallel to the central longitudinal axis of the chamber. The tubes in one line are disposed in staggered relationship with respect to the tubes in the other line. The bottom portion of the outer tube is closed and is shielded from thermal absorption by refractory materials.

This invention relates to heat exchanger type recuperators which extract heat from combustion products or flue gases and employ the heat thus extracted to warm colder air which is introduced into the chamber within recuperator tubes. More specifically, this invention relates to systems employing a series of double concentric tubes suspended in the stream of flow of the flue gases as the carriers for the air to be heated.

Metallic recuperators employing a series of double tubes or so-called "bayonet tubes" as heat exchangers have been known for some time. A disclosure of this type of system is contained in U.S. Patent 2,332,450. This type of system is frequently employed to extract heat from flue gases which are the combustion product of industrial furnaces and the like. By means of the heat exchanger, this extracted heat is employed to elevate the temperature of cold air which will ultimately be employed in effecting combustion.

A conventional arrangement for this type of system is to provide an elongate channel through which exhausting flue gases will pass. A plurality of recuperator tubes are suspended within the chamber. The recuperator tubes, which are depending from a header box generally located above and outside of the chamber, each consist of an outer tube and an inner tube. The inner tube has its upper end connected through the header or header box with a cold air supply duct and its lower end open and terminating short of the lower end of the outer tube. The outer tube has its lower end closed and its upper end connected through the header or header box with a hot air exhaust duct. A blower is generally provided to move air down through the inner tube and up through the annular space between the inner and outer tubes. As the flue gases move through the heat exchanger chamber, the outer surfaces of the outer tubes absorb heat which is conducted to the inner surface of the outer tube. The cold air moving upward between the outer and inner tubes moves across this heated inner surface of the outer tube and gains heat. The heated air is then exhausted through the header to the hot air exhaust duct.

In the conventional arrangement of the bayonet or recuperator tubes within the heat exchanger chamber, the

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tubes are placed in rows which extend transversely substantially completely across the chamber. It is conventional practice for each of the headers to have two or more of these transverse rows of recuperator tubes depending therefrom. It is also conventional for the closed end of the outer tube to be fully exposed to the flue gases. In this type of apparatus, a major portion of the heat transfer from the flue gases to the outer tube is effected through convection, with a minor portion of the heat transfer being effected by radiation from the flue gases and re-radiation from the heat exchanger chamber walls, which are generally refractory.

Several problems have been experienced with the conventional design. One of the more serious problems has been a lack of uniform heat transfer. For example, consider the first transverse row of recuperator tubes in the chamber. The portions of these tubes which face the chamber wall will receive substantially more radiant heat from these walls than the portions not so exposed. As a result, these portions expand at a greater rate than the other portions and this results in distortion of the outer tube in this area which in turn interferes with the uniform flow ordinarily obtainable in the annular region between the two concentric tubes of uniform configuration.

A second problem encountered relates to the overheating of the cap or closed end of the outer tube which is exposed to the convective heating by the flue gases, as well as radiant heating. As the diameter of the inner tube is generally fairly close to that of the outer tube, the annular region between the two tubes through which the upward moving air travels is relatively small as compared with the passageway in the inner tube through which the downward moving cold air travels. As a result, the air moving upward in the annular region travels at an increased velocity and functions in a very efficient fashion to cool the inner surface of the outer tube by absorbing heat therefrom. As the cap end of the outer tube underlies the open end of the inner tube, however, there is no acceleration of air flow over the inner surface of the cap end and removal of heat from this portion of the outer tube is not accomplished very rapidly. This presents the severe problem of overheating in this area, which in turn increases the likelihood of burnout or failure of this section.

Another problem with the conventional systems is the matter of limited accessibility to the chamber interior for maintenance, cleaning and repair. As the transverse rows of tubes extend substantially completely across the chamber, removal of a substantial number of tubes is frequently necessary before adequate access can be obtained.

An additional disadvantage of a design which provides rows of tubes substantially completely across the chamber is the need to avoid exceeding the allowable flue gas pressure drop in the chamber.

It is an object of this invention to provide a heat exchanger recuperator which through specific tube placement and protection results in more uniform heat distribution around the recuperator tubes and reduced likelihood of thermally induced failure of the outer tube.

It is an object of this invention to provide a heat exchanger recuperator which affords improved accessibility to the chamber interior for purposes of maintenance, repair and cleaning.

It is a further object of this invention to provide a

recuperator which will effectively reduce corrosion problems in the outer tube.

It is yet another object of this invention to provide positive protection to portions of the outer tube which are most susceptible to failure.

These and other objects will be more fully understood and appreciated from the following description of the invention, on reference to the illustrations appended hereto, in which:

FIGURE 1 is a fragmentary plan view partially broken away, of a heat exchanger recuperator of this invention; and

FIGURE 2 is a fragmentary elevation taken along 2—2 of FIGURE 1.

As is shown on the drawings, the heat exchanger recuperator selected for purposes of illustration has an elongate chamber 1, which is defined by a top wall 2, a bottom wall 3 and side walls 4. In the form shown in the drawings, the bottom wall 3 and the side walls 4 are formed as a unit, with the top wall 2 being a separate member secured so as to provide a sealed chamber 1. As is indicated in the lower portion of FIGURE 1, flue gas or combustion products are introduced into chamber 1 at section 5 through any convenient means. The term "combustion products" as used herein will refer to hot exhaust gases coming from a furnace or similar combustion chamber including any dust, mill scale or other solid matter which it may contain. The combustion products will flow longitudinally through the chamber 1 and ultimately will be exhausted therefrom to a flue (not shown). As these products pass through the chamber 1 they will contact the chamber walls 2, 3, 4 and also the outer surface of recuperator tubes 6. To the extent to which the combustion products are at a higher temperature than the walls 2, 3, 4 or tube surfaces 6, the products will transmit heat to them.

Each recuperator tube 6 consists of an inner tube 7 and an outer tube 8, each of which is cooperatively secured to and communicates with a header or header box 9 which is generally disposed exteriorly of and adjacent to the chamber 1. A plurality of such recuperator tubes depend from each header box. Each of the header boxes is divided into an upper compartment 10 and a lower compartment 11, with each compartment being sealed against direct communication with the other compartment. The inner tube 7 communicates with the upper compartment 10 and may be secured thereto by any convenient means as by flanging the tube 7. Tube 7 extends through compartment 11, but does not communicate therewith, and into outer tube 8. Within outer tube 8 it passes through top wall 2 and into chamber 1. Outer tube 8 communicates with compartment 11 and is secured in such position by any convenient means as by flanging the upper portion thereof. It passes through top wall 2 and into chamber 1. Seals (not shown) are provided to prevent direct communication between chamber 1 and lower compartment 11.

In operation, a cold air source operated by suitable means for establishing cold air flow (not shown) provides cold air to upper compartment 10 by means of cold air duct 12. The cold air enters the upper portion of inner tube 7 and flows downwardly. The bottom of inner tube 7 is open, while the lower terminus of outer tube 8 is closed or capped at end 13. This permits cold air moving in inner tube 7 downwardly to flow into outer tube 8 or what for convenience of reference will be referred to as the annular portion 14 defined by the tubes 7 and 8, and move upwardly therein. The heat absorbed by the outer surface of outer tube 8, which comes primarily from radiation from the chamber walls 2, 3, 4 and combustion products moving through the chamber, as well as convection from the combustion products, is conducted inwardly to the inner surface of the outer tube 8. Cold air moving upwardly in annular portion 14 contacts this surface and absorbs heat therefrom. It will be appreciated that as the size of the annular portion 14 is substantially less than that of inner

tube 7, the air moving through portion 14 will be moving at a higher velocity than that moving through tube 7. This increased velocity will result in more rapid heat transfer from the inner surface of tube 8 to the air moving through annular portion 14. After the air has moved through portion 14 it will enter lower compartment 11 of header 9 and will be withdrawn through header 9 to duct 15 and be conveyed to its ultimate destination, which will frequently be a combustion chamber.

Unlike conventional recuperators of this type, recuperator tubes of this invention are not disposed in transverse rows which span the entire chamber width. Recuperator tubes 6 of this invention are disposed along two parallel lines which are substantially parallel to the longitudinal central axis of the chamber 1. In the preferred form, the two lines of tubes 6 are relatively close to the central axis of the chamber and the tubes in one line are in a staggered position with respect to the tubes of the other line. Also, it is preferred that spacing of the tubes 6 in a given line be constant. This equal spacing may be such that a line drawn from the central vertical axis of one tube 6 connecting it with the central vertical axis one of the two equidistant tubes of the other line closest to it (or the closest tube in the case of an end tube) the smaller of the two angles of intersection with the central axis would be about 45 to 70 degrees and preferably about 60 degrees. Another preferred spacing arrangement is to place the tubes in each line sufficiently close to each other that two lines constructed perpendicular to the longitudinal central axis of the chamber and tangent to opposed sides of a given tube in one line (not an end tube) will each intersect at least one tube in the other line. This placement may conveniently be duplicated in each successive header 16, 17, 18 so that the two lines of tubes 6 of each header are aligned with the two lines of tubes 6 in each adjacent header.

With the arrangement of this invention, longitudinal channels on either side of the two lines of tubes are provided for direct passage of combustion products through chamber 1. Products passing through the chamber 1 will pass directly on both sides of the two lines of tube 6 and a small portion will flow in between the two lines. Unlike prior systems wherein a major portion of the transfer of heat to the tubes was accomplished by convection, this system provides for a major portion of the heat transfer (occasionally as much as 90%) to be accomplished by radiation, with only a minor portion being due to convection. The radiant heat comes from both the combustion products flowing through the chamber 1, as well as reflected radiant (or re-radiated) heat from the chamber walls 2, 3, 4. As each tube is exposed to uniform heating throughout its circumference, the problems of lack of uniform heating are eliminated. Also by eliminating the transverse rows of tubes, this invention avoids the problems of maintaining the combustion products pressure drop across the tubes at a tolerable level. The great quantity of combustion products flowing directly through the chamber prevents the creation of any significant pressure drop problems.

A further advantage of this apparatus is the fact that now only the center portion of the chamber contains tubes 6, rather than substantially the entire transverse chamber area. Access for maintenance, repair and cleaning is therefore greatly facilitated, as access to either side of the tubes and each individual tube is provided.

A shift from maximum use of convective heat transfer to maximum use of radiant heat transfer results in a great reduction in the volume of combustion products impinging directly upon the recuperator tubes 6. As these products commonly contain a substantial quantity of corrosive materials, which vary according to the fuels being used, reduction of contact between the products and the tubes produces a corresponding reduction in corrosion problems.

It has been noted that with the position of recuperator

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tubes 6 contemplated by this invention, heat is received, primarily through radiation and re-radiation, uniformly around each tube. As the air rising through an inner portion 14 moves at a high velocity, the removal of heat uniformly absorbed by the outer wall is uniformly and efficiently removed from the inner surface of the outer tube and the risk of burnout is avoided. At the closed end or cap 13 of the outer tube 8, the velocity of the air is not very high and heat transfer from the tube cap 13 to the air is not effected at a high rate. The positioning of the recuperator tube 6 in the apparatus is such that supplementary positive protection of the closed end or cap 13 of the outer tube 8 may readily be provided in order to substantially reduce the amount of heat absorbed by the cap. A shielding material, preferably refractory in nature, is placed around at least a portion of the tube cap 13 to serve as a heat shield. As a major portion of the heating of the exterior tube is effected through radiation, shielding should preferably be effected circumferentially substantially completely around the cap 13. As is shown in FIGURE 2, the cap of each outer tube 8 is spaced from the lower wall 3 of the chamber 1. Shielding materials, which may conveniently take the form of refractory brick should, therefore, extend upwardly from the lower wall 3 a greater distance than the spacing between the cap 13 and the lower wall 3.

In the form of shielding selected for illustration, three lines of refractory supporting blocks 19, 20, and 21 are disposed substantially parallel to each other and to the two lines of recuperator tubes 6. Whereas lines 19 and 21 are on opposite sides of the two lines of tubes 6, line 20 is intermediate the two lines. While it is not shown in the drawings, it will be appreciated that the ends of channels 22, 23 defined by lines 19, 20, 21 are closed in suitable fashion as by similar refractory blocks. Overlying and supported on rows 19, 20, 21 are a multiplicity of refractory blocks 24, each of which has a centrally disposed orifice of greater diameter than the outer tube 8, into which a single tube cap 13 is received. Each block 24 is supported upon two of lines or rows 19, 20, 21 and provides complete circumferential shielding of the tube cap 13 and immediately overlying tube portion. In the form selected for illustration, each block 24 has a top surface, a bottom surface and six intermediate vertical outer walls which cooperate to form a hexagonal periphery. As is shown in FIGURE 2, each block 24 will have one outer wall opposed to one outer wall of each adjacent block. The nesting or fitting together of the complementary shapes of the blocks provides a substantially continuous thermal barrier at the top surface level 25 of each of the blocks. As the blocks 24 will generally all be of the same thickness, the continuous surface will lie substantially within a plane defined by the respective top surfaces. These thermal blocks 24 coupled with their supporting blocks 19, 20, 21, therefore, combine to provide effective thermal protection for the tube caps 13.

While for purposes of illustration, specific forms of shielding structures have been illustrated and discussed, it will be apparent to those skilled in the art that numerous other shielding arrangements are contemplated by this invention. For effective shielding all that is required is that the shielding material, which is preferably refractory, extend upwardly from the bottom wall 3 a greater distance than the space between the lowermost tube portion sought to be protected and the wall 3, that the shielding material be disposed in at least two lines positioned on opposite sides of the tube rows and in relatively close proximity thereto in order to effectively shield against excessive heating caused by radiation, as well as convection and conduction. In addition, it is, preferred to provide an overlying protective member to cover the area between the rows of refractory material and the outer tube 8. It is not essential that in employing this preferred structure, that single unit blocks 24 be employed. A single block having a number of tube receiving orifices

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adapted to shield a number of tubes could be provided.

It will be appreciated that while for purposes of convenience of illustration cold air flow has been illustrated as being downwardly within the inner tube and upwardly within the outer tube, this direction of flow, while preferred, is not essential and it is permissible within the scope of this invention, where desired, to allow cold air to flow downwardly within the outer tube and upwardly within the inner tube.

It will be appreciated that by carefully selecting a specific positioning of the recuperator tubes within the heat exchanger chamber and where desired providing positive thermal protection to at least a portion of the tubes, this invention solves numerous problems encountered in previously known systems. As the major portion of heating is effected by radiation and shielding is provided at the portions of thermal transfer, the problems resulting from a lack of uniform heating and a lack of uniform heat transfer have been eliminated. Also, reduced reliance on convection serves to provide a direct and substantial reduction in corrosion problems. In addition, greatly increased accessibility to the chamber interior for cleaning, repair and maintenance are provided. As a great portion of the combustion products flow directly through a passage intermediate the chamber side walls and the rows of the recuperator tubes, concern about the control of the combustion product pressure drop across the chamber is eliminated.

While for purposes of illustration the elongate heat exchanger chamber has been illustrated and described as having a substantially straight longitudinal axis, this is not essential. The elongate heat exchanger contemplated by this invention could, for example, be curved or be composed of two or more sections disposed at ninety degrees with respect to each other or any other convenient configuration. It is an additional advantage of this invention that it possesses sufficient flexibility to be adapted for use with almost any chamber configuration. The chamber is to provide a passage for flow of the combustion products and the chamber is elongate to permit longitudinal distribution of the recuperator tubes therein. Beyond that individual needs may influence chamber configuration and design.

For purposes of illustration the recuperator has been shown as having a horizontally disposed chamber with recuperator tubes depending vertically downward from the top part thereof into chamber 1. It will be appreciated that it is the thermal effectiveness that is the essence of this apparatus and, therefore, the orientation of the chamber and the wall from which the tubes depend inwardly may be varied while retaining the benefits of the invention. For example, the chamber could have a vertical longitudinal orientation with the tubes depending horizontally into the chamber. Also the cross-sectional configuration of the chamber could be round or any other non-rectangular configuration. While these changes might effect slight modifications in the thermal efficiency of the apparatus, the essence of the invention is not disturbed by their use and such use is contemplated within the scope of this invention.

Finally, while for purposes of illustration straight recuperator tubes have been shown, it will be appreciated that other shapes of tube may be employed. For example, tubes having substantially U shape may be suspended along the center of the chamber. Header boxes could be provided at either end of such U tubes. With such tubes, it would be preferable to employ but a single tube row. Numerous other tube configurations will be obvious to those skilled in the art.

I claim:

1. A heat exchanger recuperator comprising; an elongate heat exchanger chamber; means communicating with said chamber for introducing the gaseous combustion products of a furnace into said chamber;

at least one header box adjacent at least one wall of said chamber;

said header box having a plurality of recuperator tubes extending therefrom into said heat exchanger chamber, said tubes forming at least one row substantially parallel to the longitudinal axis of said heat exchange chamber;

each said recuperator tube including an inner tube and an outer tube;

said outer tube having one end communicating with said header box and having the other end closed and spaced from the adjacent wall of said chamber;

said inner tube disposed at least in major portion within said outer tube having one end communicating with said header box and the other end disposed in close proximity to the closed end of said outer tube;

a cold air supply duct communicating through said header box with one of said tubes;

a hot air discharge duct communicating through said header box with the other of said tubes;

means for establishing flow of said cold air from said cold air supply duct in a path which moves inwardly in one of said tubes of each said recuperator tube and then outwardly in the other of said tubes of each said recuperator tube toward said discharge duct;

said recuperator tubes extending from said header box being disposed within said heat exchanger chamber in at least one row and forming longitudinal unobstructed channels in said heat exchange chamber on opposite sides of said row of tubes for the direct flow of the gaseous combustion products in paths substantially parallel to said row of tubes so that a major portion of the heat transferred from said gaseous combustion products to said tubes is by radiation; and

whereby said heat exchanger recuperator is adapted to extract heat from gaseous combustion products flowing therethrough and transfer said heat to air circulating within said recuperator tubes.

2. The heat exchanger recuperator of claim 1 in which; said heat exchanger chamber has a substantially straight longitudinal axis;

said means for establishing flow of said cold air is adapted to create downward flow within said inner tubes and upward flow within said outer tubes; said recuperator tubes are disposed in two lines substantially parallel to said longitudinal axis of said heat exchanger chamber; and

said recuperator tubes in one said line are disposed in staggered relationship with respect to the recuperator tubes in the other said line.

3. The heat exchange recuperator of claim 2 in which said chamber is of substantially rectangular cross-section and having more than one of said header boxes with the recuperator tubes of each of such header boxes being so disposed that they are longitudinally aligned with the tubes of each adjacent header box to establish two longitudinal lines of tubes parallel to said central axis.

4. The recuperator of claim 3 in which the recuperator tubes within each header box are substantially equally spaced from the adjacent recuperator tubes within the same line of said header box and the spacing is sufficiently small, that at least one of two lines constructed perpendicular to the longitudinal central axis of said chamber and tangent to opposed sides of one of said recuperator tubes of one line will intersect one recuperator tube of the other line.

5. The recuperator of claim 4 in which a line connecting the vertical central axis of one said tube with the vertical central axis of a nearest adjacent tube of the other line will intersect the longitudinal axis of said chamber with the smaller of the two angles of intersection being approximately 45 to 75 degrees.

6. The recuperator of claim 2 in which refractory shielding means prevents substantial thermal transfer to at least a portion of each of said outer tubes and said

shielding means extends upwardly from the lower wall of said heat exchanger chamber beyond each said closed end of said outer tube and is disposed in relatively close proximity to each said outer tube.

7. The recuperator of claim 6 in which said refractory means encompasses substantially entirely each said closed end of said outer tube.

8. The recuperator of claim 7 in which said refractory means comprises;

three elongate parallel rows of refractory supporting members;

two outer rows of said supporting members disposed on opposite sides of said recuperator tubes and closely adjacent thereto;

one inner row of said supporting members disposed intermediate said outer two rows and underlying the space between said two lines of refractory tubes; a multiplicity of refractory blocks each having at least one centrally disposed orifice of greater diameter than said other tubes;

each said refractory block supported on at least two rows of said supporting members in a position having each said orifice underlying one of said outer tubes with the closed end of each said tube extending into said orifice of said block.

9. The recuperator of claim 7 in which each refractory block has a single orifice, a top surface, a bottom surface and six intermediate vertical outer walls which cooperate to form a hexagonal periphery, each refractory block having one outer wall opposed to a like outer wall of each adjacent refractory block to establish a substantially continuous refractory surface.

10. The recuperator of claim 9 in which said substantially continuous refractory surface lies substantially within a plane defined by the top surfaces of said refractory blocks.

11. A heat exchanger recuperator comprising; an elongate heat exchanger chamber;

means communicating with said chamber for introducing flue gases at an elevated temperature into said chamber for flow therethrough;

a cold air supply duct extending longitudinally along said heat exchange chamber;

a hot air discharge duct extending longitudinally along said heat exchange chamber;

a plurality of recuperator tubes extending into said heat exchange chamber in at least one row substantially parallel to the longitudinal axis of said heat exchange chamber;

each said recuperator tube including an inner tube and an outer tube;

said outer tube having one end connected to one of said ducts and having the other end closed and spaced from the adjacent wall of said chamber;

said inner tube disposed at least in major portion within said outer tube and having one end communicating with said other duct and the other end disposed in close proximity to the closed end of said outer tube;

means for establishing flow of said cold air from said cold air supply duct in a path which moves inwardly in one of said tubes of each said recuperator tube and then outwardly in the other of said tubes of each said recuperator tube toward said discharge duct;

said recuperator tubes being disposed within said heat exchange chamber in at least one row and forming longitudinal unobstructed channels in said chamber on opposite sides of said row of tubes for the direct flow of said flue gas in paths substantially parallel to said row of tubes so that a major portion of heat transfer from said gaseous combustion product to said tubes is by radiation; and

whereby said heat exchanger recuperator is adapted to extract heat from said flue gases flowing there-

through and transfer said heat to air circulating with-
in said recuperator tubes.

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U.S. Cl. X.R.

165—142; 263—20