

Aug. 22, 1939.

L. KOOISTRA

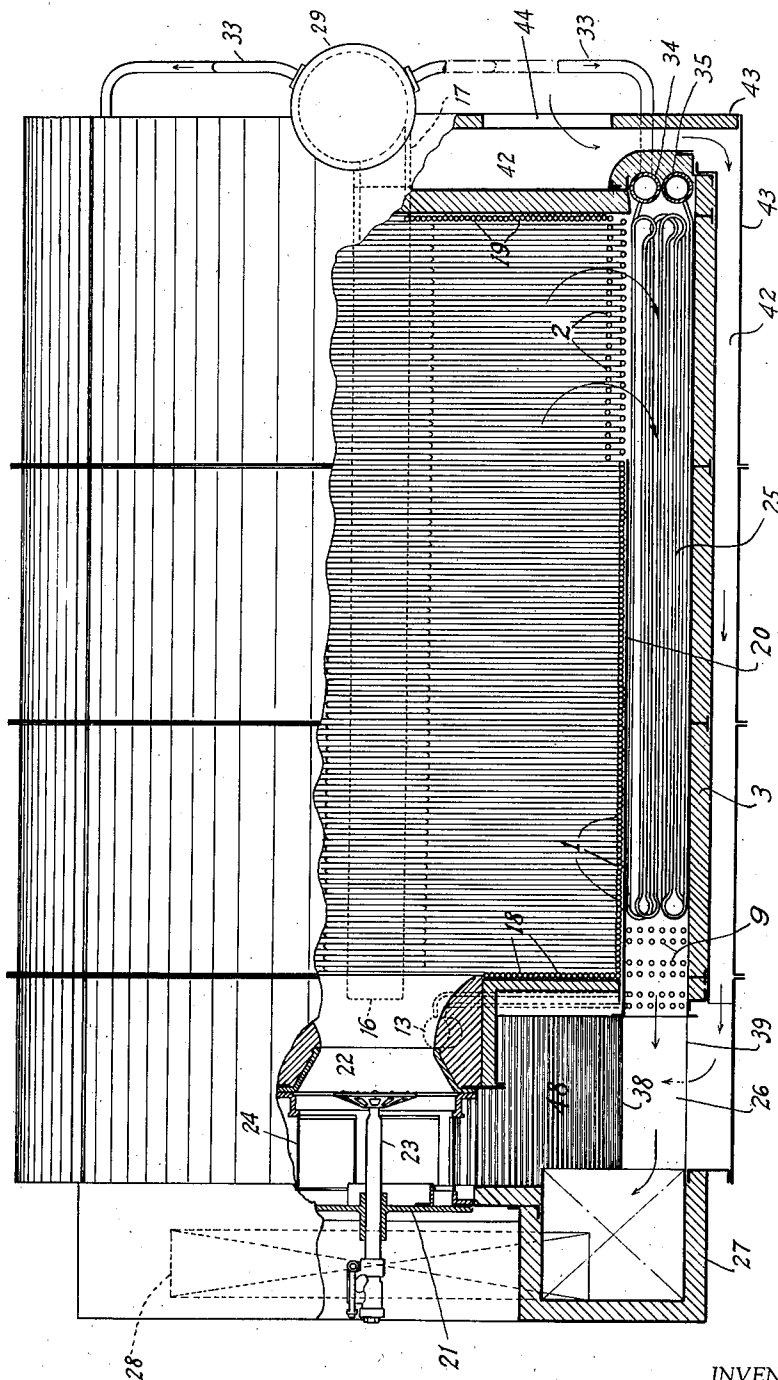
2,170,145

HEAT EXCHANGER

Filed Dec. 20, 1935

4 Sheets-Sheet 1

Fig. 1



INVENTOR.
Lambert Kooistra
BY *Paul R. Hancock*
ATTORNEY.

Aug. 22, 1939.

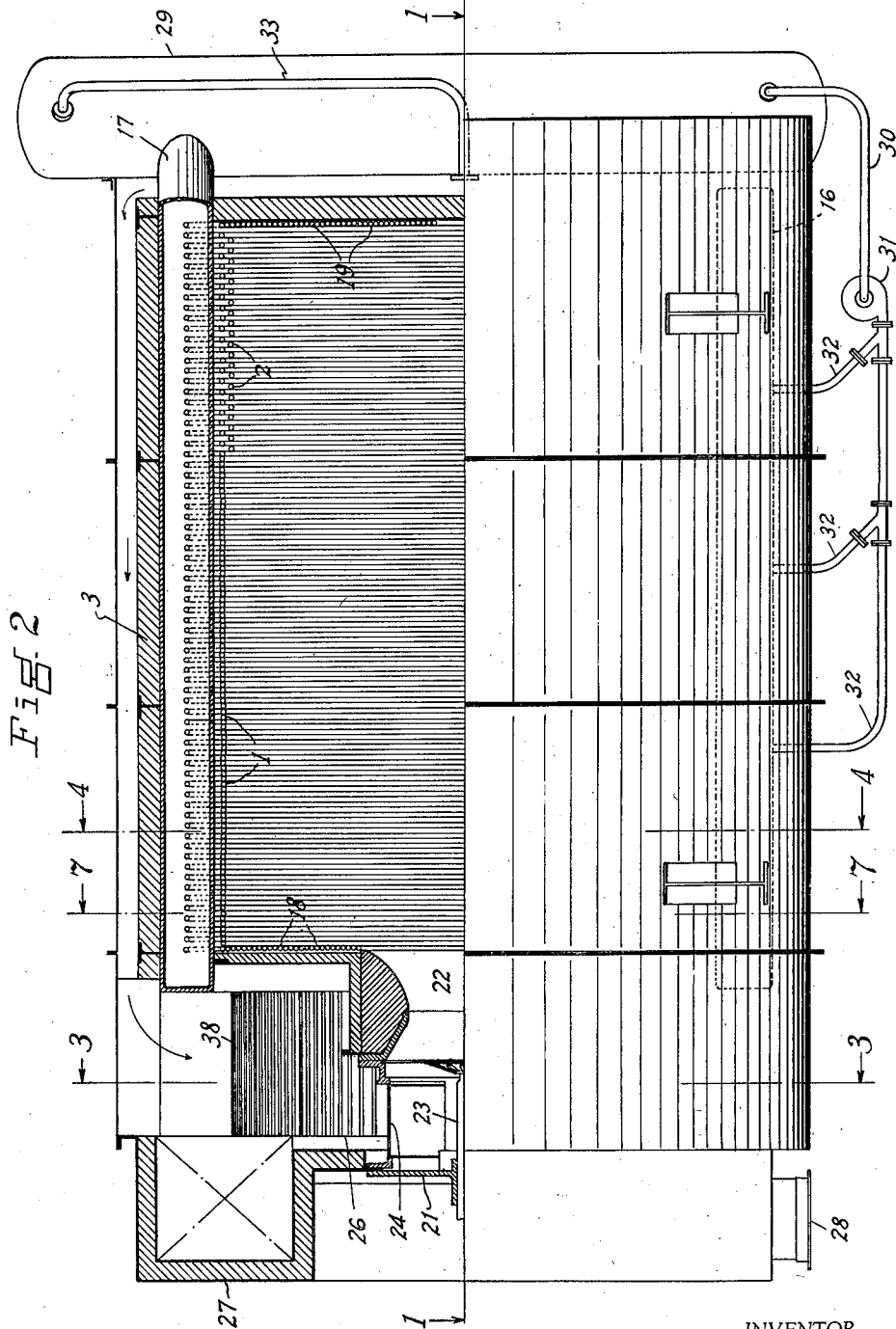
L. KOOISTRA

2,170,145

HEAT EXCHANGER

Filed Dec. 20, 1935

4 Sheets-Sheet 2



INVENTOR.
Lambert Kooistra
BY *Paul R. Newcomb*
ATTORNEY.

Aug. 22, 1939.

L. KOOISTRA

2,170,145

HEAT EXCHANGER

Filed Dec. 20, 1935

4 Sheets-Sheet 4

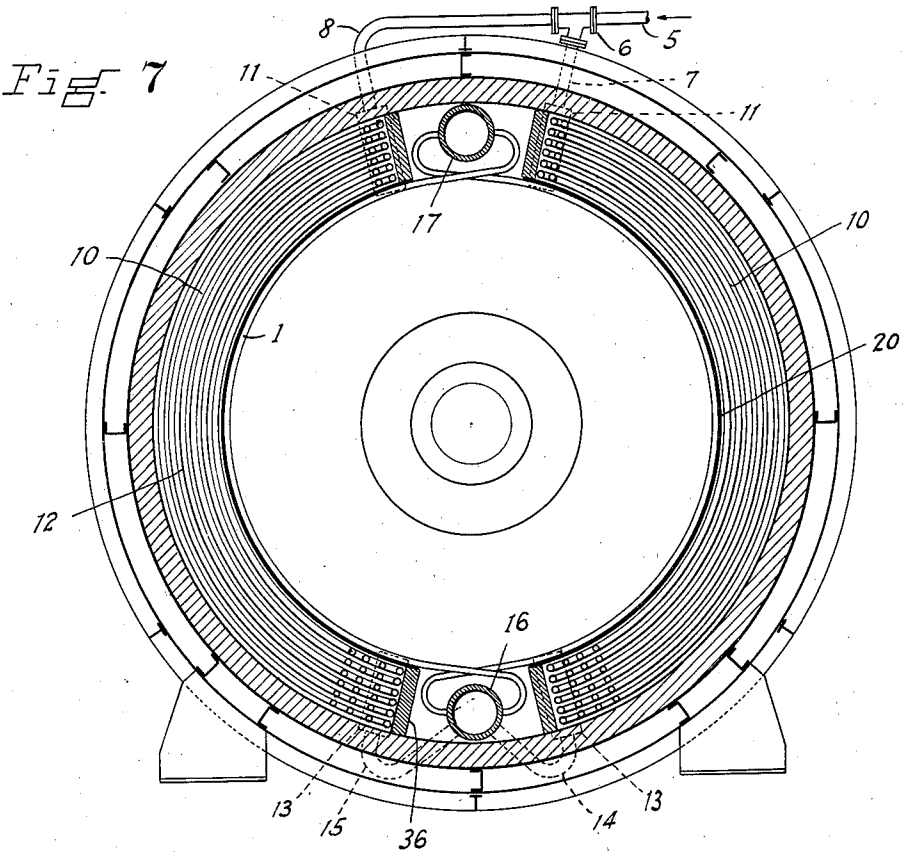
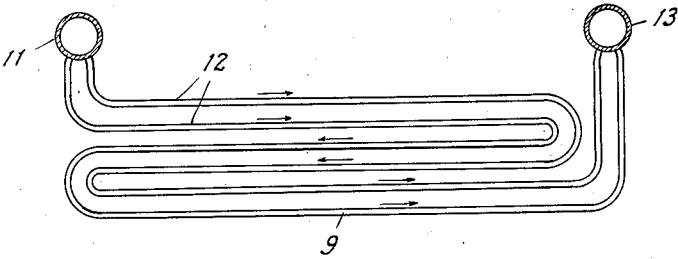


Fig 8



INVENTOR.
Lambert Kooistra
BY *Paul R. Howard*
ATTORNEY.

UNITED STATES PATENT OFFICE

2,170,145

HEAT EXCHANGER

Lambert Kooistra, Barberton, Ohio, assignor to
The Babcock & Wilcox Company, Newark, N. J.,
a corporation of New Jersey

Application December 20, 1935, Serial No. 55,378

14 Claims. (Cl. 158-1.5)

This invention is a heat exchange apparatus inclusive of means for transfer of heat from a gas to a liquid, and means for transfer of heat between fluids of the same physical character.

The invention as disclosed herein has as one feature thereof a heat exchange device in which there is a transfer of heat from one gaseous fluid to another, as for example, in the indirect heating of combustion air by means of hot gases from a furnace.

A further object is to provide an air heater in which the air and gas are caused to pass through separate adjoining passages on opposite sides of a heat-conductive dividing wall.

Another object is to provide an air heater formed of curved plates defining passages for the flow of gas and air in separate streams, and maintaining for each fluid a substantial uniformity of cross-sectional area of individual flow passages from entrance to outlet ends.

An additional object is an annular assembly of air heater plates, the plates being spaced circumferentially, and passages between the plates permitting the flow of one fluid generally parallel to the central axis, and the flow of the other fluid in a generally radial direction, that is, from one circumferential boundary of the assembled plates toward the other circumferential boundary.

A still further object is to provide in an air heater formed of plates annularly arranged, a curvature of plates which will permit a cross-sectional area of passage at the inner circumference at least as great as that at the outer circumference, and for specific consideration, the maintenance of a substantial uniform flow area from one circumference to another.

The drawings illustrating my invention are as follows:

Fig. 1—plan view partly in section showing a boiler, its furnace and associated air heater.

Fig. 2—side elevation partly in section, of the same related parts as in Fig. 1.

Figs. 3 and 4—transverse half-sections of the boiler unit taken along lines 3-3 and 4-4 respectively of Fig. 2, Fig. 3 illustrating the circular formation of furnace and the annular arrangement of air heater, and Fig. 4 completing the circular formation of the furnace and indicating the arcuate arrangement of superheater tubes.

Fig. 5—an enlarged isometric and fragmentary view of the air heater showing the passages for gas and air.

Fig. 6—a diagram indicating the development of a suitable curve for the air heater plates.

Fig. 7—sectional view, taken on line 7-7 of Fig. 2, showing the symmetrically arranged groups of economizer tubes.

Fig. 8—a developed view showing the return-bend formation of economizer tubes.

As disclosed in the drawings, the structure embodying my invention comprises a special high pressure boiler unit suitable, for example, for mobile service such as in yachts or other small vessels, or for somewhat more specialized service as, for instance, in airplanes, or wherever a compact light weight and efficient arrangement is either desired or required.

The general formation of the unit is cylindrical, the furnace combustion chamber being centrally arranged and circumscribed by rows of vapor generating tubes 1 and 2. An outer cylindrical wall 3 spaced from the rows of generating tubes, provides an annular space 4 for the return flow of furnace gases and the accommodation of additional heating surface over which the hot gases flow after leaving the furnace chamber.

The boiler is designed for forced circulation of fluid through the economizer and vapor generating sections in series, the supply of liquid being delivered by means of a feed pump (not shown) and entering the system through inlet pipe 5. The liquid is conducted through branched fitting 6, pipe connections 7 and 8 to the economizer 9 which is located at one end of the annular space 4 and is arranged in sections 10 which are symmetrically disposed on opposite sides of the unit.

Each economizer section comprises an inlet header 11, tubes 12 and an outlet header 13, a plurality of tubes being connected to each header to provide a number of flow paths in parallel, and having their intermediate portions bent back and forth across the stream of heating gases. In the sectional view Fig. 7, for example, six rows, consisting of two tubes each are shown connected to each of the headers 11 and 13, thus providing twelve parallel paths for the flow of fluid in each section, and twenty-four parallel paths for the entire economizer. The rows of economizer tubes are curved as shown in Fig. 7 to conform to the shape of the annular space 4, but for clarity of disclosure, a developed view is included as Fig. 8 to show the return-bend formation of the tubes in each row. The liquid entering the tubes from inlet headers 11 is advanced through the tubes and into outlet headers 13 in a direction which is generally counter-current to the flow of the heating gases through annular space 4.

The heated fluid from the economizer is delivered through suitable connections 14 and 15

to the inlet header 16 of the boiler and which header is located within the annular space 4 at the bottom of the furnace. Vapor generating tubes 1 and 2 are connected at one end to inlet header 16 and at the other end to outlet header 17, the tubes being formed in helical coils providing a multiplicity of series flow paths in parallel for the forced flow of the heated fluid from inlet header 16 to outlet header 17.

Additional groups of vapor generating tubes 18 and 19 at opposite end walls of the furnace, are also connected in parallel between the headers 16 and 17, each group consisting of flat coils of tubes, with the number of turns for each coil being so selected as to provide individual flow paths having substantially the same resistance to fluid flow as individual coils of tubes 1 and 2.

The generating tubes 1 at the front portion of the furnace are closely spaced and arranged in a single row, while the generating tubes 2 toward the rear of the furnace are arranged in two rows, the convolutions of each row being spaced and those of the two rows staggered to provide spaces between the tubes for the escape of combustion gases from the furnace. A cylindrical shell 20 surrounding the closely spaced furnace tubes 1, completes the seal against the escape of furnace gases between tubes at this location. A fuel burner 21, of a type well known for the combustion of fuel in suspension, is mounted in the burner opening 22 at the front of the furnace and, as shown, includes a centrally arranged fuel pipe 23 and an air register 24 having dampered openings in its peripheral wall for entrance of combustion air. The gases of combustion travel longitudinally toward the rear of the furnace, passing between the tubes 2 into the annular space 4, and in their flow through the annulus toward the front end, the gases contact in sequence the superheater tubes 25, economizer tubes 12 and air heater 26, finally leaving the setting through a circular breeching 27, having a suitable discharge opening 28 in its outer wall.

A stand-pipe or separator 29 is disposed at the rear of the unit and outlet header 17 makes connection to the same for tangential entry of vapor and liquid discharged from the furnace tubes 1, 2, 18 and 19. The separator 29 serves to accumulate the entering mixture of steam and water and as a reservoir for liquid supply to the vapor generating tubes. A water level is normally carried in the separator at about the center line of the furnace, water being taken from the lower portion of the separator and fed through pipe 30 to the circulating pump 31, and being delivered through pipes 32 to the inlet header 16.

The mixture entering the separator 29 is divided thereby into its constituents, the liquid being retained in the lower portion and the vapor leaving through tube connections 33 to the superheater inlet headers 34. The superheating surface is symmetrically arranged on opposite sides of the vertical center-line of the unit and occupies a portion of the annular space 4, the superheater tubes 25 extending longitudinally of the furnace axis and being looped back and forth to form continuous flat coils radially arranged within the annular space and connected at one end to inlet headers 34 and at the other end to outlet headers 35. Walls 36 are positioned at the extremities of the groups of superheater tubes, forming dividing walls between the superheater and economizer tube compartments and the spaces in which the inlet and outlet headers

16 and 17 are located. The superheater headers are bent to conform to the curvature of the annular space 4 within which they are preferably located, suitable connections (not shown) being made to the outlet headers 35 for delivery of the superheated vapor to the point of use.

Referring now to the air heater 26, this comprises curved plates 37, of a heat-conductive material such as metal, which are spaced apart and assembled in annular formation at the front of the furnace, the assembly having a radial dimension between inner and outer cylindrical boundaries 38 and 39 approximately equal to the radial dimension of the annular space 4. The alternate spaces between plates are closed at their inner and outer ends by suitable closure pieces 40 leaving their longitudinal ends open for the passage of hot products of combustion or exhaust gases in their travel through the air heater from annular space 4 to the breeching 27. The remaining spaces between plates are closed only at their longitudinal ends, preferably by separate closure pieces 41, leaving those spaces open at the cylindrical boundaries 38 and 39 for the entrance of relatively cool air at 39 and exit of heated air at 38, from whence it is delivered to the burner, and ultimately the furnace, for combustion purposes. The plates may be spaced apart at equal distances, or if desired, at unequal distances to provide, for example, passages of greater cross-sectional area for the heating fluid than for the fluid which is being heated. Furthermore, the air heater may extend through an arc less than 360°, or may even be made in sections spaced apart circumferentially, each section comprising an assembly of spaced plates to form the passages for gas and air. In the combination shown, and before reaching the aforesaid plate air heater, the air absorbs a certain amount of heat from the walls of the setting by flowing through the space 42 between the setting walls and an outer casing 43 in which opening 44 is provided for the entrance of cold air.

It will be readily understood that with the use of flat plates radially arranged, and for a given space between plates at the outer boundary 39, the space between plates at the inner boundary 38 would be considerably less, so that for the flow of air as described, the flow area provided for the heated air would be less than that for relatively cold air, which would be contra to the principle that the heated air requires more space if friction is to be minimized. In order to secure a space of substantially uniform area throughout, plates of special curvature are therefore employed, instead of flat plates, the preferred form of curve being the involute as developed in Fig. 6.

Referring to Fig. 6, the diagram follows the usual geometric method of laying out such a curve and with a brief description will therefore be readily understood. The circles 38a and 39a represent the inner and outer circumferential boundaries of the air heater plate assembly. Line AB is a diameter of the base circle 38a whose center is at C and line Bb, drawn at right angles to AB is equal in length to the semicircumference of the circle. Line Bb is divided into a convenient number of equal parts as indicated at b-b1, b1-b2, b2-b3 and so forth. The same number of equal divisions of the semicircumference are indicated at points I, II, III, etc., and tangents to the circle are drawn through the points. Distance I-aI is made equal to circumferential distance b-b1, II-aII equal to b-b2, 75

III— a III equal to $b-b_3$, etc., these points determining the involute as desired. The diagram shows the method repeated for two additional curves so that altogether three successive plates 45, 46 and 47 of the air heater assembly are represented. Both wide and narrow spacings have been indicated to further clarify the disclosure. By this method of plotting the involute, the curves intersect any given tangent to the circle at distances differing by the amount that the curves are circumferentially spaced at the base circle 38a. These tangents are normal to the curves at the points of intersection and are a direct measure of the spacing between plates which remains constant for all circumferences. It is therefore possible by using plates of involute curvature to select a desirable minimum spacing at the inner circumference 38 and maintain the same distance between plates for all locations up to and including the maximum diameter at 39. The intersection of the plates with the cylinder 39 will indicate greater circumferential spacings but these are not to be confused with the true distances of separation which are measured normal to the surfaces of the plates. With circle 38a equal in diameter to the inner diameter of the assembled plates, the streams of heated air are directed radially toward the burner 21 and under some conditions the converging streams thus produced might set up eddy currents in the space 48 between the air heater and the burner, and interfere with the satisfactory delivery of air to the burner. A non-radial delivery may readily be provided with plates of involute curvature which will cause the streams to enter the space 48 tangentially, thus producing a whirling effect on the body of air as it moves inwardly toward the burner. The tangential delivery of parallel, non-converging streams is accomplished by selecting an inner diameter 38 for the assembled plates which is greater than the diameter of base circle 38a, or conversely, developing the involute from a base circle which is smaller than the inner diameter 38. The angle at which the streams enter the space 48, that is, their deviation from a radial direction, may be varied over a comparative wide range to suit the requirements of particular cases.

I claim—

1. Apparatus for heating air for the combustion of fuel in suspension, a burner receiving said air circumferentially of its axis, and means forming interspersed paths for the flow of air and heating gases through said apparatus and including curved plates for guiding the air in streams distributed circumferentially of the burner axis.

2. An air heater of hollow cylindrical formation, a fuel burner arranged concentrically thereof, said air heater having means comprising curved plates arranged to define separate interspersed passages for the flow of combustion air and a heating medium and to cause heated air to be discharged toward said burner in tangentially directed streams.

3. An air heater comprising annularly arranged spaced plates forming alternate passages for the flow of fluids of different temperatures in a plurality of streams, means causing one fluid to flow parallel to the central axis of the plate assembly, and other means to cause a second fluid to enter its passages at a location remote from the axis and to leave the passages in non-radial streams at a location nearer said central axis.

4. In combination, a furnace chamber, a burner

positioned in a wall thereof and having inlets for combustion air circumferentially of the burner axis, an air heater adjacent and at least partially surrounding said inlets having means including plates forming interspersed passages for the flow of exhaust gas and combustion air therethrough in heat exchange relation, and means causing the gas and air to flow through separate passages, some of said passages being formed to direct the air therethrough in streams generally transverse of the burner axis and to deliver heater air toward said burner in predetermined increments distributed about said axis.

5. In combination, a furnace chamber, a burner positioned in a wall thereof and having inlets for combustion air circumferentially of the burner axis, an air heater adjacent and at least partially surrounding said inlets having means including plates forming interspersed passages for the flow of exhaust gas and combustion air therethrough in heat exchange relation, and means causing the gas and air to flow through separate passages, some of said passages being formed to discharge heated combustion air from said heater in streams generally transverse of the burner axis and to deliver said air toward said burner in predetermined increments distributed about said axis.

6. A fuel burner receiving heated air circumferentially of its axis, an air heater having plates circumferentially spaced about said axis, means forming combustion air flow passages between said plates, and means for heating air flowing through said passages by gaseous products of combustion from said burner, said passages being formed and arranged to discharge the heated air toward the burner transversely of its axis in streams distributed circumferentially thereof.

7. A fuel burner receiving combustion air circumferentially of its axis, and heating means supplying air in substantially uniform quantities throughout the circumference of said burner, said means including spaced plates of substantially involute curvature defining separate interspersed flow passages for combustion air and hot products of combustion within said heating means, and said passages being formed and arranged to direct the air and products of combustion through the respective passages in transversely related directions.

8. A heat exchanger comprising spaced plates arranged in annular formation and having opposite edges thereof at the inner and outer circumferential boundaries of said formation, and means forming fluid-flow passages between said plates including passages of greater length from one boundary to another than the radial distance between said boundaries, the plates between which said last named passages are formed being of involute curvature to provide passages of uniform flow-area for fluid flowing in the direction of said greater length.

9. A heat exchanger comprising spaced plates arranged in annular formation and having opposite edges thereof at the inner and outer circumferential boundaries of said formation, and means forming passages between said plates for fluid-flow in transverse directions, said plates being of substantially involute curvature to provide passages of uniform cross section and of greater length from one boundary to another than the radial distance between said boundaries.

10. An air heater of hollow cylindrical formation, a fuel burner arranged concentrically thereof, said air heater having means forming

passages for the flow of fluids therethrough in heat exchange relation, said passages being interspersed circumferentially and each being separate from an adjoining passage, means for directing a heating fluid through some of said passages, and means for directing air to be heated through other passages, said air heater being arranged to discharge the heated air toward said burner through outlets formed at the inner circumference of said formation.

11. An air heater of hollow cylindrical formation, means for burning fuel arranged concentrically thereof, said air heater having means comprising curved plates arranged to define separate interspersed passages for the flow of combustion air and a heating medium, and means for discharging heated air from said heater toward said fuel-burning means in tangentially directed streams.

12. An air heater of hollow cylindrical formation, a fuel burner and its combustion chamber arranged concentrically thereof, said air heater having means comprising curved plates arranged to define separate interspersed passages for the flow of combustion air and hot products of combustion, and means for discharging heated combustion air from said heater toward said burner and chamber in tangentially directed streams.

13. An air heater comprising annularly ar-

anged spaced plates of involute curvature forming alternate passages of uniform cross-section for the flow of fluids of different temperatures in a plurality of streams, means causing one fluid to flow parallel to the central axis of the plate assembly, and means to cause a second fluid to enter its passages at one circumferential boundary of said annularly arranged plates and to leave the passages in non-radial streams at the other circumferential boundary.

14. In combination, a combustion chamber, a burner arranged at one end thereof, a pair of annular compartments surrounding said chamber, the inner compartment being connected to said chamber at the end opposite said burner to receive exhaust gases from said chamber, the outer compartment forming an air passage co-extensive with the chamber and intermediate compartment, a combustion air heater at the burner end of said compartments having separate exhaust gas and combustion air flow passages in communication with said compartments, and means delivering exhaust gases and combustion air from said compartments to the respective passages, said air heater having its air passages positioned and formed to direct the heated air in a plurality of streams toward the axis of said burner.

LAMBERT KOOISTRA.