

June 27, 1961

F. W. RIEHL

2,989,952

COMBUSTION AIR PREHEATER

Filed Dec. 23, 1957

4 Sheets-Sheet 1

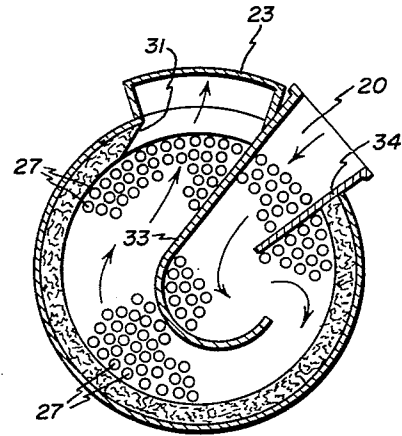
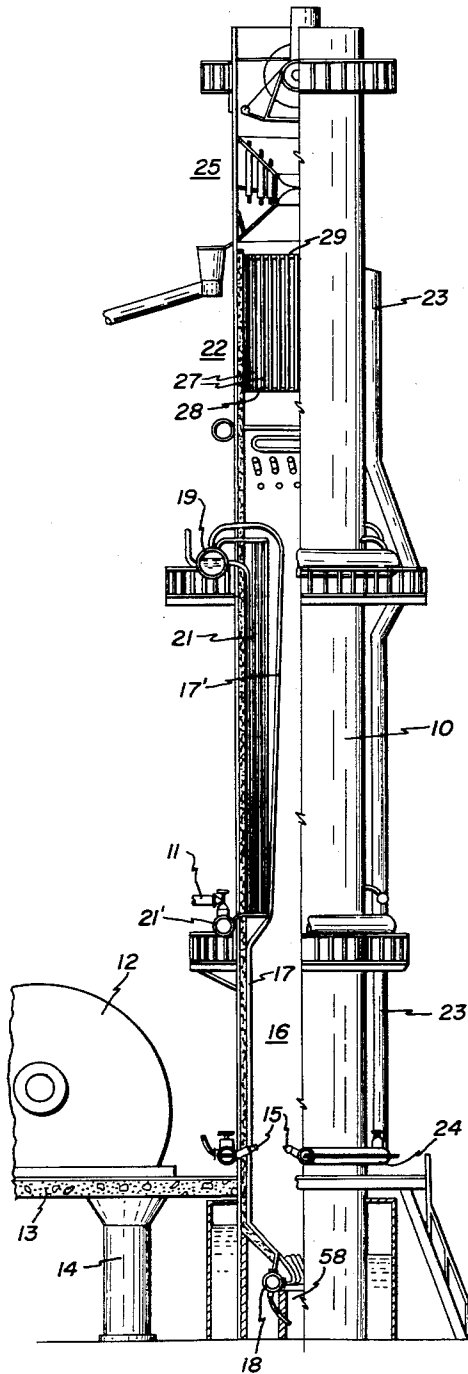


Fig. - 2

Fig. - 1

INVENTOR.
Frederick W. Riehl

BY

McBrew & Edwards

ATTORNEYS

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F. W. RIEHL

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4 Sheets-Sheet 2

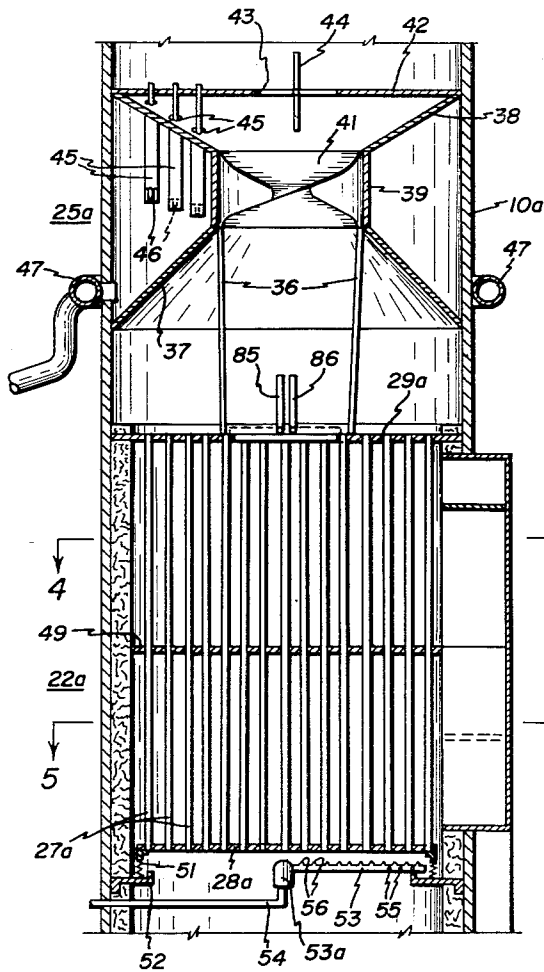


Fig. -3

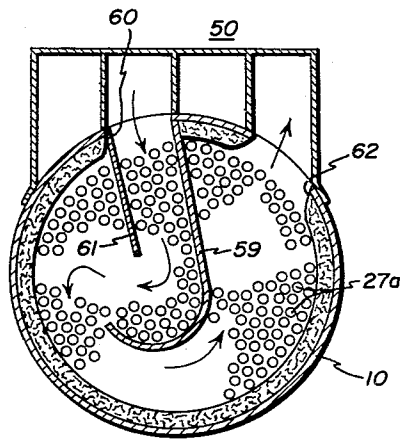


Fig. -4

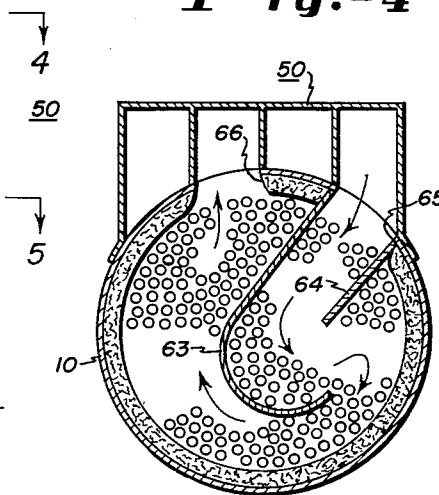


Fig. -5

INVENTOR.
Frederick W. Riehl

BY

McGraw & Edwards

ATTORNEYS

June 27, 1961

F. W. RIEHL
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4 Sheets-Sheet 3

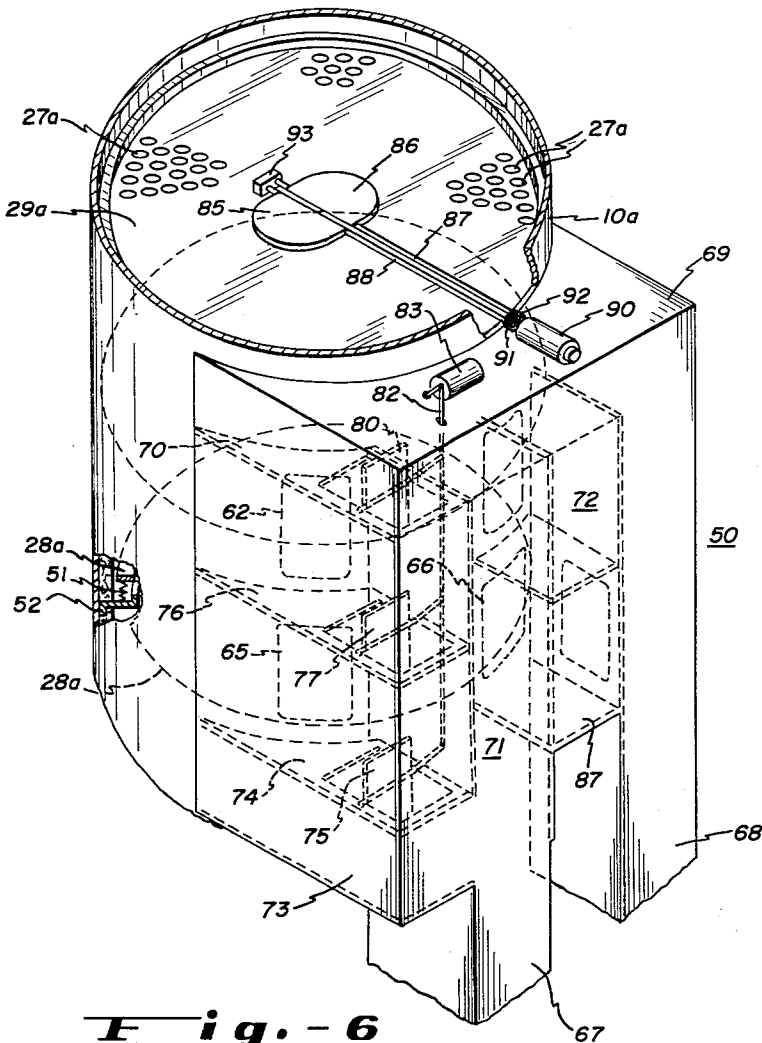


Fig. - 6

INVENTOR.
Frederick W. Riehl
BY
McBrew & Edwards
ATTORNEYS

June 27, 1961

F. W. RIEHL

2,989,952

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4 Sheets-Sheet 4

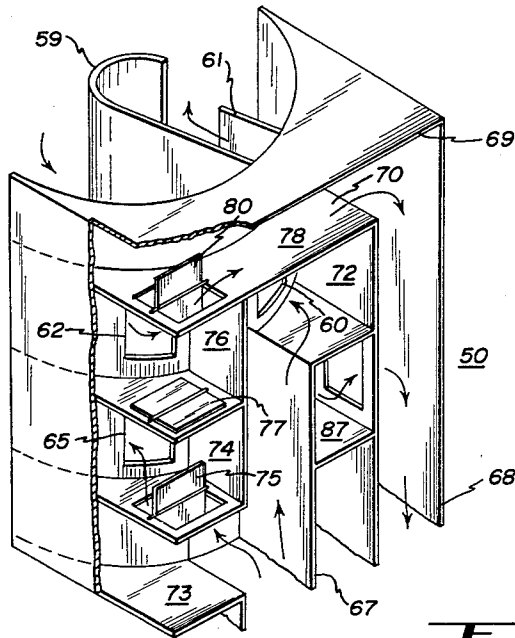


Fig. - 7

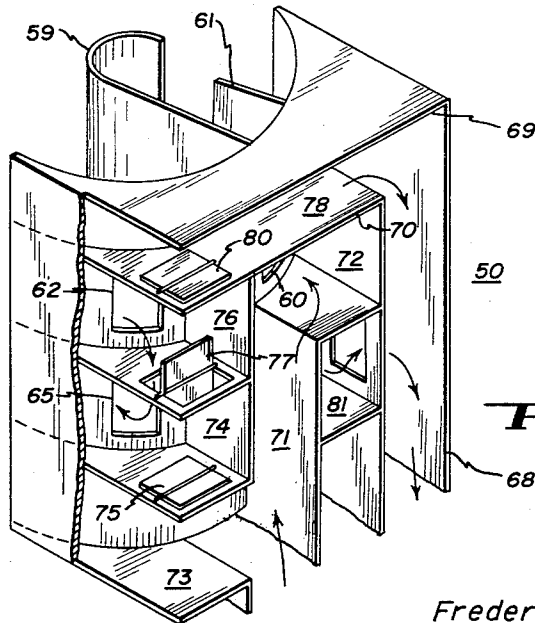


Fig. - 8

INVENTOR.
Frederick W. Riehl

BY
McGraw & Edwards

ATTORNEYS

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2,989,952

COMBUSTION AIR PREHEATER

Frederick W. Riehl, 2347 Albion St., Denver, Colo.
Filed Dec. 23, 1957, Ser. No. 704,449
9 Claims. (Cl. 122-1)

This invention relates to air heating equipment and particularly to an improved air preheater for heating air supplied to the furnaces for combustion within the boilers of power plants.

The present application is a continuation-in-part of the present inventor's parent application Serial No. 210,417 filed February 10, 1951 which was issued on December 24, 1957 as Patent No. 2,817,321, and of a divisional application thereof, Serial No. 601,670 filed August 2, 1956 now abandoned.

Various types of heat exchangers have been employed heretofore for preheating the air supplied to the combustion apparatus of power plants. While these preheaters have been satisfactory for specific purposes and within predetermined ranges of operation, it is desirable to provide improved apparatus to secure more effective use of the temperature gradients available and to provide a greater degree of control of the temperature of the preheated air together with assuring a minimum pressure drop of air and gas flow. Accordingly it is an object of this invention to provide an air preheater of improved and efficient design.

It is another object of this invention to provide an improved air preheater for boiler furnaces and the like which affords more effective control of the temperature of the preheated air over wide ranges of heat loads.

It is a further object of this invention to provide an improved air preheater for boiler furnaces and the like which affords variable control of the heated air temperature.

In carrying out the objects of this invention in one embodiment thereof a preheating unit is provided which comprises a multiplicity of straight gas tubes arranged vertically in the gas flow passage and sealed in opposite end plates, the space between the plates and around the tubes providing an air heating passage. The air heating passage is provided with an inlet and an outlet substantially coextensive with the length of the tubes and located in the sides of the preheater together with a baffle arrangement for directing the air to be heated about the tubes transversely of the direction of passage of the combustion gases. The baffle arrangement is further constructed to provide a steadily increasing cross sectional area for the air path from the inlet to the outlet and thus to provide increased volume for the heated and expanded air. In another embodiment the arrangement of air and gas passages is similar to that of the first embodiment and includes a division of the air circulating zone into two separate compartments in which the circulating baffle arrangement is opposite so that in one compartment the air to be heated flows around the tubes in an opposite direction to that of the other compartment. In addition an air damper control is provided so that the two compartments may be connected for either series or parallel flow, the flow paths being selected so that the loadings of the two compartments are substantially equal. Further control of the preheater is effected by a damper arranged to shut off selected ones of the gas tubes for securing more effective use of the gas tube surface during light loads.

The features of novelty which characterize the invention will be pointed out with particularity in the claims annexed to and forming a part of this specification. The invention itself, however, together with further objects and advantages thereof, will be better understood upon

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reference to the following description taken in connection with the accompanying drawings in which:

FIG. 1 is an elevational view partly in section of a turbine power plant boiler provided with a preheater embodying this invention;

FIG. 2 is a sectional view along the line 2-2 of FIG. 1 showing the preheater construction;

FIG. 3 is an enlarged vertical section view of a preheater similar to that shown in FIG. 1 including a modification of the invention;

FIG. 4 is a sectional view along the line 4-4 of FIG. 3;

FIG. 5 is a sectional view along the line 5-5 of FIG. 3;

FIG. 6 is an enlarged perspective view partially broken away showing the air preheater of FIG. 3; and

FIGS. 7 and 8 are perspective views similar to FIG. 6 illustrating the two conditions of air flow of the preheater.

Referring now to the drawings the power plant boiler and stack assembly illustrated in FIGS. 1 and 2 is the same unitary stack and boiler as that disclosed in the above-identified parent and divisional applications. The power plant as illustrated in FIG. 1 comprises a combined boiler and stack assembly arranged in a vertical cylindrical shell 10 which acts both as a supporting structure for the boiler and auxiliary units and as the stack. Steam generated in the assembly 10 is discharged through an outlet 11 to a steam turbine 12 through suitable supply lines which have not been illustrated. The turbine 12 is mounted on a platform 13 supported on columns 14 immediately adjacent the boiler assembly 10. A plurality of burners 15 which may employ either gaseous or liquid fuel are arranged in a ring about the lower portion of the boiler which provides a combustion zone 16. The inside of the cylinder 10 is lined with water tubes 17 which provide the active boiler surface and extend from a lower header or mud drum 18 to an upper steam drum 19, certain of the tubes 17 being bent out as indicated at 17' to provide screen tubes which protect banks of superheater tubes 21 from the intense heat of the hot combustion gases rising through the center of the stack. The superheater tubes 21 connect the steam drum 19 and a toroidal superheated steam header 21 arranged about the outside of the stack about midway between the drums 18 and 19, and the discharge conduit 11 is connected to the superheater header 21' to supply superheated steam to the turbine. An air preheater 22 is provided in the stack 10 above the boiler zone, the stack providing the side walls or enclosure of the preheater. Fresh air supplied to the heater through a side inlet 20 is connected through the air heater and thence to a passage 23 and downwardly to a toroidal air supply manifold 24; the manifold extends about the stack adjacent the burners 15 and is connected to supply the preheated combustion air to the burners. The combustion gases rising through the stack pass through the air preheater 22 and then are conducted through a dust collector or fly ash removal section 25 and thence out the top of the stack. As illustrated the preheater 22 comprises a multiplicity of vertically arranged parallel gas tubes 27 which lie in the path of the hot combustion gases rising through the stack and are sealed into lower and upper plates 28 and 29 so that all the gases rising through the stack must pass through the tubes 27. The great number of small tubes 27 assures a large heat transfer surface while providing ample gas flow capacity without requiring that the tubes have great length. The plates 28 and 29 divide the space about the tubes into a separate compartment and as shown in FIGURE 2 this compartment is in open communication with the intake connection 20 and with a discharge connection or outlet 31 which conducts the heated air directly into the conduit 23. The inlet 20 and the outlet 31 extend for substantially the full length of the tubes 27 and are

so arranged that the fresh air admitted to the inlet 20 is directed through a path of expanding cross section around the tubes 27. The path of the air through the preheater is determined by an upright baffle 33 which extends between the plates 28 and 29 and is curved as shown to direct the air from the inlet 20 horizontally around the tubes in the center and thence to the outside and around the compartment toward the outlet, a shorter section of baffle 34 being provided to cooperate with the baffle 33 to direct the air initially toward the center of the preheater. It will thus be apparent that as the air passes through the compartment between the plates 28 and 29 and is heated it expands and the passageway from the inlet 20 to the outlet 31 is enlarged to allow for this expansion and provide more uniform air velocity through the flow path. The fresh air may be supplied to the preheater through the inlet 20 by a suitable fan or forced draft equipment (not shown). The gradually expanding passage through the preheater materially reduces the frictional drag therethrough so that a larger quantity of air may be delivered to the burners 15 without the use of more than a minimum of external power, thus avoiding various velocity pressure drop conditions. The air traveling through the generally helical passage around the gas tubes about the baffles 33 and 34 will have considerable turbulence thereby facilitating the rate of heat transfer between the walls of the tubes 27 and the air being heated.

The modification of the invention illustrated in FIGS. 3 to 8, inclusive, employs a preheater using essentially the same arrangement of combustion gas tubes and air baffles as that illustrated in FIGS. 1 and 2 and also includes additional features whereby the preheating of the air may be accomplished more efficiently and may be controlled in accordance with changes in the load on the boiler. In view of the similarity of construction, corresponding parts of the modification of FIGS. 3 to 8 have been designated by the same numerals as those employed in FIGS. 1 and 2 with the addition of the suffix letter "a."

Referring now to FIG. 3 it will be noted that the preheater unit 22a comprises a pair of spaced plates 28a and 29a extending across the casing 10a and connected by a multiplicity of tubes 27a which provide the sole gas passages between the portion of the stack 10a below the preheater to that above the preheater. The preheater is supported at its upper periphery by securing the plate 29a to the side wall of the stack so that it is suspended within the stack; additional support for the preheater is provided by a plurality of rods 36 secured to the plate 29a at their lower ends and at their upper ends to the inner rim of a frusto-conical baffle 37. The baffle defines a central passageway up through the stack above the plate 29a and helps to maintain constant gas velocity. The frusto-conical form of the baffle 37 provides a secure support for the preheater and also acts as the lower wall of the fly ash remover 25a. The fly ash remover or dust collector 25a includes a second frusto-conical baffle 38 inverted with respect to the first baffle and connected to the first baffle by a cylindrical wall 39 within which is arranged a single plate spiral or helical baffle 41 for imparting a twisting movement of the gases rising through the center of the stack. The dust collector 25a is closed by a plate 42 having a circular opening 43 at the center which may be closed by a damper 44 in order to direct the gases rising from the baffle 41 through semi-circular openings into a plurality of tubes 45 and thence downwardly into the ring-shaped chamber formed between the baffles 37, 38 and 39. The gas from this chamber is discharged through inner tubes 46 which pass upwardly through the plate 42 to the top of the stack to atmosphere. Thus the gases which are directed through the tubes 45 are caused to move downwardly and to be reversed suddenly which throws out from the gases any solid particle such as fly ash or dust contained therein. The space be-

tween preheater outlet and stack shell provides a large storage space for fly ash. When liquid fuel is being employed or when for other reasons it is not desired to use the dust collector the damper 44 is opened so that it lies in the position shown whereupon the gases move directly upwardly to atmosphere through the center of the stack thus short circuiting the dust collector. Ash or dust collected in the unit 24a and which accumulates around the bottom of the baffle 37 may be removed through operation of an automatic ash removal system indicated at 47.

The space about the tubes 27a and the unit 22a is divided into upper and lower compartments by a baffle plate 49 which is similar in form to the plates 28a and 29a and the vertical baffles in the two compartments are arranged to circulate air in a horizontal plane in opposite circular directions, the air being supplied and removed through a duct and damper assembly designated generally by the numeral 50 at its side. In order to allow for expansion and contraction of the unit 22a due to change of temperature about the tubes 27a, the lower plate 28a is connected to the side walls of the casing 10a by a flexible joint 51 of pleated metal which is sealed between the plate 28a and an annular ring or shoulder 52 secured to the walls of the casing 10 below the unit 22a. The shoulder 52 also acts as a rest for a rotary soot blower 53 which is rotatably mounted on a bearing 53a at the center of the stack and has its outer end supported on a track or shoulder 52. The soot blower 53 is actuated by steam supplied through a conduit 54 and is self rotated by a jet of steam passing through one or more openings 55 in the side of the arm 53; the high velocity steam for removing the fly ash from the tubes 27a is directed upwardly through a plurality of jets 56 on the top side of the arm 53. When the unit 22a is employed in a combined draft stack and boiler assembly located in upper half thereof as illustrated, the fly ashes removed during the idle periods of the system fall to the bottom where they are collected in an ash hopper 58 shown at the bottom of the casing 10 in FIG. 1. When the unit 22a is employed in other applications a suitable ash hopper may be located conveniently close to the bottom of the unit directly below whatever inlet ducts are provided for supplying the combustion gases which are to pass through the unit.

The structural arrangement of the baffles within the upper and lower compartments of the unit 22a is shown in FIGS. 4 and 5. In the upper compartment as shown in FIG. 4 a baffle 59 extends from the right hand side of an inlet opening 60 and curves around the center of the compartment and cooperates with a straight baffle 61 to provide a gradually expanding passageway for the air to be heated in the same manner as the baffles 33 and 34 of FIG. 2. The air is discharged from the upper compartment through an outlet 62, both the inlet and the outlet communicating with ducts within the assembly 50.

The lower section of the compartment shown in FIG. 5 is provided with a curved baffle 63 which cooperates with a straight baffle 64 to provide a gradually increasing air path for the air admitted to the compartment through an inlet 65 and passing around the baffles to an outlet 66, the inlet and the outlet communicating with passages in the assembly 50 in a manner similar to that of the upper compartment shown in FIG. 4. It will be noted that the direction of passage or rotation of the air going through the upper and lower compartments is opposite, the inlet to the upper compartment being directly above the outlet to the lower compartment and vice versa.

This opposite air flow arrangement in the two compartments tends to equalize the heat transfer along the combustion gas tubes 27a so that a substantially uniform heat transfer characteristic is provided for the preheater. The manner in which this is accomplished will be understood by considering a single tube 27a which must pass through both compartments. If the tube is located so

that it passes through the inlet zone of the lower compartment it will pass through the outlet zone of the upper compartment, thus the tube will lie in the lower air temperature zone of the lower compartment and in the higher air temperature zone of the upper compartment. On the other hand a tube which passes through the outlet or higher air temperature zone of the lower compartment will pass through the inlet or lower air temperature zone of the upper compartment. This arrangement provides a desirable counterflow relationship of the air paths and combustion gas paths and assures greater effectiveness of the heat transfer system.

The upper and lower compartments are connected with control ducts in the assembly 50 in a manner such that they may be connected either in series or in parallel relationship with respect to the flow path of the air to be preheated. This arrangement facilitates the control of the air temperature in accordance with the load demand on the system.

The structural arrangement of the damper control and air supply and exhaust assembly 50 is shown in FIGS. 6, 7 and 8. As illustrated in these figures the assembly 50 includes a generally rectangular box-like structure, the rear edge portions of the walls of which are shaped to conform to the curved wall of the cylindrical casing 10a so that the casing constitutes the back wall of the assembly. The structure is provided with an air intake duct 67 and a discharge duct 68 which is arranged to be connected to a conduit for conveying the preheated air to the burners of a furnace in the same manner as the duct 23 illustrated in FIG. 1. The inlet duct 67 communicates directly with an inlet passageway extending vertically from the duct to a horizontal cross wall or partition 70 spaced from the closed top wall 69 of the unit 50, the inlet passageway being designated generally at 71 on the drawing. The duct 71 communicates directly with an inlet chamber 72 in front of the inlet 60 to the upper air compartment, these passages being open at all times. The lower end of the passage 71 communicates with a chamber or duct 73 directly below an entrance chamber 74 which communicates directly with the intake opening 65 of the lower compartment. A damper 75 is provided to control the communication between the chambers 73 and 74, and, when it is open, air may pass directly from the intake 67 to the inlet 65 and thence through the lower compartment of the preheater. Immediately above the chamber 74 is a similar chamber 76 which is in direct communication with the discharge opening 62 of the upper compartment of the preheater and communication between the chambers 74 and 76 is controlled by a damper 77. When this damper is open, air discharged from the upper compartment through the opening 62 may pass downwardly into the chamber 74 and thence into the inlet 65 of the lower compartment. The chamber 76 also communicates with a cross duct 78 which opens directly into the discharge duct 68; communication between the chamber 76 and the cross duct 78 may be provided upon opening of a damper 80, and when this damper is open air discharged from the upper compartment through the outlet 62 may pass directly from the outlet to the discharge duct 68. The outlet 66 from the lower compartment communicates directly with a chamber 81 which is completely closed except for direct communication with the outlet duct 68. It will thus be apparent that the inlet opening 60 of the upper compartment is always in communication with the system inlet 67, and the outlet opening 66 of the lower compartment is always in communication with the outlet 68 of the system.

The three dampers 75, 77 and 80 are operated simultaneously by connection with an operating rod 82 actuated by a damper operating motor 83. The dampers are connected to the rod 82 so that when the dampers 75 and 80 are open the damper 77 is closed, and vice versa. It will not be apparent that when the dampers 75

and 80 are in their open positions and the damper 77 is closed, as shown in FIG. 7, the air from the intake 67 will enter both the upper and the lower compartments, and, as indicated by the arrows, will pass around the baffles in the respective compartments where the air is heated and then flow out the respective discharge openings 60 and 66 from whence it will flow to the discharge duct 68. This connection arranges the two compartments in parallel with respect to the air flow.

When the dampers are moved to their opposite positions, as shown in FIG. 8, with the damper 77 open and the dampers 75 and 80 closed, air from the inlet duct 67 passes upwardly to the top of the passage 71, as indicated by the arrows, and thence through the inlet 60 to the upper compartment through which it flows and is heated; the heated air passes out through the outlet 62 downwardly through the opening about the damper 77 thence through the inlet 65 to the lower compartment through which it flows and is further heated and from which it is discharged through the outlet 66 to the outlet duct 68. It will thus be apparent that, when the dampers are in position with the dampers 75 and 80 closed and the damper 77 open, the two compartments are connected in series in the air flow path, the air flowing first through the upper compartment and then through the lower compartment before being discharged to the outlet air supply. This arrangement assures a counterflow relationship of the air and combustion gases when the two compartments are connected in series since the coldest air passes first through the upper compartment where the combustion gases are cooler and thence after heating, through the lower compartment where the combustion gases are at their highest temperatures.

Additional control of the preheater which facilitates its operation at low loads is secured by providing a pair of hemispherical dampers 85 and 86 mounted on shafts 87 and 88, respectively, and which are positioned to cover a group of the tubes 27a in the center of the preheater. These dampers 85 and 86 are moved in unison so that both are either in their open position as shown in FIG. 3 or in their closed position as shown in FIG. 6. The dampers may be moved from their open to their closed position by operation of a motor 90 connected to drive the shaft 88 through a gear 91 and the shaft 87 through a meshing gear 93 of the same size as the gear 91. The ends of the shafts 87 and 88 opposite the gears 91 and 92 are mounted in bearings in a block 93. When the dampers are in their open position as shown in FIG. 3 the combustion gases rise through the central group of tubes and the heater may be operated at full capacity. Should the load be reduced the flow of the combustion gases may be restricted to the outer tubes by closing the dampers 85 and 86; this makes it possible to maintain the velocity of the combustion gases through the tubes 27a although a reduced total volume of the gases is flowing.

Both the motors 83 and 90 are arranged so that the dampers of the preheater may be controlled from a remote point, thus the operator may change the control condition of the preheater whenever he desires to do so in order to compensate for changes in the boiler load. From the foregoing, it is apparent that this invention provides a simple and easily controlled preheater which makes possible the more efficient operation of the combustion equipment and boiler of a power plant.

Although the invention has been disclosed in connection with a specific type of boiler construction other applications will readily be apparent to those skilled in the art. Therefore, it is not desired that the invention be limited to the details of construction illustrated, and described, and it is intended by the appended claims to cover all modifications which fall within the spirit and scope of the invention.

I claim:

1. In a power plant or the like having burners for the combustion of fuel and air and an outlet for the dis-

charge thereof, an air preheater comprising spaced plates having a plurality of openings therein positioned to interrupt the flow of heated gases, a plurality of open-ended tubes extending between said spaced plates and in flow connection with matched openings through said plates to provide a plurality of passages through which heated gases may pass, members joining the outer edges of said spaced plates for enclosing the tubes disposed between said plates, said members providing an inlet opening for the introduction of air flow between said plates and an outlet opening through which the heated air passing through said preheater may be removed, and baffle means within said enclosure extending between said spaced plates for preventing direct flow from said inlet opening to the outlet opening, said baffle means being cooperatively placed within said enclosure to form a passage between said inlet opening and said outlet opening of gradually increasing cross sectional area along the flow direction from the inlet to the outlet.

2. In a power plant or the like having burners for the combustion of fuel and air and an outlet for the discharge thereof, an air preheater comprising spaced plates having a plurality of openings therein positioned to interrupt the flow of heated gases, a plurality of open-ended tubes extending between said spaced plates and in flow connection with matched openings through said plates to provide a plurality of passages through which heated gases may pass, members joining the outer edges of said spaced plates, said members providing an inlet opening through which air may be introduced and an outlet opening through which the heated air passing through said preheater may be removed, and baffle means within said enclosure extending between said plates positioned to form a passageway between said inlet and outlet openings having a cross sectional area that increases in the direction of flow in an amount corresponding to the amount of expansion per unit weight for the air over the temperature range existing between the inlet opening and the outlet.

3. In a steam generating plant or the like of the type including an upright cylindrical structure serving the dual purposes of draft stack and boiler housing and providing an air and combustion products flow system comprising fuel burners adjacent the base of said structure together with means for introducing air through said burners and a centrally open passage upwardly through said structure through which heated products of combustion rise under the influence of the high draft created by the combustion temperature of said products, the improvement which comprises an air preheater positioned within said structure above the steam producing elements thereof, said preheater comprising a plurality of open-ended tubes aligned with the flow direction of said combustion products through the central passage, conduits for introducing air through the side face of the cylindrical structure adjacent the air preheater, baffle means interiorly of said preheater forming a passage therethrough adapted to direct the incoming air in contact with said tubes to the center of said preheater and thence outwardly to a point of discharge at the side face of the structure, said passage being of gradually increasing cross sectional area as the air is heated, and conduit means for receiving said heated air at the point of discharge and delivering said heated air to the point of use.

4. In a power plant or the like having burners for the combustion of fuel and air and an outlet for the discharge thereof, an air preheater comprising spaced plates having a plurality of openings therein positioned to interrupt the flow of heated gases, a plurality of open-ended tubes extending between said spaced plates and in flow connection with matched openings through said plates to provide a plurality of passages through which heated gases may pass, members joining the outer edges of said spaced plates for enclosing the tubes disposed between said

plates, a partition plate positioned intermediate said spaced plates for dividing the space therebetween into two compartments, said members providing inlet openings for the introduction of air to each compartment and outlet openings through which the heated air passing through said compartment may be removed, and baffle means within each of said compartments extending between said partition and the respective ones of said spaced plates for directing the passage of air from the inlet to the outlet of each of said compartments, said baffle means being arranged in each compartment to form a passage from the inlet to the outlet thereof having a gradually increasing cross sectional area along the flow direction from the inlet to the outlet, the inlet and outlet opening of each of said compartments being oppositely positioned with respect to the openings of the other compartment whereby the air flows through said compartments in counterflow relationship.

5. An air preheater for a power plant or the like as set forth in claim 4 including means providing an inlet air connection and an outlet air connection and means including dampers movable to one position for connecting said compartments in series between said inlet and outlet connections and to a second position for connecting said compartments in parallel between said connections.

6. An air preheater for a power plant or the like as set forth in claim 4 including means providing an inlet air connection and an outlet air connection, and means including dampers movable to one position for connecting said compartments in series between said inlet and outlet connections and to a second position for connecting said compartments in parallel between said connections, said damper means when in position to connect said compartments in series directing the air from said inlet connection to the inlet of the one of said compartments adjacent the outlet end of said tubes and from the outlet of said one compartment to the inlet of the other of said compartments, whereby the air is directed in counterflow relationship to the gases passing through said tubes.

7. An air preheater for a power plant or the like as set forth in claim 1 comprising means including a damper positioned adjacent the outlets of a plurality of said tubes less than the total number of tubes and arranged to cut off the flow of gas through said plurality of tubes for providing two alternative conditions of operations to control the flow of hot gases through said preheater.

8. In a power plant or the like having burners for the combustion of fuel and air and an outlet for the discharge thereof, an air preheater comprising a cylindrical casing, a pair of spaced plates mounted in said casing transversely thereof to form a compartment therein, each of said plates having a plurality of openings positioned in matched pairs, a plurality of open-ended tubes extending between said spaced plates and each connected between a pair of matched openings through said plates to provide a plurality of passages through which heated gases may pass, means for supporting one of said plates rigidly with respect to said casing, means including an expansible seal connected between said casing and the other of said plates for affording movement of said other plate longitudinally with respect to said casing, means providing an air inlet and an air outlet for said compartment between said plates, and baffle means within said compartment extending between said plates for preventing direct flow from said inlet opening to said outlet opening, said baffle means being positioned to form a passage between said inlet opening and said outlet opening of gradually increasing cross sectional area along the flow direction from the inlet to the outlet.

9. A heat exchange and gas treating unit for power plants and the like, comprising an upright substantially cylindrical casing, a heat exchange element comprising a pair of spaced plates within and extending across said casing to provide a compartment therein, each of said

plates having a multiplicity of holes therethrough, a plurality of tubes in said compartment each connecting corresponding holes in said plates and providing passages through said plates and across said compartment, means for conducting a fluid across said tubes within said compartment for heat exchange with fluid flowing through said tubes, means including a frusto-conical partition section in said casing above said heat exchange element for providing an annular closed chamber about the center of said casing, means for directing the fluid flowing from said tubes alternatively through said chamber or directly out of said casing, and hanger means for supporting said heat exchange element from said frusto-conical partition section.

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