April 11, 1939. J. J. SPALDING, JR 2,153,942

HEAT EXCHANGING APPARATUS

Filed Feb. 3, 1937 4 Sheets-Sheet 1

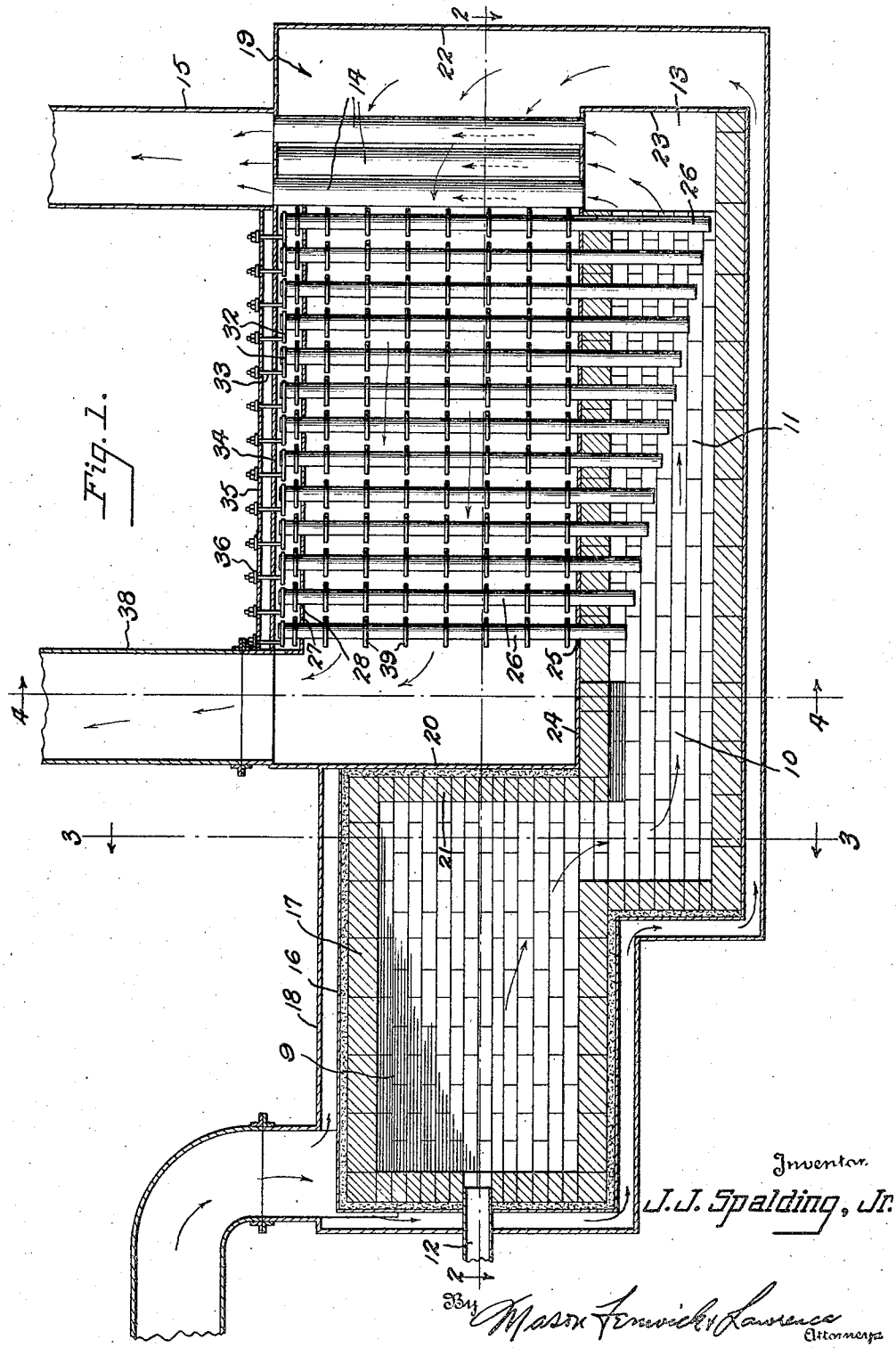


Fig. 1.

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Filed Feb. 3, 1937 4 Sheets-Sheet 2

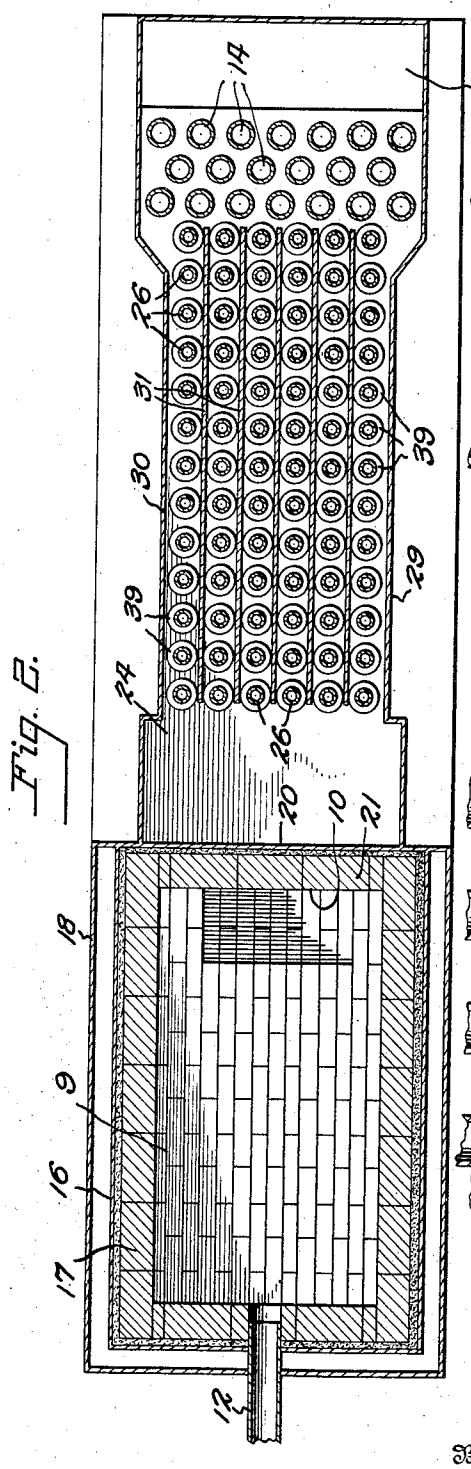


Fig. 2.

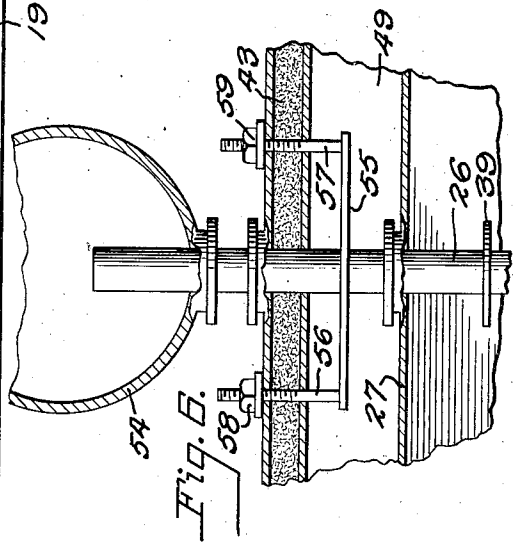


Fig. 6.

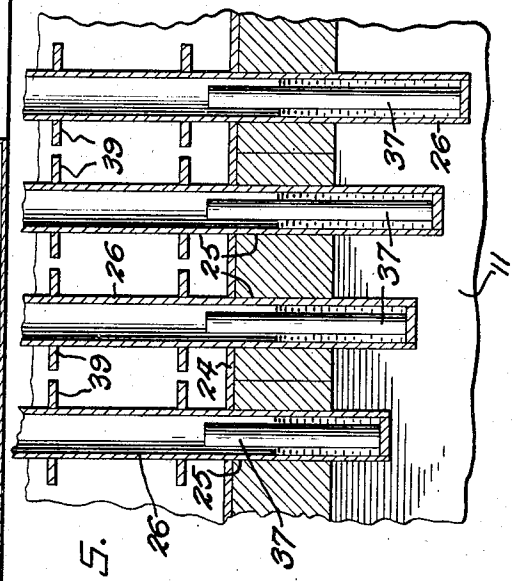


Fig. 5.

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HEAT EXCHANGING APPARATUS

Filed Feb. 3, 1937 4 Sheets-Sheet 3

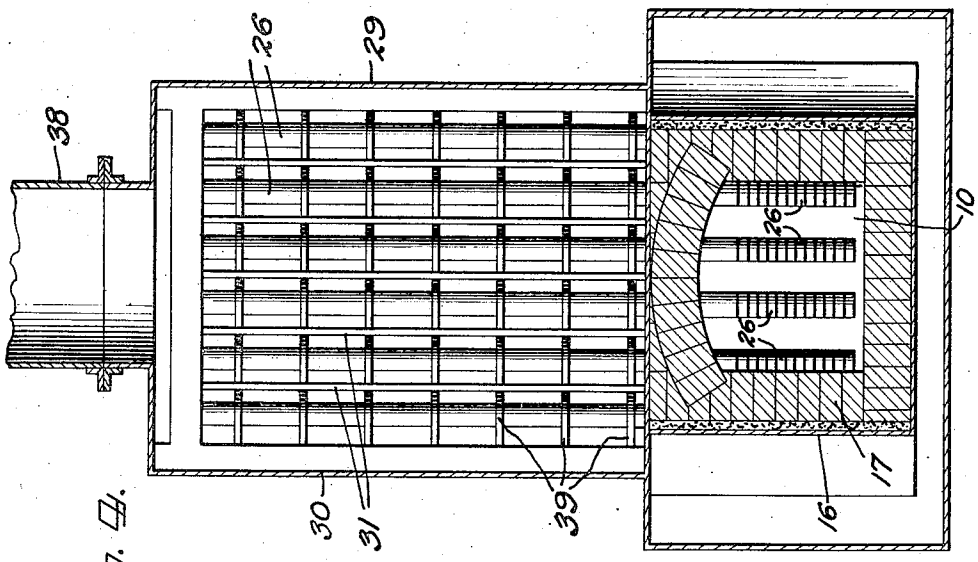


Fig. 4.

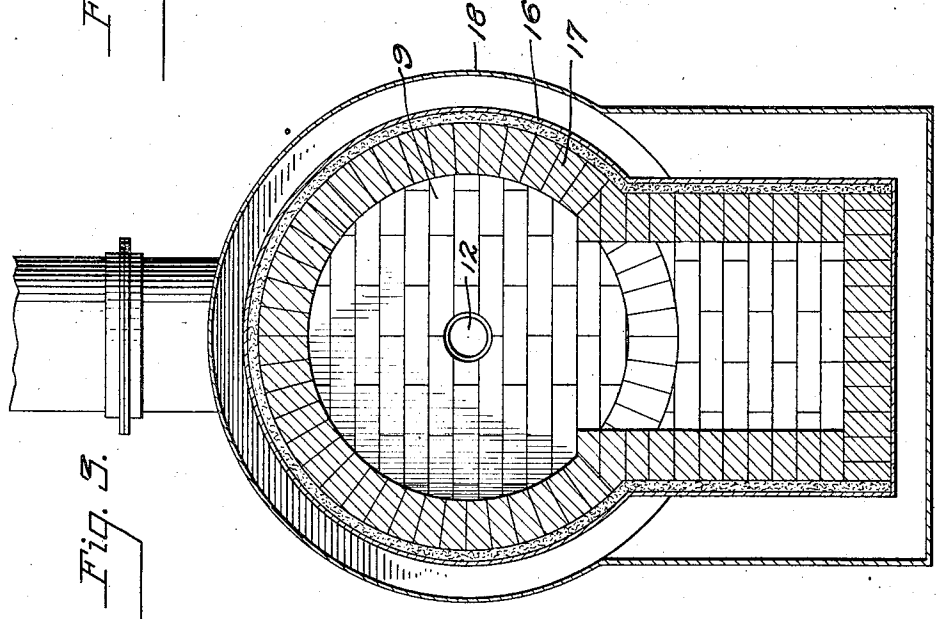


Fig. 5.

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HEAT EXCHANGING APPARATUS

Filed Feb. 3, 1937 4 Sheets-Sheet 4

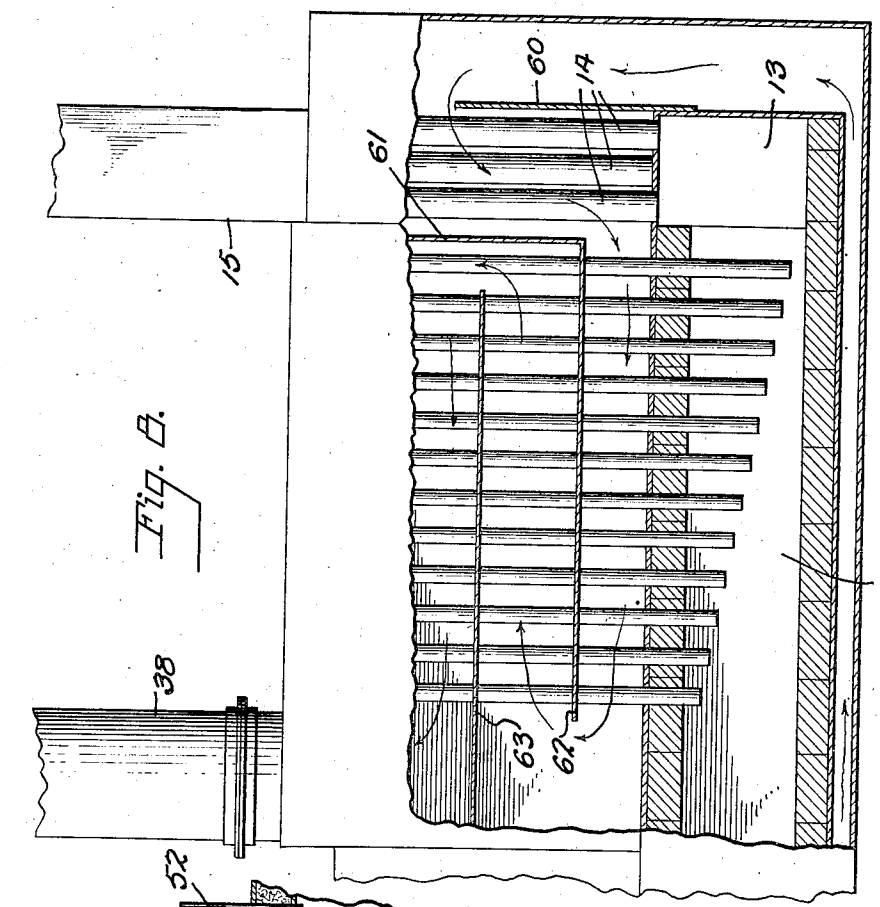


Fig. 8.

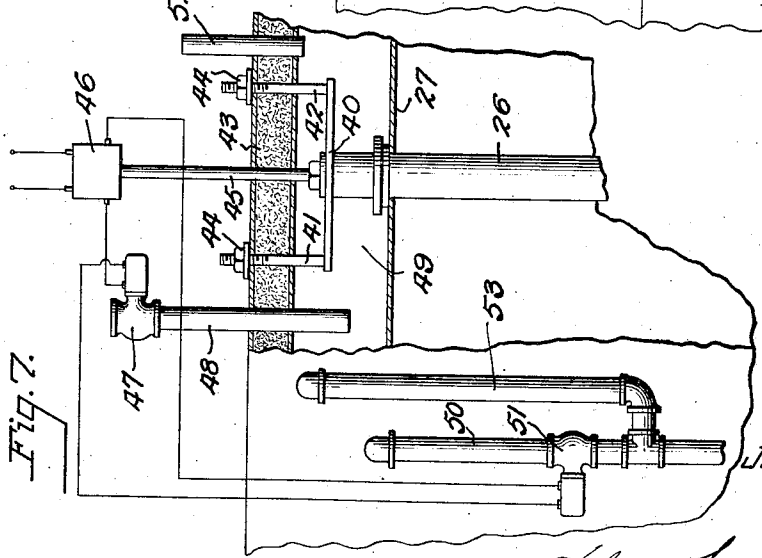


Fig. 7.

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Patented Apr. 11, 1939 2,153,942

UNITED STATES PATENT OFFICE

2,153,942

HEAT EXCHANGING APPARATUS

Jack J. Spalding, Jr., New York, N. Y.

Application February 3, 1937, Serial No. 123,901

6 Claims. (Cl. 257—1)

This invention relates to heat exchanging apparatus in general; and more particularly, to apparatus adapted to supply hot air for the heating of buildings, factories, airplane hangars, etc., and for dehydrating chemicals and food stuffs and for drying cloth or other material.

The main object of the invention is to improve the efficiency of air heating systems in order to extract practically all the heating units possible from a source of radiant heat.

Other objects will become apparent as the detailed description thereof proceeds.

In the drawings:

Figure 1 is a central longitudinal section through a heat exchanger embodying the present invention;

Figure 2 is a horizontal section taken on the line 2—2 of Figure 1;

Figure 3 is a vertical transverse section taken on the line 3—3 of Figure 1;

Figure 4 is a vertical section taken on the line 4—4 of Figure 1;

Figure 5 is a sectional detail illustrating details of construction of parts of primary heating units subjected to heat of combustion;

Figure 6 is a fragmentary detail illustrating the invention as applied to water heating purposes;

Figure 7 is a fragmentary detail illustrating a means for preventing injury to the heat transferring unit under certain conditions of operation; and

Figure 8 is a fragmentary sectional elevation illustrating a modified form of the invention.

As shown in the drawings, the apparatus comprises a combustion chamber 9 connected by a passageway 10 to a primary heat transfer chamber 11. A conduit 12 connects the combustion chamber 9 with a fuel burner (not shown) or any other suitable source of radiant heat. The end of the heat transfer chamber 11 remote from the conduit 12 forms an exhaust chamber 13 connected by flues 14 to an exhaust stack 15.

Various chambers just described have their walls constructed of sheet material 16 lined with refractory brick 17. An outer casing 18 surrounds the casing formed by the sheet material 16 and forms an air chamber which extends over the top of the combustion chamber 9, along the front end of said combustion chamber, and along the bottom of the combustion and primary heating chambers, to a comparatively large air chamber 19.

The chamber 19 comprises a front wall 20, adjacent to the rear wall 21 of the combustion chamber 9, and a rear wall 22 spaced sufficiently from the rear wall 23 of the chamber 13 to provide for easy flow of the air from the air chamber formed between the casings 16 and 18. The bottom wall 24 of the air chamber 19 extends along the top of the primary heat transfer chamber 11, and is provided with apertures 25 through which extend the primary heat transfer units 26. The upper wall 27 of the chamber 19 extends substantially parallel to the wall 24 and is provided with apertures 28, through which the upper ends of the heat transfer units 26 are adjustably mounted.

As shown in Figure 2 of the drawings, the heat transferring units 26 are arranged in parallel vertical rows between the side walls 29 and 30 of the air chamber 19, the said rows being separated from each other by vertical plates 31. Each of the heating units 26 has secured to its upper end a bracket 32 from one end of which a rod 33 projects upwardly through the parallel walls 34 and 35 at the top of the air chamber 19. The upper ends of the rod 33 are screwthreaded to receive the adjusting and lock nuts 36 by means of which the primary heat transfer units 26 can be adjusted vertically in the air chamber 19.

As will be apparent from Figure 1 of the drawings, the first transverse row of units 26 projects only a slight distance into the primary heat transfer chamber 11. Each succeeding row of units projects further into the heat transfer chamber 11 so as to expose progressively greater areas to the radiant heat of the flame and gases passing through the chamber 11. This construction is used because the intensity of the heat in the heat transfer chamber 11 obviously decreases as it passes through the chamber, since some radiant heat is absorbed by each of the transverse rows of the heating units 26. Obviously, the greater heat exchanging areas are required at the rear end of the chamber in order to absorb as much of the heat as possible.

Each of the heating units 26 comprises a boiler tube or metal pipe which is sealed at its lower end. The tube or pipe thus sealed is then partly filled with mercury, water or some other such substance, adapted to vaporize under the action of heat applied to the tube, and to condense at the upper end of each tube because of heat transfer between the tube and the air passing around and across the same. The upper end of the tube is sealed so as to prevent escape of the substance placed therein or of its vapor.

In the event that a substance should be used in the tubes 26 having a very low heat conductivity as compared with water, a metal bar 37

(see Figure 5) is mounted in the tube 26 before the vaporizing substance is inserted in the tube. Only that part of each tube which is exposed to the radiant heat in the chamber 11 is filled with the vaporizing substance. The radiant heat is absorbed by this substance and causes it to boil and form a vapor. This vapor passes to the upper part of the primary heat transfer units which lie in the path of the air to be heated and which passes across the flues 14 and across the units 26 to the hot air outlet stack 38.

The insertion of the metal bar 37 in each primary heat transfer unit decreases the cross-sectional area of the unit materially, and thereby increases the rate of flow of heat from the vapor in these tubes to the walls of the tubes to the air which is to be pre-heated. The metal bar also decreases the amount of vaporizing substance required in each tube. In the case of a ruptured tube, the smaller quantity of mercury vapor, etc., which might be used as the vaporizing substance, adds to the safety of the unit. Furthermore, when mercury is used as the vaporizing substance, the cost of the metal bar which displaces the mercury is much less than the cost of the displaced mercury itself.

The upper parts of the primary heat transfer units, in the path of the air to be heated, are preferably provided with fins 39 to provide larger heat conducting surfaces for transferring heat from the vapor in the tubes to the air surrounding them. The units and fins are in turn cooled by transmitting their heat to the air to be heated; and the vapor is continuously condensing to a liquid which runs down the tube to the lower parts of the units which are exposed to radiant heat.

It is known that metal tubes such as iron, steel, etc. which contain a liquid, transmit their heat very quickly to the liquids contained therein. If these tubes are properly proportioned to the quantity of heat they are to absorb, the temperature of the metallic tube is only slightly higher in temperature than the liquid it contains. Mercury, or some similar substance, is preferred to water when the air is to be heated to high temperatures. This is because of the high boiling point, about 680° F. of mercury. With low pressures in the tubes, vapor temperatures of 800 to 900° F. can be obtained. Where it is required to heat large volumes of air, the radiant heat is more efficiently absorbed if the last few rows of the primary heat absorbing units are partly filled with some other substance having a lower boiling point than mercury; for example, water may be used instead of mercury for this reason.

Under similar conditions each square foot of primary heat transfer unit in this exchanger will raise one pound of air more degrees Fahrenheit than a square foot of conventional heat transfer tubes or passages, where the products of combustion scrub the outside of the tube, and the air scrubs the inside thereof, or where the products of combustion pass through the insides of the tubes and the air to be preheated scrubs the surface of the outside of the said tube. For the same amount of heat taken out of the fuel, this type of preheater reduces materially the required surface of the conventional heat transfer units exposed to the products of combustion on one side and the air to be preheated on the other.

This efficiency of operation in the present system is due to the fact that hot gases, such as products of combustion contain no latent heat, and when a pound of such gases gives off 1 B. t. u. its temperature drops about 4° F. Due to these characteristics, when such gases are passed through the tubes at an initial temperature of about 1000° F. and air is blown against the tubes, the mean temperature of the combustion gases and tubes is comparatively low. For any given heating area, the rate of heat transfer varies directly as the difference between the mean temperature of the tubes and the temperature of the air to be heated. Therefore the heating area must be increased as the mean temperature decreases.

The mercury vapor at low pressure contains about 117 B. t. u.'s per pound, and when it condenses to a liquid, it does not lose any temperature provided it is constantly replaced by additional vapor. The primary heat transfer units in this system, are therefore heated by vapor at the same temperature throughout their entire length. The fins on such tubes only tend to condense the vapor more rapidly, but the tubes remain at practically the same temperature throughout. The mean temperatures of tubes heated by passing products of combustion through them, are substantially decreased when fins are used. It is well known that a liquid transmits heat to a tube at a faster rate than a gas. The vapor condenses on the inside surface of each heat transfer unit in liquid form; and since this liquid remains at the same temperature as the vapor, the transfer of heat to the primary unit is at a greater rate than when gases are employed to heat the tube. This type of heat exchanger gives low flue gas temperature even when the air is preheated up to 600 or 800° F.

After the gases of combustion pass through the heat transfer chamber 11, they are conducted through the flues 14, which may be considered as secondary transfer units, to the stack 15. The box or chamber 13 and the flues 14 connected thereto are wiped by the air at a high velocity and having a mean temperature of about 100° F. This operation reduces the temperature of the flue gases to any reasonable degree required, depending upon the surface area of these secondary heat transfer units, the draft loss through these units and the velocity of the air passing across such secondary heat unit. The air thus initially heated passes across the upper parts of the primary heat transfer units 26 to the outlet stack 38, and is thus brought up to the desired temperature which may be 700° F. or more.

In this system, means are provided to prevent injury to the primary heat transferring units if for any reason the flow of air through the preheater is stopped, or if the combustion chamber is overfired. Obviously, if the flow of air to be preheated is stopped, the radiant heat in the combustion chamber might overheat the primary transfer units because no heat is being absorbed therefrom. This safety mechanism is illustrated particularly in Figure 7 wherein is shown one of the tubes 26 connected at its upper end to a cross piece 40 connected at its opposite end to the bolts 41 and 42 which extend through the heat insulated casing 43 and are screwthreaded at their upper ends to receive the adjusting nuts 44. The top of the tube 26 is connected by a pipe 45 to a temperature control switch 46. The switch 46 controls the operation of a water-feed valve 47 connected to a pipe 48 leading to the space between the top of the air heating chamber and the heat insulated top of the apparatus.

The chamber 49 formed between the top 27 of

the air-heater chamber and the heat insulated top 43 constitutes a reservoir for the water fed through the pipe 48. It will be understood, of course, that the joints between the pipes 26 and the top 27, and also between the bolts 41, 42 and pipe 48, and the top 43, are to be made water and air tight to the atmosphere at low pressure, with packed glands which will also allow for expansion of the primary heat transfer units 26. The reservoir 49 has connected thereto, a drain pipe 50, having a valve 51 therein also controlled in operation by the switch 46. The valve 47 is opened by the switch 46 on excessive temperatures or pressures and is closed when the temperature or pressure drops to normal. The valve 51 is closed on excessive temperature or pressure rise and is opened when temperature or pressure drops to normal. A steam or vapor vent 52 extends through the top of the reservoir 49; and an overflow pipe 53 is connected to the lower end of the drain pipe 50.

The water in the reservoir 49 absorbs heat from the primary heat transfer units 26. In the event of power failure for operating the fuel burner and the blower, the reservoir would be filled with water.

This apparatus may be used to generate hot water or steam. The arrangement for effecting this generation is illustrated in Figure 6 in which one of the primary heating units 26 extends through the top 27 of the air heating chamber and through the packed top 43 into a metallic water container 54. The part of the unit 26 within the chamber 49 is provided with a cross bar 55 having at its opposite ends the screw-threaded rods 56 and 57 extending through the packed top 43 and engaging the nuts 58 and 59, respectively, to secure adjustment of the units 26 with respect to the radiant heat chamber 11. The joint between the unit 26 and the members through which it passes must, of course, be provided with the usual glands for making an air and water tight joint. The upper end of the tube 26 is sealed and the vapor rises throughout its entire length as in all the other tubes. In view of the fact that the vapor in the tube 26 is at the same temperature throughout its entire length, it is obvious that heat will be transferred from the units to the water in the container 54.

In the operation of a hot water or steam generator part or all of one row of heat transfer unit, or even more, can be extended upwardly into the tank which is filled partly or wholly with water. The amount of hot water or steam to be generated can be regulated by the number of heat transfer units used, as well as by the amount of surface of these units exposed to the water.

In applying the fins to the heat transfer units, ordinary standard wrought iron washers are used for this purpose. The diameters of the holes in the washers are, or can be reamed, slightly less than the diameter of the tubes. The washers are then heated so as to expand sufficiently to be slid onto the tubes which form the primary heat transfer units. It is a simple matter to locate and space these washers as desired; and when they cool, they grip the tubes and reinforce them considerably.

As shown in Figure 8 of the drawings, the air chamber 19 may be provided with a baffle plate 60 extending vertically above the top of the chamber 11. A second baffle plate 61 is arranged vertically and connected to a horizontal plate 62, mounted below another baffle plate 63. Obviously, there may be any number of these baffle plates mounted in the air heating chamber, and they must be arranged so as to cause the air to be heated to flow in a tortuous path back and forth across the heat transfer units 26.

In the conventional heat exchanger, there is a considerable draft loss of the products of combustion through the exchanger, otherwise it must be made excessively large or be made of costly alloy steels. It is customary in the ordinary exchanger to use a blower to force the products of combustion, the temperature of which has been diluted with stack gases, or with large quantities of excess air, through the exchanger. These gases enter at about 1000° F. and leave at about 500° F. The air is also usually forced through the exchanger with a blower. Owing to the large surface required to transmit the heat and the comparatively low mean temperature, more power is required to drive the air through the exchanger than the exchanger forming the subject matter of this application. In the present exchanger, no blower is required to draw the hot gases through the exchanger, because of the fact that a stack can be used and there is no greater draft loss than through an ordinary efficient boiler.

Numerous variations may doubtless be devised by persons skilled in the art without departing from the principles of my invention. I, therefore, desire no limitations to be imposed on my invention, except such as are indicated in the appended claims.

What I claim is:

1. In heat exchanging apparatus, a housing having a partition extending horizontally therein and dividing said housing into a lower heat transfer chamber and into an upper air heating chamber, a plurality of rows of heat-transfer units adjustable vertically through said partition to various depths within the lower chamber, means for adjusting said units vertically, means for drawing heating gases through the lower chamber and across the ends of said units projecting thereinto, and means for directing air to be heated across the parts of said units within the upper chamber, said rows of units projecting into the lower chamber at progressively increasing distances in the direction of flow of the heating gases.

2. In heat exchanging apparatus, a housing comprising a primary heat transfer chamber and an air conducting chamber separated therefrom, a plurality of heat transfer units extending across the air conducting chamber and into the heat transfer chamber, and means controlled by the temperature in one of said units for preventing excessive rise in temperature of said units due to the absence of cooling fluid in said air chamber.

3. In heat exchanging apparatus, a housing having a partition extending horizontally therein and dividing said housing into vertically superposed chambers, a plurality of rows of heat conducting tubes sealed at both ends and extending vertically across the upper chamber and through the partition into the lower chamber, means for vertically adjusting said tubes to position the lower ends of said rows at progressively increasing distances into the lower chamber, and means at the upper end of said housing operable to maintain said tubes below a predetermined upper limit of temperature.

4. In heat exchanging apparatus, a housing having a partition extending horizontally therein and dividing said housing into vertically superposed chambers, a plurality of rows of heat con-

ducting tubes sealed at both ends and extending vertically across the upper chamber and through the partition into the lower chamber, means for vertically adjusting said tubes to position the lower ends of said rows at progressively increasing distances in the lower chamber from said partition, a reservoir for cooling liquid formed in said housing and in contact with the upper end of said tubes, and means connected to one of said tubes for automatically controlling the supply of cooling liquid to said reservoir.

5. In heat exchanging apparatus, a housing having a partition extending horizontally therein and dividing said housing into vertically superposed chambers, a plurality of rows of heat conducting tubes sealed at both ends and extending vertically across the upper chamber and through the partition into the lower chamber, means for vertically adjusting said tubes to position the lower ends of said rows at progressively increasing distances in the lower chamber from said partition, a reservoir for cooling liquid formed in said housing and in contact with the upper end of said tubes, a water feed connected to said reservoir, a valve controlling said water feed, a drain pipe connected to said reservoir, a valve controlling said drain pipe, and means connected to the end of one of said tubes in said reservoir for automatically controlling said valve to maintain the temperature of said tubes below a predetermined maximum.

6. In heat exchanging apparatus, a housing having a partition extending horizontally therein and dividing said housing into a lower heat transfer chamber and into an upper air heating chamber, a plurality of rows of heat transfer units adjustable vertically through said partition to various depths within the lower chamber, means for adjusting said units vertically, means for drawing heating gases through the lower chamber and across the ends of said units projecting thereto, a stack of flues for said heating gases extending from one end of the heat transfer chamber and across the adjacent end of said air heating chamber, and means for conducting air to be heated around said heat transfer chamber and transversely of said stack of flues into said air heating chamber, said rows of units being arranged with their lower ends projecting into the heat transfer chamber at distances increasing successively in the direction of the stack of flues.

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