Nov. 19, 1957 R. L. LINCOLN 2,813,698

HEAT EXCHANGER

Filed June 23, 1954 2 Sheets-Sheet 1

FIG. 1.

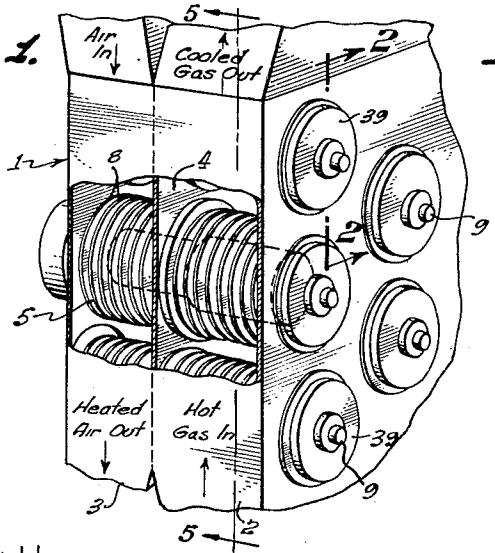


FIG. 7.

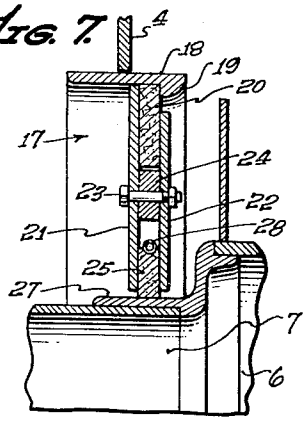


FIG. 2.

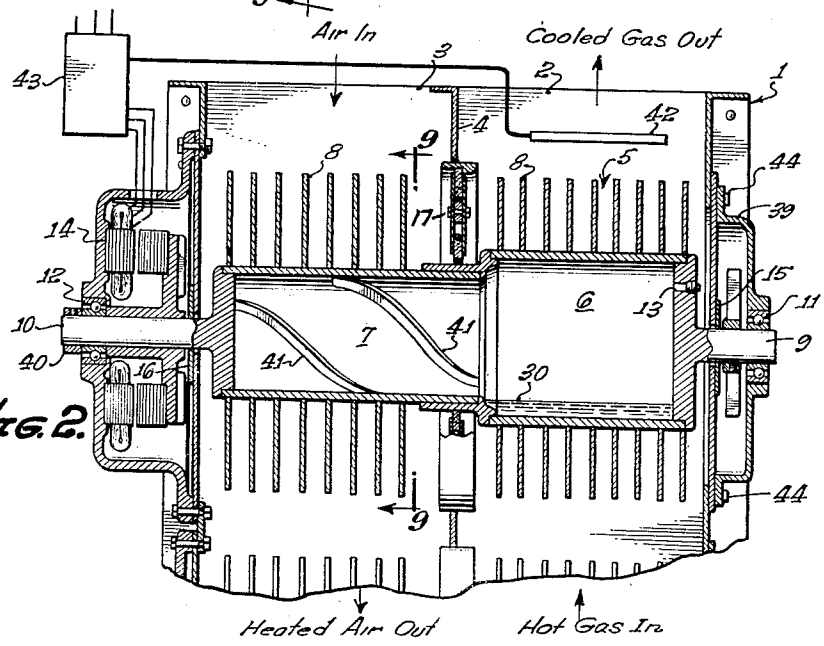
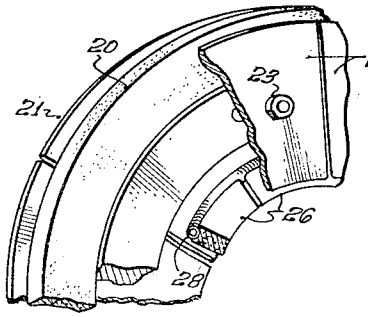


FIG. 8.



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HEAT EXCHANGER

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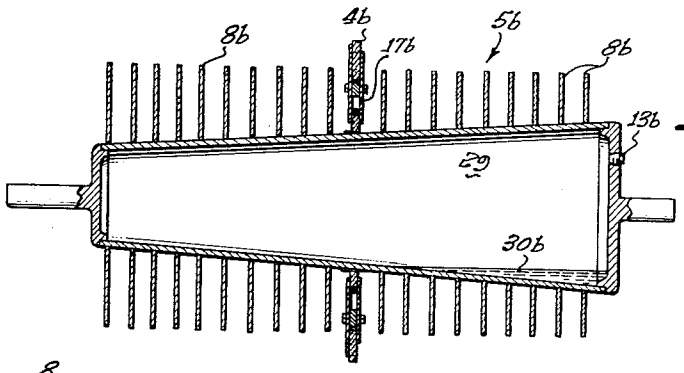


FIG. 3.

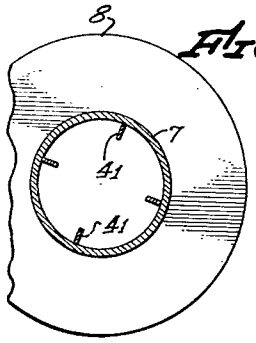
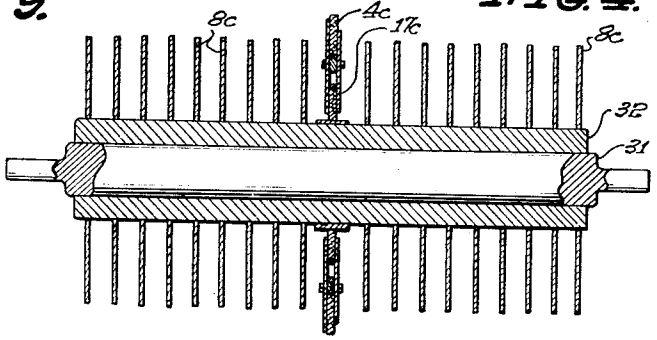


FIG. 9.

FIG. 4.



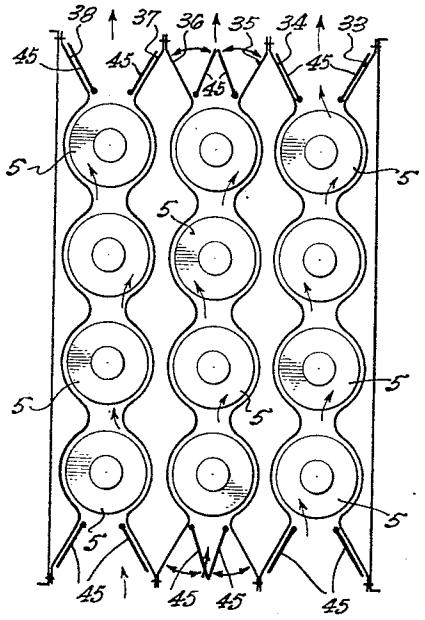
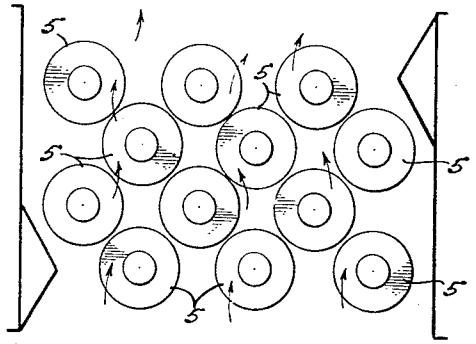


FIG. 5.

FIG. 6.



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HEAT EXCHANGER

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Application June 23, 1954, Serial No. 438,791

7 Claims. (Cl. 257—2)

This invention pertains to new and novel improvements in heat exchangers.

The invention more particularly relates to air preheaters, or the like, adapted to transfer heat from a hot gas to a gas at a lower temperature.

Arrangements of this type are utilized for the purpose of recovering heat from the escaping combustion gases from steam boiler furnaces of power plants and industrial plants to heat air which is to be used for supporting combustion of the fuel in these furnaces.

In the past, equipment of this type has been identified as plate, tubular, and regenerative systems. The plate and tubular systems provide a metal barrier between the combustion gases and the air to be heated, and depend for their operation upon heat being transmitted through metal. Velocities are low, with a resulting low heat transmission coefficient. The units tend to be large, heavy, and expensive. They do, however, prevent mixing of the combustion gases and the air to be heated. These types are hard to clean because the small, long passages become clogged with solids deposited from the combustion gas. Inspection, cleaning, and replacement are difficult and expensive. Sulfuric acid often is formed and serious corrosion results. The regenerative type involves baskets of metal which are slowly rotated, first in the gas stream to absorb heat, and then into the air stream to give up the heat to the air. These are more compact, lighter, and somewhat less expensive. However, because of the passage of metal from the combustion gases to the air, serious leakage occurs. Because of this leakage the size and power requirements of the forced and induced draft fans must be increased, thus adding to the cost of building and operating the boiler.

The present invention teaches a heat exchanger arranged horizontally in heat transfer relation with a fluid from which is to be extracted and a second fluid which is to be heated thereby.

It is therefore an object of this invention to provide a heat exchanger having new and novel features of construction.

It is another object of this invention to provide a heat transfer unit comprising a rotary tube having a portion in heat transfer relation with hot gases, and another portion in heat transfer relation with the air to be heated.

It is another object of this invention to provide an efficient heat exchanger having a high coefficient of heat transfer.

It is a further object of this invention to provide a new and novel arrangement of a vertical seal operatively associated with the rotary tube to thereby provide a minimum of gas leakage between the hot gases and the gas to be heated.

It is yet another object of this invention to provide a heat exchanger tube having a captive heat transfer medium.

It is still another object of this invention to provide a heat exchanger which is rotatable and controllable to obtain a proper heat transfer relation between the hot gases and the gas to be heated.

It is yet another object of this invention to provide a heat exchanger which extracts heat from combustion gases in such a manner as to maintain the temperature of such gases above the dew point thereof (about 230° F.) to avoid condensation of corrosive vapors.

It is still another object of this invention to provide a heat exchanger of flexible design so that many or few units may be combined in operative relation.

It is another object of this invention to provide an arrangement that is easy to install, easy to replace, and which may be maintained with a minimum of cost.

Other objects of invention will become apparent from the following description, taken in connection with the accompanying drawings, in which:

Fig. 1 is a perspective view with parts broken away, of an arrangement of my invention;

Fig. 2 is a cross-section along the line 2—2 of Fig. 1;

Fig. 3 is a view similar to Fig. 2, showing an alternative arrangement of the invention.

Fig. 4 is a view similar to Fig. 2, showing still another alternative arrangement of the invention;

Fig. 5 is a view taken along the line 5—5 of Fig. 1, illustrating shrouds which may be used for conducting gases past the heat exchanger;

Fig. 6 is a view similar to Fig. 5 showing an alternative arrangement of the heat exchanger.

Fig. 7 is a detail view of the seal between the two passageways;

Fig. 8 is a perspective view of the seal illustrated in Fig. 7; and

Fig. 9 is a sectional view along the line 9—9 of Fig. 2.

Referring to the drawings there is shown a casing 1 having passageway 2 for conducting gases such as combustion gas from a furnace or the like to a stack for discharge to the atmosphere in a manner well known in the art. Casing 1 also contains a passageway 3 for conducting air to the firebox of the furnace for supporting combustion therein. Passageways 2 and 3 are divided by a wall 4. Operatively associated with said passageways and in heat transfer relationship with respect thereto, is a heat exchanger element or rotor referred to generally as 5. In the preferred form of the invention the rotor is hollow and comprises an enlarged evaporator portion 6 located in passageway 2 and a smaller condenser portion 7 located in passageway 3. Fins 8 are provided to promote transfer of heat from the hot gases to portion 6 of the exchanger, and from 7 to the gas to be heated in passageway 3. Member 5 is provided with trunnions 9 and 10 mounted in suitable bearings 11 and 12. A safety valve 13 prevents rupture of the rotor from excess temperature or pressure.

At one end of the rotor there is provided a motor 14 of any suitable type for driving member 5 with respect to the casing. Preferably this is an electric motor of the axial gap type; however, it is to be understood that other types of driving means, such as turbine, mechanical, or other arrangements may be used if so desired.

A suitable seal may be provided at 15 and 16 to prevent gas or air from leaking into the bearings and the operating mechanism for driving the member 5.

A seal is provided at 17 for preventing intermingling of the gases in passageways 2 and 3. This seal comprises a ring member 18 welded or otherwise suitably fastened to wall 4. Ring member 18 is provided with a rim portion 19 against which material 20 of asbestos or the like is held in sealing engagement by the pressure differential between passageways 3 and 2. In power plant practice passageway 3 is normally maintained at a higher pressure than passageway 2.

A pair of split cover rings 21 and 22 engage opposite

sides of material 20 and hold the same in operative shape by means of a bolt 23 adapted to draw cover rings 21 and 22 together. Spacer ring 24 limits the inward movement of these rings. Also contained between rings 21 and 22 is a carbon seal ring 25 made up of segments 26 and held in sealing engagement with each other and with surface 27 of member 5 by coil spring 28.

In the preferred form of the invention, member 5 is provided with an enlarged tubular portion 6 and a smaller tubular portion 7 interconnected therewith. The tube contains a volatile fluid such as water, Dowtherm, mercury, or the like. A predetermined amount of fluid is placed in the tube, depending upon the size of the tube, the type of fluid, and conditions under which it will operate. Air is evacuated from the inside of the tube, and a combined seal and safety element is provided at 13 in the nature of a pressure- or temperature-responsive relief device. Member 13 will open under an excessive precalculated temperature or pressure condition.

Heat is absorbed from the hot gases in passageway 2 by fins 8, and transmitted to the tubular portion 6 for volatilizing the fluid contained therein. Fins 8 are preferably round disks, but may be blades normal to the rotor or at other angles thereto if so desired, or other suitable projections for increasing the effective area of the heat transfer surface. The volatilized fluid will then travel into portion 7 where it will give up heat to the gas traveling in passageway 3 by way of fins 8. Upon having heat extracted therefrom by the gas moving through passageway 3, the fluid condenses and is returned to portion 6 of the tube.

Rotation of member 5 about its longitudinal axis will tend to throw the fluid in 6 to the perimeter thereof to place the same in the best possible position for ready volatilization. The volume of fluid is so chosen that it will cover only the inside surface of portion 6 when the member 5 is rotated. The high velocity of the disks spinning in the hot gases transfers large quantities of heat to the metal of the disks or fins 8 and then through the disks and tube metal to the liquid inside the tube. The liquid will readily boil to a vapor and in the vacuum it will flow to the cooler portion 7 of the tube. The vapor condenses on the inside of portion 7 and the released heat is conducted through the metal to the surface of disks 8 connected thereto where the heat is transferred to the gas passing through passageway 3. The condensed liquid flows from the smaller portion 7 of the rotor to the larger portion 6, where the cycle is repeated.

Condensate resulting from the cooling of the fluid in portion 7 will return to portion 6. Since portion 6 is larger in diameter than portion 7, fluid in portion 6 will remain therein until volatilized, and condensate in 7 adjacent 6 will tend to flow to 6. To promote the flow of condensate from 7 to 6, spiral deflectors 41 or the like may be placed internally of 7. Condensate will collect against these deflectors and because of their spiral construction, rotation of the rotor will positively move the condensate to portion 6. The space in 7 between the deflectors then provides a surface relatively free of liquid for condensing fluid received from 6.

Efficiency in heat transfer is promoted by rotation of member 5. Since the velocity difference between a gas and a member in heat transfer relationship therewith affects the efficiency of heat transfer, rotation of member 5 can result in a higher heat transfer rate regardless of the velocity of the gases in passageways 2 or 3. By controlling the speed of rotation, the gas temperature in passageway 2 may also be maintained at a temperature above the dew point at which moisture condenses out of the gas (approximately 2300° F.). This is an important factor of my invention, since condensation results in acids being deposited on the metals, with resultant corrosion.

Member 5 may be made of non-corrosive material such as stainless steel or the like, insofar as portion 6 and fins 8 connected thereto are concerned, whereas portion 7 and the fins 8 connected thereto may be made of less-expensive material. The interior of the portion 6 may be made rough to promote volatilization, whereas the condensing surfaces of 7 are made smooth to permit efficient condensation.

Special wetting agents or non-rusting agents may be added if desired.

As a variation of the above two-diameter rotor of Fig. 2, the rotor may be made in the form of a frustum of a cone, as in Fig. 3, referred to generally as 5*b*, in which member 29 has attached thereto fins 8*b* in a manner similar to that illustrated in Fig. 2. Seal 17*b* is attached to wall 4*b* and functions in the same manner and is made of the same construction as seal 17. Volatile fluid 30*b* is received within the conical sector which is evacuated and provided with a safety means 13*b*, in the same manner as the arrangement illustrated in Fig. 2.

Still another variation of the rotor design is illustrated in Fig. 4, in which there is provided a solid cylindrical member 31 provided with a sleeve 32 of copper or other material having good heat transfer properties. Fins 8*c* are attached to member 32 and function in the same manner as fins 8 in Fig. 2. A barrier wall 4*c* and seal 17*c* separate the gases in the passageways as in Fig. 2. In this form of the invention the volatile fluid is omitted and heat is transferred through sleeve 32 and fins 8*s*.

Referring to Fig. 5 there is provided if so desired, regardless of the form of the rotor, shells or cases 33, 34, 35, 36, 37, and 38, operatively associated with a series of rotors 5. These casings follow the contour of the rotors and are spaced therefrom a predetermined amount so as to direct the hot gases in efficient heat transfer relationship to the portions of the rotor in its various forms.

The rotors may alternatively be arranged in staggered relationship, as illustrated in Fig. 6, with the hot gases flowing therebetween on the one end of the heat exchanger, and the gas to be heated flowing therebetween at the other end.

A control system may be used comprising a thermostat 42 arranged in passageway 2 and operatively connected to motor 14 through a suitable control 43 to drive the same in such a manner that the heat transfer through the heat exchanger will be at such a value at all times that the temperature of the hot gases through passageway 2 do not drop below a predetermined temperature (usually the dew point of the gas), thus eliminating the deposit of acid-laden condensate. Control 43 is of well known construction and causes motor 14 to operate between predetermined temperature ranges in a manner well known in the art. Arrangements of this type may be found illlustrated in publications as The Standard Handbook of Electrical Engineers, seventh edition, by Knowlton, section 7–298; The Westinghouse Engineer, July 1956 issue, published by the Westinghouse Electric Co.; and a handbook of the American Society of Heating and Air Conditioning Engineering, Inc., 1956 Guide, chapter 39.

When it is desired to replace the heat exchangers, or clean or repair them, it is necessary only to remove the casing 39 which is suitably bolted to casing 1 at 44, remove end thrust bearing 40 from shaft 10, and withdraw the rotor, together with seal 17, from the casing through the opening left by member 39. A new or reconditioned rotor may then be installed quickly and easily with a minimum of shut-down time.

Several banks of inlet and outlet passageways may be combined into the system if so desired, and dampers 45 may be placed in the passageways for controlling passage of gases therethrough, or for closing off certain banks if desired for shut-down or repair purposes.

My arrangement has many advantages over present units in that a high coefficient of heat transfer is obtained and maintained due to the novel features of construction. Not only is a high operating coefficient obtainable, but it is maintained because of control of velocity differential

between the rotor surface and the gas, the excellent distribution of flow, and the fact that dirt will not be deposited, or will tend to be removed from the heat exchanger on account of its rotating action, and the heat transfer rate is maintained high because of clean surfaces.

Corrosion is reduced to a minimum because deposits of condensed acid-containing material are prevented. By maintaining the temperature of the gas leaving the unit sufficiently high, deposits of acid are eliminated. Controlling the speed of rotation of the heat exchanger units to control the transfer of heat prevents extracting heat from the gases to the extent of causing condensation and undesired deposits of acid.

Additionally, gas leakage between the air passageway and the hot gas passageway is kept at a minimum due to the novel construction of the heat exchanger and the seal used therewith.

My heat exchanger rotor is readily replaceable and, when removed, is easy to clean and repair if necessary. Cleaning may be made in place by isolating a given bank of heat exchangers and giving them a water bath in place, using a built-in drain to collect the water.

Although the invention has been described and illustrated in detail, it is to be clearly understood that the same is by way of illustration and example only, and is not to be taken by way of limitation, the spirit and scope of this invention being limited only by the terms of the appended claims.

I claim:

1. In a device of the class described, walls defining a pair of adjacent passageways, one of said passageways adapted to conduct a hot gas and the other of said passageways adapted to conduct a cool gas, means for transferring heat from said hot gas to said cool gas comprising hermetically sealed heat exchanger tubes supported within said walls with their longitudinal axes located generally horizontally, said tubes being each individually rotatable and comprising an evaporator portion located within the hot gas passageway and a condenser portion located within the cool gas passageway, a volatile fluid within said tubes, means for individually rotating each of said tubes about its respective longitudinal axis to throw said fluid against the periphery of said evaporator portion to be volatilized by heat from said hot gas and thereupon flow to said condenser portion to transfer heat to said cool gas and then return to said evaporator portion, and means responsive to the temperature of the gas in said hot gas passageway for controlling the individual speed of rotation of said exchangers to control the rate of heat exchange and thereby avoid reducing the temperature of said hot gas to below a predetermined value.

2. A device as recited in claim 1 in which said evaporator portion is of greater diameter than said condenser portion.

3. A device as recited in claim 1 in which each said tube is in the form of a frustrum of a cone with the larger portion of the cone comprising the evaporator portion.

4. A device as recited in claim 1 in which each said tube is provided with circular fins having their axes coincident with the axis of said tube.

5. A device as recited in claim 1 and further including shroud means for conducting said hot gas and said cool gas in heat transfer relation with said plurality of heat exchanger tubes.

6. In a device of the class described, the combination of walls defining a pair of adjacent parallel passageways of which one passageway conducts a linear stream of hot gas from which heat is to be removed and the other conducts a linear stream of cool gas to which heat is to be added, means for transferring heat from the hot gas to the cool gas comprising an elongated, tubular, hermetically sealed element of circular outline in transverse cross section and disposed with its longitudinal axis substantially horizontal, said element comprising an evaporator section located within the hot gas stream and a condenser portion within the cool gas stream, said evaporator section having a cross section greater than said condenser portion, a body of volatile liquid contained within the tubular element and occupying a minor fraction of the internal space within the element, a plurality of disc-like fins on and projecting radially outwardly from the element into each passageway and disposed substantially parallel to the direction of gas flow in each passageway, means to rotate the element and the attached fins about the horizontal axis of the element at a rotational speed sufficient to distribute the liquid in a relatively thin film over the interior surface of the evaporator section and means within said condenser portion for returning condensate from said condenser portion to said evaporator section.

7. A device as recited in claim 6 and further including means responsive to the temperature of the gas in said hot gas passageway for controlling the speed of rotation of said element to thereby obtain optimum heat transfer at temperatures of said hot gas above a preselected temperature.

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