

Oct. 31, 1939.

E. T. LINDEROTH

2,178,481

HEAT EXCHANGING APPARATUS

Filed Feb. 2, 1937

5 Sheets-Sheet 1

Fig. 1.

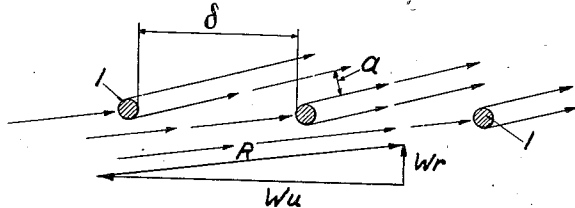
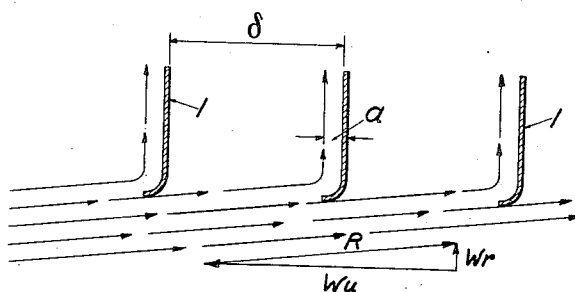


Fig. 2.



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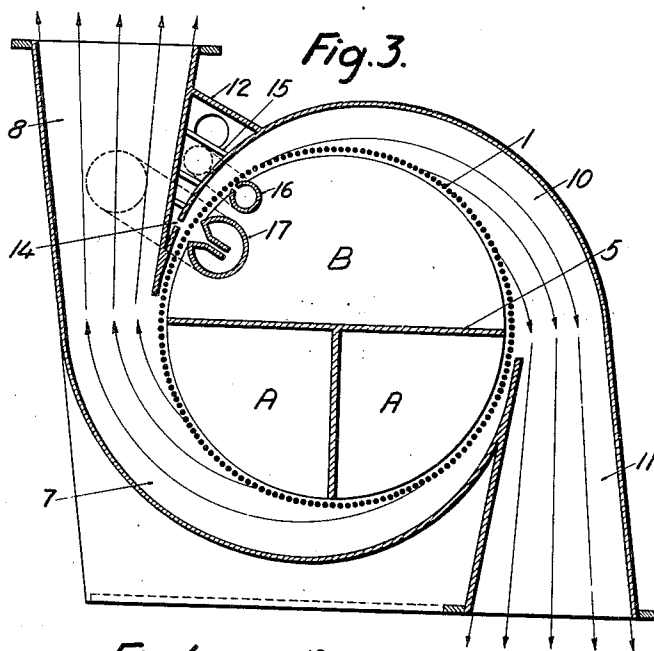
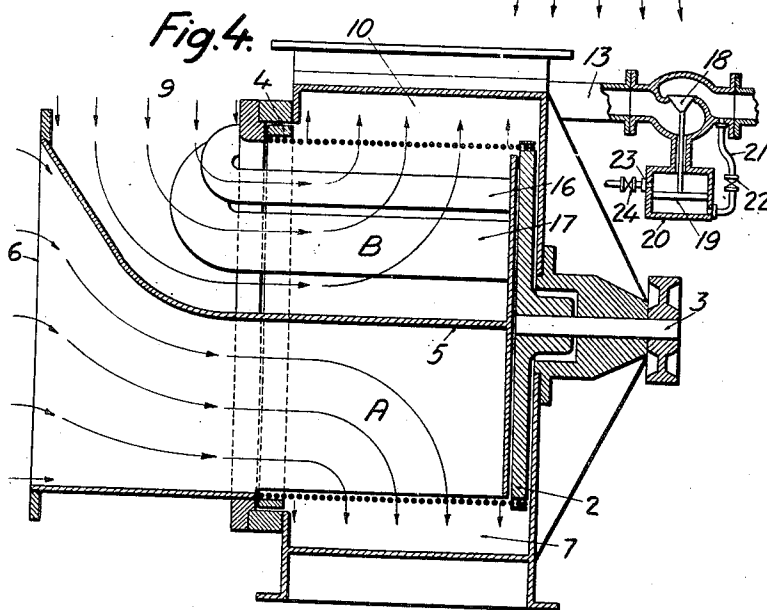
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5 Sheets-Sheet 2



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5 Sheets-Sheet 3

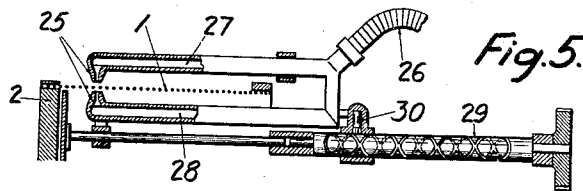


Fig. 5.

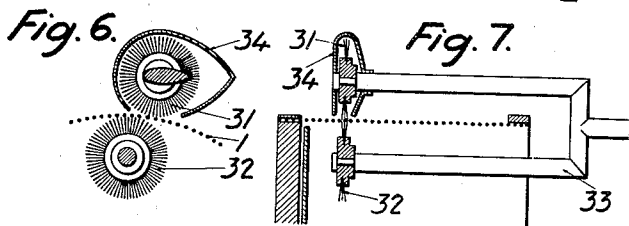


Fig. 6.

Fig. 7.

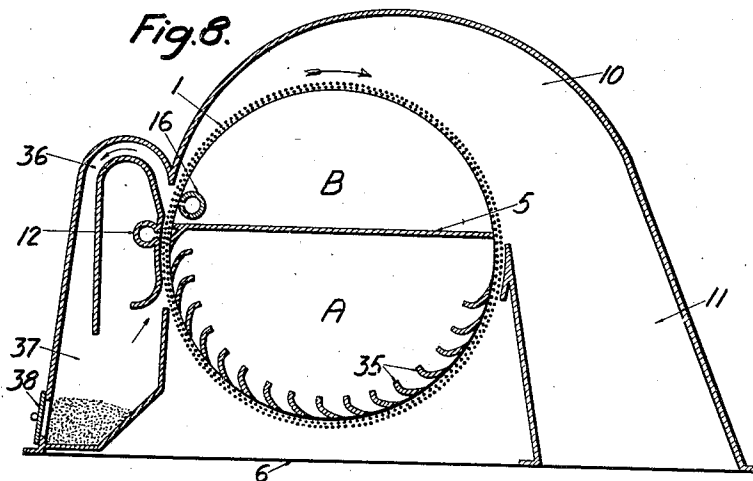


Fig. 8.

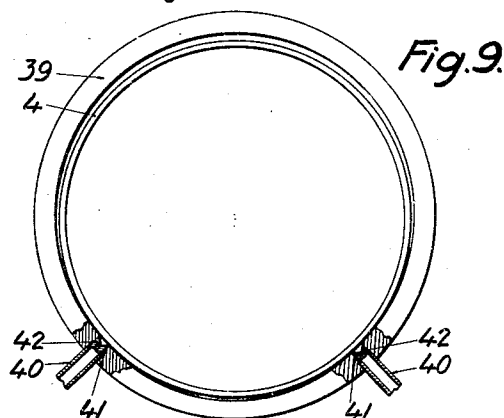


Fig. 9.

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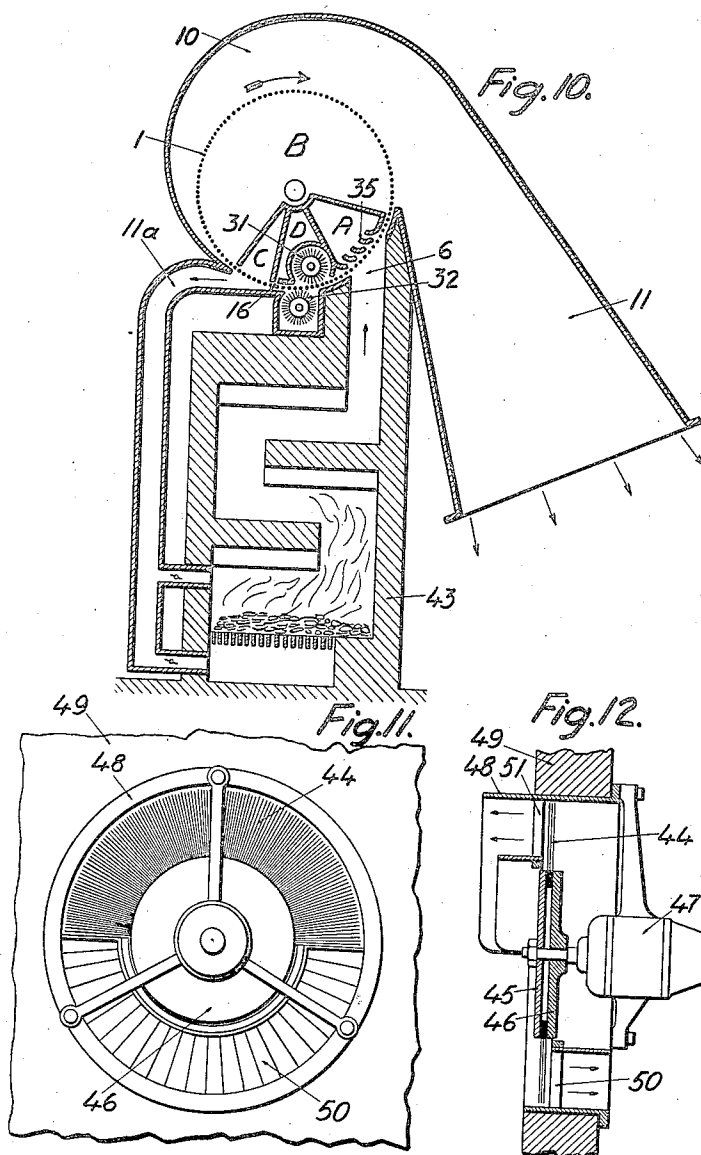
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5 Sheets-Sheet 4



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2,178,481

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5 Sheets-Sheet 5

Fig. 13.

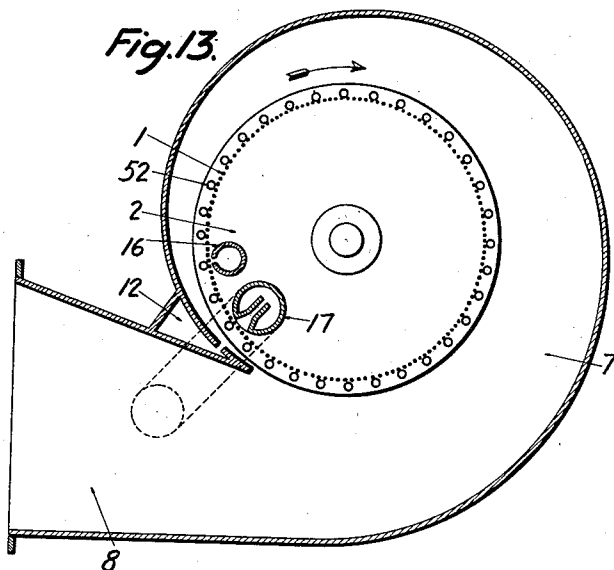
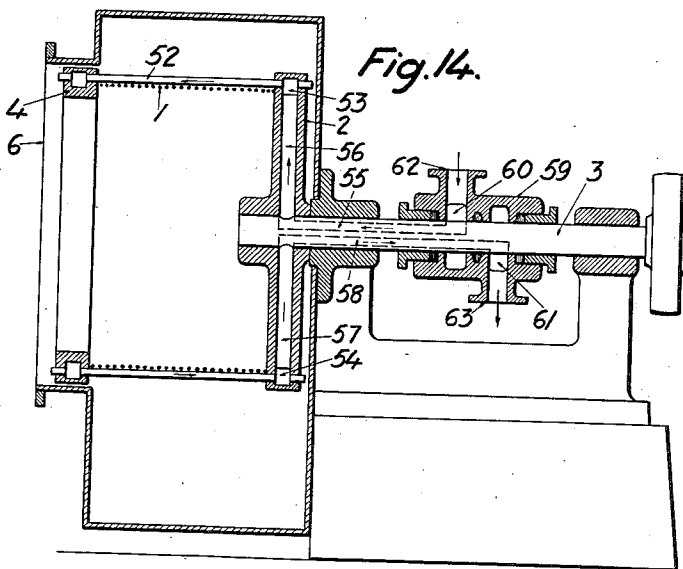


Fig. 14.



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UNITED STATES PATENT OFFICE

2,178,481

HEAT EXCHANGING APPARATUS

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Application February 2, 1937, Serial No. 123,705

In Sweden February 11, 1936

8 Claims. (Cl. 257—6)

This invention relates to heat exchanging apparatus for utilizing the heat in warm exhaust gases, such as from steam boilers, furnaces, drying plants, and the like.

5 The subject matter of the invention is particularly directed to a regenerative air preheater, although, the idea forming the basis of the invention may be applied in utilizing the gas heat for another purpose, such as preheating water, 10 in which case, however, the regenerative heat transmission principle must be abandoned.

According to the invention the heat transfer surface consists of wires, or similar elements, for example in the shape of one or several wire 15 gauzes, which are spaced in such a way relatively to one another and to the relative direction of motion between the flowing gas and the heat surface that the gas current is divided into thin layers which are considerably thinner than the 20 distance between the elements.

A very suitable embodiment, by which a considerable increase of the heat transmission output is obtained, is to dispose wire gauze in the shape of a cylinder rotating at a peripheral 25 speed which is considerably greater than the radial speed at which the gas flows through the wire gauze.

In order to illustrate the output thus obtained reference is made to the known fact that if a 30 fine-meshed wire gauze is held above a flame the flame is not able to penetrate the wire gauze because the glowing gas masses are quickly cooled to such a low temperature that the combustion ceases. This output is extraordinary since in 35 comparison with common heat surfaces it means an exceptionally high specific heat transmission output.

For example, the gases in a steam boiler have to flow a long way before a corresponding cooling 40 has been effected. The cooling in the wire gauze takes place in a distance less than a millimetre, viewed in the direction of flow. The high heat transmission of the wire gauze is particularly due to the fact that the gas is divided into a number of thin layers with intermediate cooling 45 surfaces whereby the gas layers are quickly cooled.

The output obtained in the indicated embodiment by the rotation of the wire gauze cylinder is illustrated diagrammatically in Figure 1 of the accompanying drawings, in which:

1 indicates wires disposed axially in the wire gauze cylinder. In the triangle below Figure 1 Wu represents the peripheral speed of the wire 50 gauze cylinder, and Wr the radial flow speed at

which the gas flows through the wire gauze. R then indicates the relative movement between the gas and the wires 1. It is just the same as if the gas had moved against the wire gauze in the direction R. The thickness of the gas layers a, 5 which flow through the spaces between the wires 1, now becomes only a fraction of the distance s between the wires. Thus, in order to obtain a thorough heating and cooling respectively of the whole gas layer the heat may be conducted a considerably shorter distance than if the gas flowed 10 through the wire gauze perpendicularly to the surface of the same. Thus, the described embodiment involves a considerably increased specific heat transmission output. 15

Under these circumstances the axial wires in the gauze are the most active ones although the turbulence caused by the rotation of the wire gauze increases the heat transmission output also in the tangential wires. A suitable arrangement 20 according to the invention is to dispose the wire gauze in such a way in the cylinder that the wires will be located at an angle of 45° to the axis. The heat exchange surface may also be composed of axial wires only, the said wires being 25 arranged so as to form a cylinder. Instead of wires 1 one may also dispose corresponding elements in the shape of sheet metal strips without abandoning the basic idea of the invention.

An example is shown diagrammatically in Figure 2 in which the strips are indicated by 1 just as the wires in Figure 1. The other reference 30 numerals also of Figure 2 relate to the same details as those of Figure 1. In the device according to Figure 2 the gas layers a are cooled and 35 heated respectively mainly from one side only. By way of recompense the elements 1 have here greater dimensions in the direction of flow of the gas than the wires in Figure 1. However, the most active part of the heat exchanger surface 40 is always the one located nearest to the border of inflow. According to the present invention the elements composing the heat transfer surface should therefore be very short in the direction of flow of the gas, and preferably shorter than the 45 distance between the elements. This also makes it possible to obtain an effective scavenging from soot, since according to the invention the gas flows through the heat exchange surface, i. e., the intermediate spaces formed between the elements in the heat surface, are meant to have 50 exceptionally small sections.

The heat transmission coefficients obtained according to the invention are so high that a slight soot layer on the heat surface would be sufficient 55

to make it impossible to obtain coefficients. Therefore, the invention also includes such a sweeping device that the heat surface may be held completely free from soot.

5 Preferably, the rotating heat exchange surface is disposed in a known way in a fan casing whereby the heat exchanging apparatus also serves as a fan.

Some embodiments of the invention are illustrated in the accompanying drawings.

10 Figure 3 is a cross section and Figure 4 a longitudinal section through an apparatus according to one embodiment relating to a regenerative air preheater.

15 Figure 5 is an elevational view of a modified cleaning device wherein some of the parts are shown in section.

Figure 6 is a sectional view of a mechanical sweeping device.

20 Figure 7 is a side view of the apparatus shown in Figure 6.

Figure 8 is a cross-sectional view of another form of the heat exchange apparatus.

25 Figure 9 is an elevational view illustrating means for rotatably supporting a wire gauze heat transfer member.

Figure 10 is a sectional view of another form of heat transfer apparatus.

30 Figure 11 is an end view of apparatus for recovering heat in ventilation.

Figure 12 is a sectional view of the apparatus shown in Figure 11.

Figure 13 is a cross sectional view showing another form of heat conducting element; and

35 Figure 14 is a longitudinal section of the apparatus shown in Figure 13.

The regenerator consists of a cylindrical shaped wire gauze 1, supported at one end by a disc-shaped wheel 2 which is rotatably mounted on a shaft 3. At the opposite end of the wire gauze cylinder the wire gauze is strengthened by an external ring 4. The interior of the wire gauze cylinder is by means of a stationary baffle or partition 5 divided into two chambers, one for the gas A and one for the air B. The hot gases enter the chamber A through the connection piece 6, pass through the rotating wire gauze cylinder 1, and are thrown out from the same into the lower spiral casing 7 surrounding the wire gauze cylinder on its underside. The spiral casing 7 merges into an upward directed diffuser 8 in which the kinetic energy of the gas is converted into pressure energy.

40 The air is sucked in at 9, passes the chamber B, flows through the wire gauze cylinder 1, and is thrown into the upper spiral casing 10 and the downward directed diffuser 11 in which the kinetic energy of the air is converted into pressure energy. Consequently, the apparatus is a gas fan as well as an air fan. Simultaneously it preheats the air and cools the gas. The heat transfer takes place through the wire gauze which absorbs heat from passing gas and gives off heat to the air passing therethrough.

45 Thus, due to the draft in the chimney to which the gas is conducted from the diffuser 8, and due to the flow resistance in grate and furnace and steam boiler respectively and in gas and air canals connected between the diffuser 11 and the connection piece 6 there is always a lower pressure in the chamber A and the spiral casing 7 than in the chamber B and the casing 10. Consequently, no leakage of smoke gases to the air can take place, only a flow of air to the gas. However, this leakage of air becomes insignificant due

to the small radial thickness of the regenerator. By a suitable positioning of the stationary partition 5 the air and gas currents may be so guided that a minimum of mixing is obtained under the pressure conditions considered to be normal for the preheater.

A very important detail in the construction of the air preheater is the cleaning device. This said device consists of a steam distributing chamber 12 disposed outside the casing 10, steam being supplied to the said chamber through the tube 13. From the chamber 12 the steam flows out through a narrow slit 14 located quite close to the wire gauze cylinder 1 and extending along its whole width. Thus, the steam is projected radially through the wire gauze. The inside of the steam chamber is stiffened by a number of stays 15.

If desired, also a similar steam blower 16 may be disposed on the inside of the wire gauze cylinder.

According to the invention it is intended to use very fine-meshed wire gauze to obtain a high heat transmission output. If no particular steps were taken, stray cinder, half-burnt chips and other coarse particles accompanying the gas would be separated and collected on the inside of the wire gauze cylinder. To preclude this, there is provided a slit tube 17 inside the wire cylinder, the tube 17 catching the steam projected from the outer steam chamber 12. One end of the tube is closed and the other end is connected to the diffuser 8. Thus, the particles, which are carried by the wire gauze cylinder, will be blown into this tube and conveyed to the chimney with the cooled gases.

The current from the steam blower may also be conveyed into the heated air, unburnt particles being returned to the furnace and combusted.

4 If in such a case a very dense gauze is used the apparatus acts to reduce smoke since it then works as a self-cleaning filter for the smoke gases.

An air preheater according to the present invention has to be swept very often if the intended high heat transmission output shall be maintained. The use of the preheater in practice requires a fully automatic operation of the sweeping device.

5 An embodiment of a device for the automatic supply of steam to the sweeping is shown in Figure 4. A conical valve 18 is adapted to shut off the steam supply to the steam blowers 12 and 16. The valve 18 is operated by a piston 19 in a cylinder 20. The area of the piston is larger than that of the valve cone. The steam is supplied beneath the piston through a thin tube 21 which communicates with the steam pressure supply in front of the valve 18. The supply of steam to the underside of the piston is choked by a valve 22 or a stationary choking member so that the pressure beneath the piston rises slowly. When this pressure has risen to such a value that the force exerted by the piston 19 overweighs the pressure upon the conical valve 18 the latter is opened. As the friction is smaller in motion than at rest and as the pressure upon the valve 18 is somewhat reduced at the very instant when it leaves the seat, the valve will open rather quickly if the movable parts have a small mass. Consequently, the steam will be discharged as a shot through the exhaust openings. When the piston has risen a certain distance it closes an opening 23 in the upper part of the cylinder 20,

whereby the air above the piston 19 is compressed and moderates the upward motion of the piston. When the piston has passed the opening 23, the steam pressure is let out from the underside of the piston whereafter the piston begins to move downwards. For moderating the downward motion of the piston there is preferably disposed a choking member 24 for the steam from the outlet opening 23.

Another embodiment of a cleaning device is shown in Figure 5 which relates to a continuously operating sweeping apparatus. Two small steam nozzles 25 are disposed one on each side of the wire gauze 1. Steam or compressed air is supplied through a flexible hose 26 and a movably disposed branch tube 27, 28. If the regenerator is cylindrical according to the above described embodiment the branch tube is provided with two axially positioned branches, one on the outer side of the regenerator and one on the inner side of the same. The outer branch 27, which lies in the air or gas current from the regenerator, has preferably a streamline-shaped profile in order not to impede the gas or air current. The branch tube 27, 28 is given a slow reciprocate motion in the axial direction by a suitable transmission, for example a rotatably mounted screw spindle 29 provided with two helically cut grooves, one of the grooves being right-handed and the other left-handed. At the ends of the spindle the helical grooves merge in a known way into one another so that a pin 30 engaging in the helical groove receives a reciprocate motion by the rotation of the screw spindle. The reciprocate motion of the pin 30 is transmitted to the branch tube 27, 28 to which the pin is pivotally connected so that a flat part of the pin extending into the helical groove may adjust itself freely according to the pitch of the helical groove. The screw spindle is slowly rotated by a suitable transmission from the rotating regenerator.

Figures 6 and 7 show a mechanical sweeping device by which the regenerator screen 1 may be kept clean from soot without consuming steam or compressed air for this purpose. The device consists of two round, rotatably disposed brushes 31 and 32 mounted on a fork-shaped frame 33 which is so arranged that one brush moves on each side of the wire gauze 1. The frame 33 is given a reciprocate motion in a manner similar to that described in connection with the steam sweeping apparatus according to Figure 5. The leg of the frame 33 located in the air or gas current from the regenerator is preferably streamline-shaped. The brush of the same is likewise provided with a streamline-shaped casing 34. The brushes 31 and 32, roll against the regenerator and are thereby rotated. The brushes will sweep over the whole surface of the regenerator due to the reciprocate motion and keep the same clean. The brushes may also be made in the shape of rolls extending over the whole width of the regenerator, thus making the reciprocate motion unnecessary. The brushes should in this case be arranged in such a position as not to disturb the gas or air current. An example of such a construction will be hereinafter described.

If a greater cooling of the gas and a higher air preheating respectively are desired than can be obtained by an air preheater according to Figures 3 to 4 one may dispose two or several layers of gauze in the regenerator, at the same time applying the counter-current principle.

An embodiment of such an air preheater is shown in Figure 8. The rotating cylindrical regenerator 1 has here two layers of wire gauze. The gas is admitted at 6 and flows through the regenerator radially from the outside inwards. At the inside of the rotating regenerator there are in the lower portion of the same disposed stationary guide rails 35 which catch the gas current and convert its kinetic energy into pressure energy. The gas is collected in the chamber A beneath the stationary screen 5 and is conducted to the chimney. The air is sucked in through the chamber B, passes the regenerator radially from the inside outwards, and is thrown through the helical worm casing 10 to the diffuser 11. In order to prevent overflow of gas to the air, where the regenerator moves in the direction from the gas chamber A to the air chamber B, a passage way 36 is provided for the gas-mixed air separated from the regenerator. The gas air mixture is returned to the gas inlet side and is here guided through the regenerator towards the guide rails 35. If desired, the gas air mixture is conducted past the regenerator into the cooled gas. The bottom of the passageway 36 merges into a chamber 37 in which soot and stray cinder are collected. The chamber 37 is emptied through the door 28. 12 and 16 are steam blowers for effecting the cleaning of the heat exchange cylinder.

Due to the fact that the regenerator according to Figure 8 has two or more layers of gauze and is passed in counter-current it is possible to cool the gas to a lower temperature than the heated air because the inner wire gauze, through which the colder gas and the colder air pass, assumes a lower temperature than the outer wire gauze through which hot gas and preheated air pass.

Under some conditions, it may be desired to dispense with a supporting construction within and around the regenerator. This is possible in small and moderately large regenerators by arranging the inner wire gauze with the wires diagonally at an angle of 45° to the wires of the outer gauze. If, moreover, the wire gauzes are fixed to the wheel 2 and the ring 4 (see Figure 4) and the gauze layers are mutually supported or joined at several places a rather rigid construction is obtained. However, if fine-meshed gauze formed of small diameter wire is to be employed large wheels cannot be used without special supports. In such a case the following construction is suggested:

In Figure 9 the reference numeral 4 indicates a ring which stiffens one end of the wire gauze cylinder (compare Figure 4). 39 is the corresponding ring in the casing, which surrounds the ring 4. Through two tubes 40 and two bores 41 in the ring 39 steam under pressure (or compressed air) is admitted to the space between the ring 4 and the ring 39. The ring 4 then floats in the ring 39 and may be turned without there arising any frictional resistance. In order to limit the steam consumption a small choking nozzle 42 is inserted in each bore. Moreover, the play between the rings should not be greater than what is necessary with respect to the heat expansion. Further, the ring 39 has an eccentric recess in its lower part between the two bores. Thus, if the ring 4 sinks against the ring 39 contact will first take place adjacent the bores 41. In order that the contact surface shall have a certain size and offer a sufficient pressure surface to the steam it is preferable to allow the ring 4 to wear itself into the ring 39 adjacent the two bores by means of

grinding paste. No third supporting point (at the top) is necessary for the ring 4 if the latter is sufficiently heavy in relation to the wire gauze so that it is not raised by the vibrations of the gauze.

An embodiment of the invention relating to a directly fired hot air generator for drying, or for heating is shown in Figure 10.

For such a purpose the gas quantity to be cooled becomes only $\frac{1}{40}$ to $\frac{1}{50}$ of the air quantity to be heated if the apparatus is directly fired. The gas is very hot, viz. 1,200 to 1,500° C. At the same time the preheated air should be free from smoke gases and soot all of which necessitates a particular construction. For this purpose the air preheater of the countercurrent type is selected. However, only a single layer of wire gauze is necessary since in view of the great quantity of cooling air the wire gauze assumes a low temperature so that the gas is effectively cooled. The countercurrent principle is chosen in this case only in order that by the centrifugal force soot and stray cinder shall be thrown out from the regenerator through which the gas is led from the outside inwards.

The air preheater is located above a furnace 43 in which fuel is combusted with a large excess of air. The furnace is made so high and the gas passage so long that the gases will have time to combust completely prior to their being led off at 6 and projected through the regenerator 1. No considerable radiation from the fire takes place since the same is surrounded by insulating masonry on all sides. Thus, the gases are not cooled until they flow through the regenerator, and consequently a high combustion efficiency may be expected. Only a small part of the regenerator is contacted by the smoke gases which are caught by the guide rails 35, collected in the chamber A and led off to the chimney. The largest part of the regenerator is cooled by cool air which is admitted through the chamber B and thrown out by the rotating regenerator into the spiral casing 10 and the diffuser 11. Behind the gas-contacted part of the regenerator, viewed in the direction of rotation, there is a space for a sweeping device which in this case preferably should be made in the shape of two cylindric rotating brushes 31 and 32 extending over the whole width of the wire gauze. Between the sweeping device and the air chamber B within the regenerator a chamber C is provided for air which is to carry away soot and ashes removed by the brushes from the regenerator. The transport air is caught by a small diffuser 11a and is admitted as combustion air into the furnace. If desired, blowing away of stuff from the regenerator may be facilitated by compressed air which is admitted through the chamber D and flows continuously through a slit 16 extending over the whole width of the regenerator. If compressed air as well as brushes are used the air need not have so high a pressure but it may be produced plentifully in a simple way by a fan (not shown in the drawings). In order that hot combustion gases from the furnace shall not leak into the chamber around the brush 32 the chamber may be supplied with overpressure by connecting it with the just mentioned fan for scavenging air. In this construction the penetration of smoke gases into the heated fresh air is impossible.

Finally, Figures 11 and 12 show an embodiment of the invention for heat recovery in ventilation. The regenerator here consists of radially extending wires 44 clamped between two disc wheels 45, 46, carried by the shaft of an electric

motor 47. The device is supported by a cylindrical frame 48 inserted in an outer wall 49 of the room to be aired. Fresh air is sucked in by the stationary guide vanes 50 against which the air is thrown by the regenerator during rotation of the latter. The guide vanes must be so shaped that they catch the air current from the regenerator and direct it towards the interior of the room to be aired. The vanes 50 cover the lower half of the inside of the regenerator. On the outer side of the regenerator there is in the same way disposed a vane rim 51 which directs an air current outwards to the free air outside the wall. This air is cooled when passing through the regenerator, and the heat is conveyed over to the fresh air which flows in counter-current through the apparatus.

By such an apparatus it will be possible to obtain an ample ventilation also at cold atmosphere without necessarily entailing any great losses of heat.

In all of the above described apparatus air has been used as cooling medium. However, without departing from the basic idea of the invention the construction may be modified so that also liquids, such as water, may be heated by means of the heat of the exhaust gases. The problem in such a heating has always been the heat transmitting output on the gas side, which output, at least within the ranges of temperature where the radiation is minimal, is rather bad in view of the low thermal conductivity of the gases. One has therefore usually enlarged the surface of the water tubes on the gas side (wrought-iron ribbed pipes). According to the present invention this surface enlargement consists of wire gauze or the like, and at the same time in the manner described above the good heat transmitting output of the wire gauze is further increased by causing the heat surface to rotate. An embodiment of such an apparatus is shown in Figures 13 and 14.

The water is heated in a number of thin tubes 52 mounted on the wheel 2 in such a way that they form a cylindric rim. Within this rim of tubes a wire gauze 1 is disposed and soldered to all of the tubes along the whole length of the tubes so that a good heat conducting contact arises between the wire gauze and the tubes. The wire gauze is preferably so placed that the wires lie at an angle of 45° to the tubes, in order that all of the wires shall be soldered to the tubes.

For the circulation of the water through the tubes 52 the following steps are taken. One end of the tubes is connected to a hollow ring 4. At the opposite end the tubes are connected to the wheel 2 and communicate here with an annular canal in the wheel. This canal is by means of two walls (not shown in the drawings) divided into two semicircular parts 53 and 54. The water is admitted to one canal 53 by a canal 55 in the shaft 3 and by a radial extending canal 56 in the wheel 2. From the canal 53 the water flows through half the number of tubes to the ring 4 and from the said ring through the other tubes to the annular canal 54. From here the water flows through the radial extending canal 57 to a canal 58 in the shaft 3. For admitting the water to, and leading the same off from the rotating shaft 3 a casing 59 is disposed around the shaft, the said casing being provided with two annular canals 60 and 61, which are connected to the inlet and outlet tubes by means of pipe sockets 62. and 63. The annular canal 60 communicates with the canal 55 in the shaft and the annular canal

61 with the canal 58. The two annular canals 50 and 61 are tightened against the shaft by packing bushes.

The gas to be cooled is admitted at 6, is projected through the wire gauze 1 to which the gas delivers its heat, and is thrown into the spiral casing 7 to the diffuser 8. Thus, also this apparatus acts as a fan at the same time as a gas cooler. The sweeping device 12, 16 and 17 is of the same construction as described in connection with Figures 3 and 4.

If desired, the heat surface may be increased by a further layer or layers of wire gauze around the tube rim 52. In order that the passage through which the heat is to be conducted through the thin wires in the gauze, shall be as short as possible the tubes 52 should be made very thin so that they may be placed at an insignificant distance from one another. The apparatus may preferably be carried out in such a way that the gas flows through the wire gauze from the outside inwards, the fan action being obtained by a stationary vane rim located inside the wheel, as hereinabove described.

Having now described my invention, what I claim as new and desire to secure by Letters Patent is:

1. Heat exchange apparatus for cooling and heating gases passing therethrough comprising in combination, a rotatable regenerator which consists of at least one substantially cylindrical shaped wire screen providing an apertured heat exchange member, means for projecting a supply of heated gas through the apertures of the heat exchange member, means circumferentially displaced from the first means for projecting an unheated gaseous medium through the apertures of said heat exchange member, the wires of said screen being circumferentially spaced with respect to each other and the transverse dimensions of each of said wires in a direction radially of the heat exchange member being less than the circumferential spaces between the wires whereby the gases in passing through the screen are divided into layers by the rotation of the heat exchange member which layers are considerably thinner than the circumferential dimensions of said spaces.

2. Heat exchange apparatus for cooling and heating gases passing therethrough comprising in combination, a rotatable regenerator which consists of at least one substantially cylindrical shaped wire screen providing an apertured heat exchange member, means for projecting a supply of heated gas radially through the apertures of the heat exchange member, means circumferentially displaced from the first means for projecting an unheated gaseous medium radially through the apertures of said heat exchange member, the wires of said screen being circumferentially shaped with respect to each other and the sectional dimensions of each of said wires in a direction radially of the heat exchange member being less than the circumferential spaces between the wires whereby the gases in passing through the screen are divided into layers by the rotation of the heat exchange member without completely filling the apertures thereof which layers are considerably thinner than the circumferential dimensions of said spaces.

3. Heat exchange apparatus for cooling and heating gases passing therethrough comprising in combination, a rotatable regenerator which consists of at least one substantially cylindrical shaped wire screen providing an apertured heat

exchange member, means for projecting a supply of heated gas through the apertures of the heat exchange member, means circumferentially displaced from the first means for projecting an unheated gaseous medium through the apertures of said heat exchange member, the wires of said screen being circumferentially spaced with respect to each other and the transverse dimensions of each of said wires in a direction radially of the heat exchange member being less than the circumferential spaces between the wires whereby the gases in passing through the screen are divided into layers by the rotation of the heat exchange member which layers are considerably thinner than the circumferential dimensions of said spaces, and said heat exchange member being adapted to be rotated at a peripheral speed which is manifoldly greater than the speed at which the gases flow through the screen.

4. Heat exchange apparatus according to claim 1 in which the heat exchange cylinder is supported at one end by a ring which is rotatably disposed in an outer casing, said casing having openings in the lower part thereof into which a gaseous pressure is supplied for causing said ring to flow in said casing during relative rotation therebetween.

5. In heat exchange apparatus for cooling and heating gases passing therethrough in combination of, a rotatable regenerator which consists of at least one substantially cylindrical shaped wire screen providing an apertured heat exchange member, means for projecting a supply of heated gas through the apertures of the heat exchange member, and means circumferentially displaced with respect to the first mentioned means for projecting an unheated gaseous medium through the apertures of the heat exchange member and the radial dimensions of the wires of the screen being less than the circumferential dimensions of the apertures.

6. Heat exchange apparatus for cooling and heating gases passing therethrough comprising in combination, an annular regenerator having a dry surface mounted for rotation at relatively high speeds, said regenerator including axially extending wires, said wires being circumferentially spaced with respect to each other and the transverse dimension of each wire in a direction radially of the regenerator being less than the circumferential spaces between the wires, means for projecting a supply of heated gas radially against said wires and through the spaces between the wires, and means circumferentially displaced from the first means for projecting an unheated gaseous medium radially against said wires and through the spaces therebetween.

7. Heat exchange apparatus for cooling and heating gases passing therethrough comprising in combination, an annular regenerator having a dry surface mounted for rotation at relatively high speeds, said regenerator including two layers of axially extending wires, the wires of said layers being circumferentially spaced with respect to each other and the transverse dimension of each wire in a direction radially of the regenerator being less than the circumferential spaces between the wires, means for projecting a supply of heated gas radially against said wires and through the spaces between the wires, and means circumferentially displaced from the first means for projecting an unheated gaseous medium radially against said wires and through the spaces therebetween.

8. Heat exchange apparatus for cooling and heating gases passing therethrough comprising in combination, an annular regenerator having a

dry surface mounted for rotation at relatively high speeds, said regenerator including at least two layers of wires, the wires of said layers being circumferentially spaced with respect to each other and the cross section of each wire being less than each space between the wires, means for projecting a supply of heated gas against said wires and

through the spaces between the wires, and means circumferentially displaced with respect to the first means for projecting an unheated gaseous medium against said wires and through the spaces therebetween.

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