United States Patent

[11] 3,598,179

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[54] **HEAT EXCHANGER**
5 Claims, 7 Drawing Figs.

[52] **U.S. Cl.** **165/111,** 165/122, 165/145, 165/176
[51] **Int. Cl.** **F28b 1/06,** F28b 9/08, F28b 9/10
[50] **Field of Search** 165/110, 111, 176, 175, 112, 113, 143, 144, 145, 122

[56] **References Cited**

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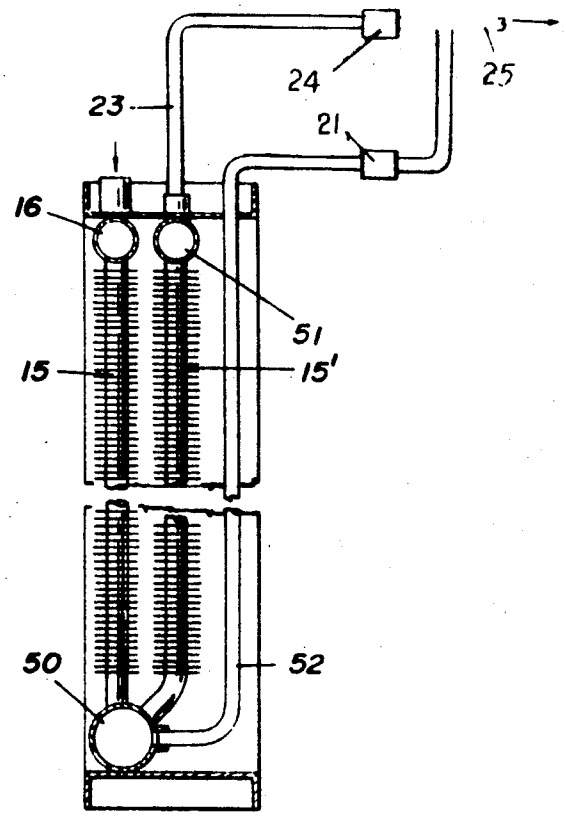
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ABSTRACT: The invention provides a heat exchanger comprising first and second rows of vertically arranged tubes, the outlets of the tubes in each row being connected to separate condensate headers, to which separate traps are connected, and the steam inlets of the second row of tubes being connected to the steam outlets of the first row of tubes whereby the tubes of the first row are automatically purged and air binding is prevented.



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SHEET 1 OF 3

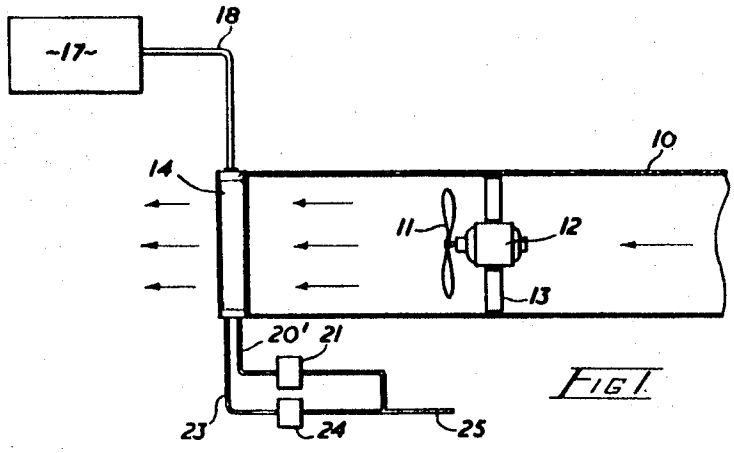


FIG 1.

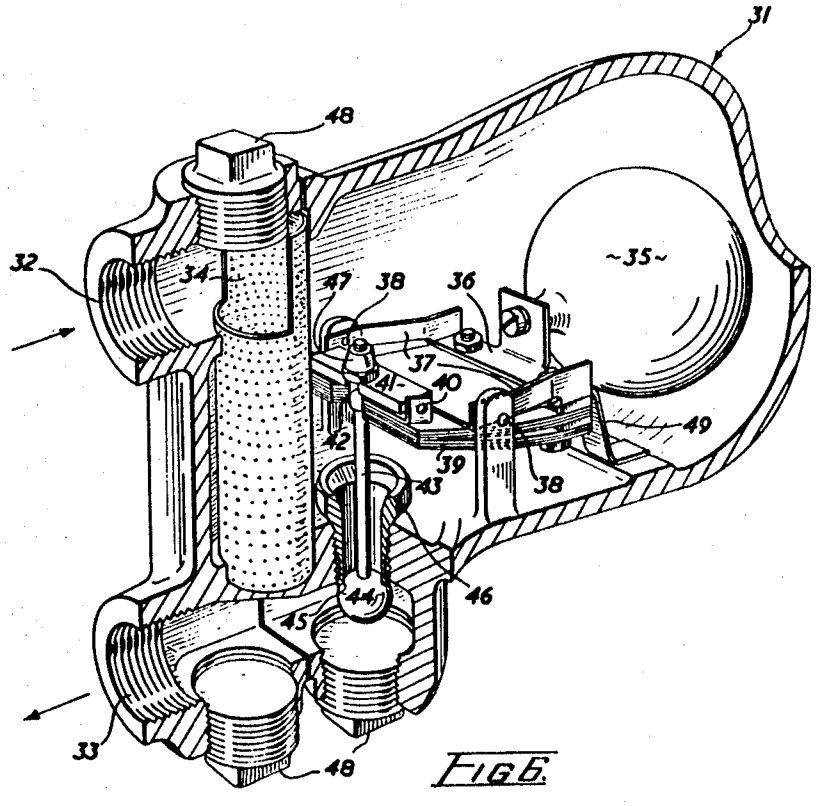


FIG 6.

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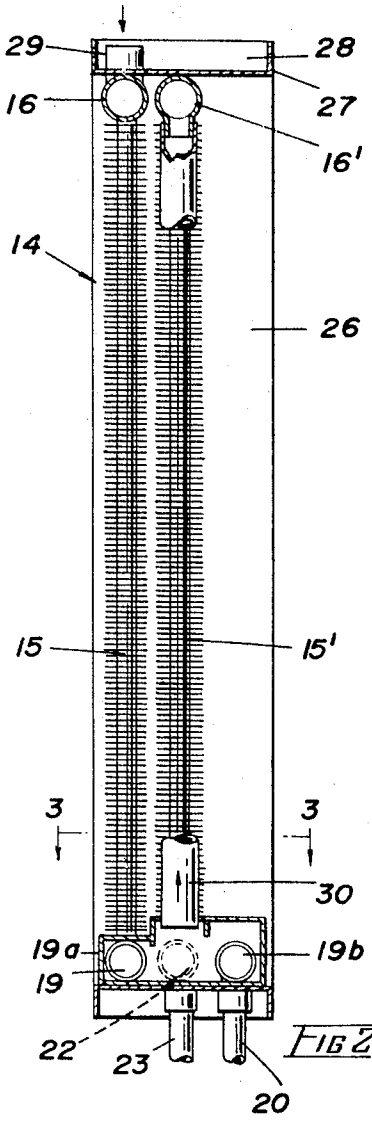


FIG 2

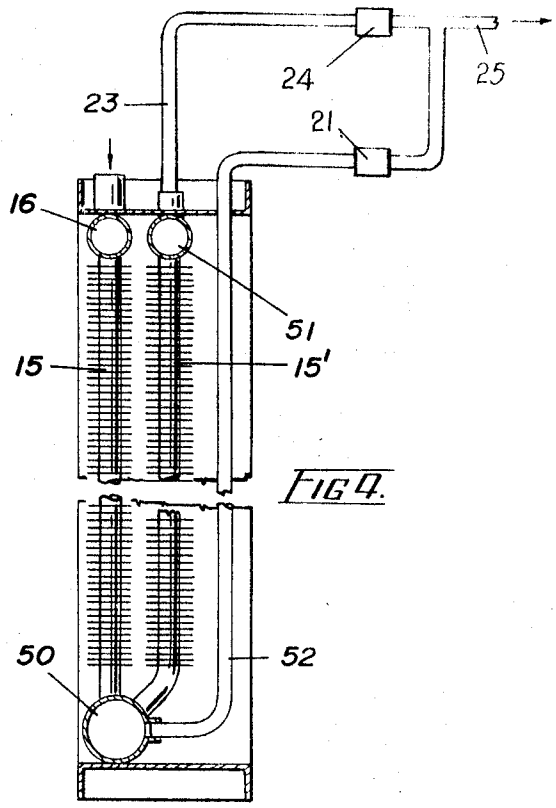


FIG 4.

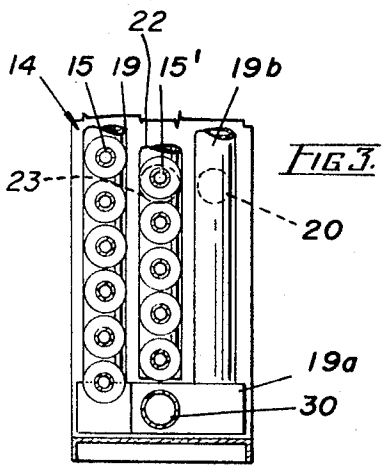


FIG 3.

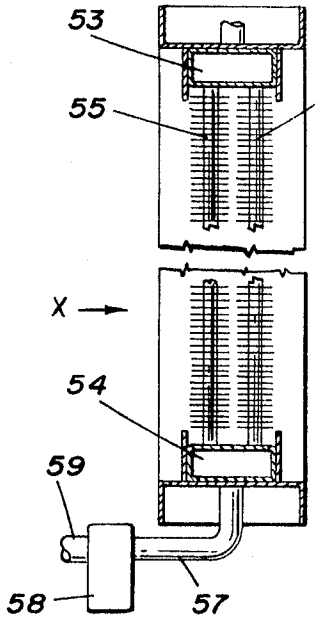


FIG 7.

PRIOR ART

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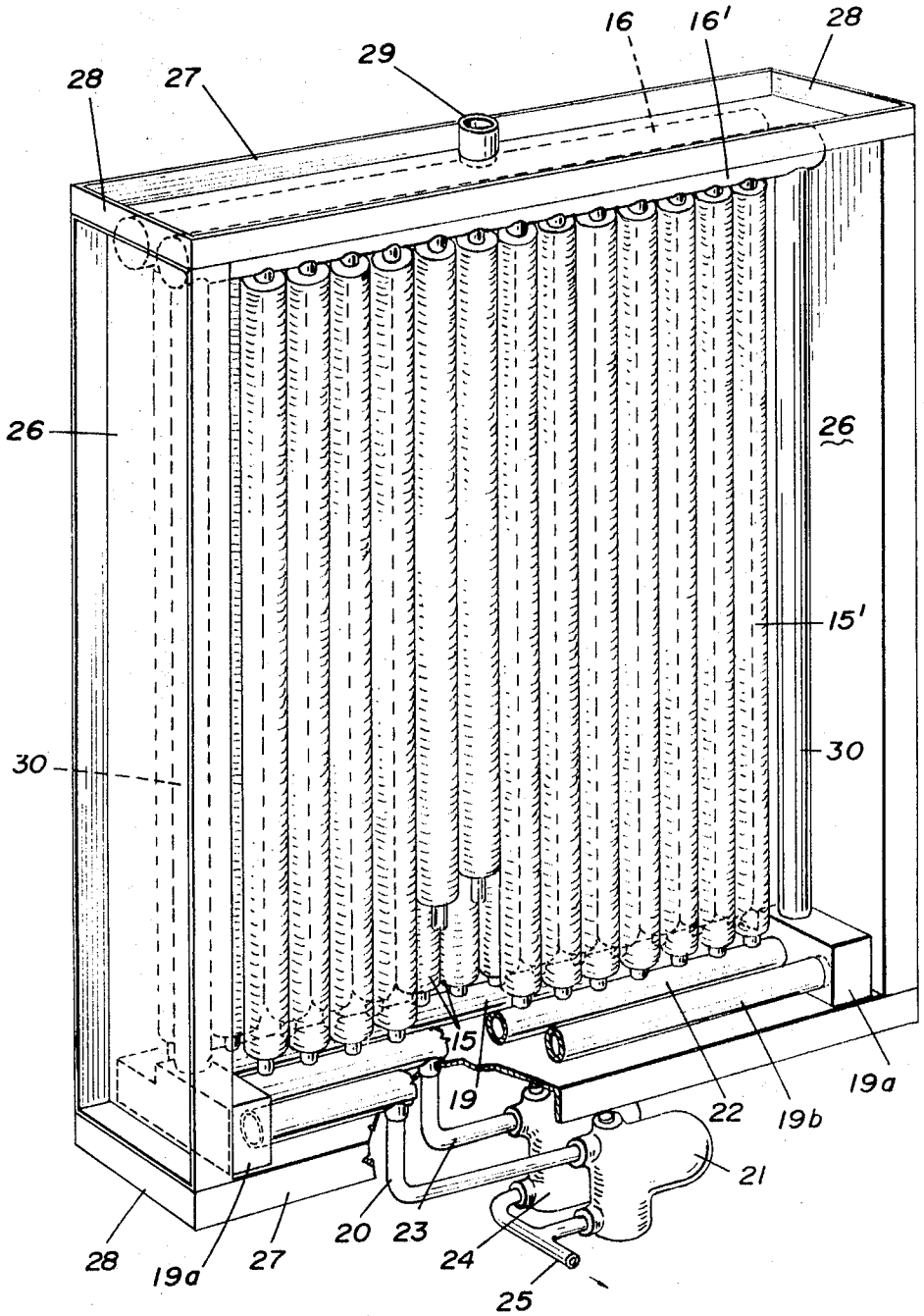


FIG 5

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HEAT EXCHANGER

BACKGROUND OF THE INVENTION

This invention relates to heat exchange apparatus, and is concerned particularly with apparatus for passing steam in heat exchange relation with air having an initial temperature below the freezing point of water; such apparatus is commonly called blast coil or heater coil apparatus.

It is known to employ steam to heat air for use in the heating of buildings such as factories, aircraft hangars and the like. One form of apparatus used for heating the air comprises two or more rows of heat exchanger tubes arranged one behind the other; steam is passed through the tubes from a common steam header, the air being propelled across the exterior of the tubes by means of a fan, and the condensate being collected in a common condensate header. The exteriors of the tubes are normally encircled with fins, either integral with the tubes or wound on, to increase the rate of heat transfer from the hot tubes to the cooler air. It has been found that, under certain conditions of airflow when the air is initially at a temperature below the freezing point of water, the condensate which forms in tubes of the row of tubes with which the air first comes into contact, freezes and bursts the tubes. A row of tubes with which the air first comes into contact is hereinafter called a "-first row." Air at a sufficiently low temperature to cause bursting of the tubes as described above is commonly encountered in the winter in, for example, the northwesterly parts of the United States and most of Canada, and the invention is particularly concerned with providing heat exchange apparatus which may be used in such northerly regions and which prevents, or at least minimizes, the freezing of condensate in the tubes.

Although the makers of heat exchanger tubes realize that a freezing problem exists in connection with heating very cold air, they have been unable to provide a satisfactory solution. So called "nonfreezing" or "steam-distributing" heating tubes which are presently on the market comprise an outer finned tube, within which is concentrically arranged an inner tube, and a clearance is provided between the outer surface of the inner tube and the inner surface of the outer tube. The wall of the inner tube is perforated all along the length and steam is supplied to the inner tube and passes through the perforations into the clearance between the tubes. This construction is intended to prevent the condensate from freezing in the tubes but it is not sufficiently effective for this purpose in apparatus having more than one row of tubes connected to a common condensate header. Moreover, such "nonfreezing tubes" cost approximately one-third more than conventional heat exchanger tubes.

Freezing may be prevented by using excessive amounts of steam e.g. bypassing steam through the tubes without restriction, but this is not practical in the majority of installations where steam is an expensive commodity; likewise, disposal of the noncondensed steam poses a problem.

In my U.S. Pat. No. 3,074,479 entitled HEAT EXCHANGE APPARATUS, issued Jan. 22, 1963, I have described a form of apparatus which goes a long way towards solving the problem of the freezing of condensate in the tubes of the first row in a twin or multiple-row heat exchanger. The solution, which does not require the use of any excess steam, is to provide means to eliminate the leg of condensate which normally builds up and freezes in each tube of the first row when this row is connected with a subsequent row or rows to a common header at the condensate ends. This is achieved by allowing the pressure drop of the steam across the tubes of the first row to be independent of the pressure drop across the tubes of the other row or rows. For this purpose separate first and second traps to prevent escape of steam but to discharge condensate are connected respectively to the tubes of the first row and the tubes of the second row.

The construction described in the above mentioned patent overcomes the problem of condensate hangup, or condensate leg formation, in the fist row of tubes, and thereby eliminates a major cause of freezing. However, there are other factors which can lead to freezing within the first row of tubes, of which the most important is air binding. It is an object of the present invention to provide a construction of heat exchange apparatus in which air binding as a cause of freezing in the first row of heat exchanger tubes is eliminated.

In the case of a row of heat exchanger tubes connected between a common steam header and a common condensate header, air binding will occur if one of the tubes is starved for steam, and the steam is not perfectly pure. (Even the best commercially produced steam carries a few p.p.m. of noncondensables. The "being-starved-for-steam" condition may occur through a peculiarity of the steam flow from the steam header, or through a greater heat dissipation from the exterior surface of the particular tube. In either case the demand for steam in the tube is greater than the supply from the steam header. Each of the companion tubes will in such a case supply a little steam to the condensate header together with air or other noncondensable fluids. This steam and the noncondensables are fed into the condensate removal end of the starved tube. In general the point of lowest pressure in a heat exchanger tube is at its outlet, i.e. where it joins the condensate header, but for a starved tube the point of lowest pressure is at some point before the outlet, because the collapse of steam volume due to condensation creates a pressure drop, which in turn causes more steam to flow in to take the place of the steam which has condensed. The starved tube draws in steam from both ends and the air and noncondensables remain at the point of lowest pressure within the starved tube. In the course of time, which may be hours or days, the quantity of air trapped in the starved tube increases, and the temperature in the area of the steam-air mixture continues to drop because the partial pressure of the steam becomes less and less. At the same time the film heat transfer coefficient for the inside of the tube decreases because of the presence of air, and finally the inner surface of the tube is cooled to a temperature below freezing point. Frost builds up rapidly until it bridges the tube, whereupon condensate rapidly fills up the remainder of the tube and freezes to burst the tube.

Under high load conditions, and especially in the case of heat exchanger tubes of relatively small cross section, a condensate leg can form in a starved tube even when air binding does not occur. This is because the steam fed back into the tube reaches a high enough velocity to interrupt the flow of condensate from the starved tube. The condensate may develop a height to provide the required suction to draw additional steam from the steam header, but it can and frequently does, freeze with disastrous results.

Periodic purging of the tubes with excess steam to clear air from the tubes cannot be carried out satisfactorily because the required amount of purging varies, because a considerable wastage of steam is involved, and because disposal of the uncondensed purging steam is a problem.

According to my invention, the above-mentioned problems are solved by providing separate steam headers and separate condensate headers for the first and second rows of heat exchanger tubes, the steam supply for the heat exchange apparatus being connected only to the first row steam header. The second row steam header is connected by plain tubes or conduit means to the condensate header of the first row of tubes, which may be structurally combined with or separate from the steam header of the second row, and the condensate headers are trapped separately as described in my U.S. Pat. No. 3,074,497.

In such an apparatus all the steam for the apparatus is supplied to the first row of tubes, the amount of steam required by the first row condensing and being removed; the steam required for the second row of tubes must also travel through the first row of tubes to the first row condensate header and from there to the second row steam header before it can

supply the second row of tubes. In this way the steam purges the tubes of the first row continuously. The most important function of this design is that it prevents all possibility of steam being fed back into the tubes of the first row with consequent air binding, but an incidental advantage is that it improves the heat transfer rate of the tubes of the first row even when not air bound.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

FIG. 1 is a diagram showing the various components of the heat exchange apparatus according to the invention;

FIG. 2 is an enlarged sectional elevation view of a detail of FIG. 1;

FIG. 3 is a section on line 3–3 in FIG. 2;

FIG. 4 is an enlarged sectional plan view of a detail of a modification of the invention;

FIG. 5 is a perspective view, partly broken away, of the heat exchanger tubes and traps forming part of the apparatus shown in FIG. 1;

FIG. 6 is a broken away perspective view of one of the traps shown in FIGS. 1 and 2;

FIG. 7 is a transverse cross section of a heat exchanger coil of the type used heretofore in installations for heating air by steam. This view is a sectional elevation as the coil is normally installed.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, and particularly to FIG. 1, there is shown a duct 10 along which cold air is drawn by a fan 11 driven by an electric motor 12 supported within the duct by struts 13. The cold air is propelled by the fan through an assembly 14 of heat exchanger tubes, details of which are illustrated in FIGS. 2 and 3. The assembly 14 comprises a first row of heat exchanger tubes indicated at 15 in FIG. 2, and a second row of heat exchanger tubes indicated at 15: also in FIG. 2. The upper ends of the tubes of the rows 15 and 15' constitute steam inlets to the tubes and are connected to steam headers 16, 16', the former being supplied through inlet 29 with steam from a source or boiler 17 by means of a steam pipe 18. The bottom ends of the tubes in the first row 15 constitute condensate and steam outlets and are connected to a first condensate header 19 which is connected by first conduit means 20' (or 20 as an alternative) to a first steam trap 21. The steam supplied to header 19 makes its way via conduit means 30 to second steam header 16. The bottom ends of the tubes of the second row 15' constitute condensate outlets and are connected to a second condensate header 22 which is connected by second conduit means 23 to a second steam trap 24. The traps 21 and 24 discharge the condensate to a hot well or condensate sump (not shown) through pipe 25.

Referring now to FIG. 5, the arrangement of the rows of heat exchanger tubes is shown in more detail. The rows of tubes are held in a rectangular frame made up of channel section side members 26 and channel section upper and lower cross members 27. The ends of the crossmembers 27 are closed by ribs 28. Secured to the underside of the upper crossmembers 27 and parallel thereto are the steam headers 16 and 16', the former being provided with a steam inlet connection 29 secured to the steampipe 18. The upper ends of the tubes in the rows 15 and 15' are secured in the lower wall of the steam headers 16, 16'. Except for the ends these tubes are finned for their full length. The finned tubes in the two rows are all similar and may be provided with reentrant orifices (not shown) at their upper ends. Plain transfer tubes 30 are connected at their lower ends to the condensate header 19, and are connected at their upper ends to the stream header 16', so that all the steam to the second row of tubes must have passed through the first row of tubes and be supplied via the transfer tubes 30.

It will be seen particularly from FIGS. 2 and 3 that the header assembly at the lower end of the heat exchanger is constructed in such a manner as to separate steam and condensate discharged from the first row of tubes. The lower ends of the tubes of the first row 15 are connected directly to the condensate header 19, which is a cylindrical pipe lying parallel to the steam header 16. This pipe communicates with two hollow box structures 19*a* to which the lower ends of the transfer tubes 30 are connected. The transfer tubes are thus connected indirectly to the condensate header 19. Also communicating with the box structures 19*a* is a drain 19*b* which receives condensate from the header 19. The lower ends of the finned tubes of second row 15' are connected to the second condensate header 22, which is of course isolated from the box structures 19*a*. The lower ends of the tubes of the second row 15' are connected to the condensate header 22, which is a cylindrical pipe having closed ends and lying parallel to the steam header 16'. The purpose of the drain 19*b* is to prevent condensate from being carried over through the transfer tubes 30, but in most practical applications carryover of condensate does not present a problem and the drains 19*b* can be omitted.

The first and second conduit means 20, 23 are connected to the condensate headers 19, 22 respectively at condensate connections intermediate the ends of the condensate headers, the first conduit means 20 actually being connected indirectly to the pipe 19 by being connected directly to the drain 19*b*. Upper and lower baffles (not shown) may be provided to shield the steam headers and the condensate headers from the full force of the cold air as it passes across the tubes, substantially as described in my above-identified U.S. Pat. No. 3,074,479.

Both of the steam traps 21 and 24 are similar and the trap 24 has been shown in FIG. 6 as illustrative of both traps. The trap comprises a hollow body 31 having a steam and condensate inlet 32 and a condensate outlet 33; the condensate and steam pass through a strainer 34 after leaving the inlet 32. A float 35 is secured to an angle member 36 having side arms 37 which are pivoted to the body 31 at 38. Also secured to the angle member 36 is a bimetallic element 39 which has secured to one end thereof upstanding lugs 40; pivoted between the lugs 40 is a bar 41 slotted at 42. Received in the slot 42 is a rod 43 having a ball 44 at its lower end and arranged to cooperate with a valve seat 45 at the lower end of an insert 46. The upper end of the rod 43 is provided with an adjusting nut 47 having a sleeve portion which is received in the slot 42. Access plugs 48 are provided in the body and a bracket 49 is secured to the float to control its lowermost position.

The trap is shown in a position it occupies when there is steam in the trap but no condensate; the steam causes the bimetallic element to bend and to lift the rod so that the ball 44 comes into contact with the seat 45 and prevents the escape of steam. When cooler condensate enters the trap, the bimetallic element straightens and the float 35 rises to discharge the condensate to the insert 46. Once the apparatus is in steady operation the float will operate to maintain a predetermined level of condensate in the trap dependent on condensate temperature and rate of flow and will discharge the excess to the hot well. It will be seen that the trap provides means to prevent the escape of steam but to discharge condensate.

A modification of the heat exchange apparatus is illustrated in FIG. 4, which is a view corresponding to FIG. 2 except that it is primarily for horizontal tube installation, and is therefore drawn in plan, with steam and condensate connections on the one side. (FIGS. 1, 2, 5 and 7 represent units designed primarily for vertical tube installations with top and bottom steam and condensate connections). Corresponding reference numerals are used to denote corresponding parts. The essential difference between this modification and the preceding embodiment is that the steam inlets of the tubes of the second row 15' are at the far ends of these tubes and are connected directly to the vertical header 50, which is in effect a combined condensate header for the first row and steam header

for the second row. The condensate header **51** of the second row **15'** is connected to the near ends of the tubes, and a trap **24** is connected to this header by a conduit **23**. The trap **21** is also it the near end of the assembly, and is connected to the condensate header **50** by a conduit **52**.

Referring now to FIG. **7** there is shown a conventional construction of heater coil in which freezing readily occurs in the tubes of the first row. (Once first row tubes freeze, second row tubes soon freeze also, because of being highly overloaded in comparison to companion tubes in the same row.) The tubes are held within a framework and are connected between a common steam header **53** and a common condensate header **54**. A first row of tubes is indicated at **55** and a second row of tubes at **56** and cold air is passed through the tubes in the direction of the arrow X.

Condensate delivered to the common condensate header **54** leaves through a conduit **57** and passes to a trap **58** and thence to a hot well (not shown) through a pipe **59**.

Thus, in the conventional apparatus a common steam header and a common condensate header are provided and the condensate ends of both rows of tubes are in communication with one another via the common condensate header. The different demands for steam in the tubes of the two rows result in differences in the pressure drops in the tubes with feedback of steam into the tubes of the first row. (They demand more steam because of heating up colder air than do the tubes of the second row.) This causes air binding or formation of condensate legs within the tubes, depending upon conditions heretofore mentioned. Either one can lead to the freezing of condensate and the bursting of tubes as explained previously. This problem is overcome to some extent by providing condensate headers as described in my above-mentioned U.S. Pat. No. 3,074,479, but condensate often still forms in individual first row tubes, or air binding takes place, with damaging results to these tubes. With a construction in accordance with the present invention, as described above, the tubes of the first row are continuously purged by the excess steam required for the second row, and air binding is thereby prevented.

The present invention thus overcomes the problems met with conventional heating coils in a manner similar to that described in my above-mentioned U.S. Patent, and additionally eliminates a further cause of freezing in a convenient and economical manner.

I claim as my invention is:

1 Apparatus for passing steam in heat exchange relation with air having an initial temperature below the freezing point of water, said apparatus comprising a plurality of exchanger tubes arranged in first and second rows, the second row being arranged behind the first row and each heat exchanger tube having a steam inlet and a steam outlet, means for directing a stream of air across the exterior surfaces of the tubes so that the air passes across the tubes of the second row, means to supply steam to the steam inlets of the tubes of the first row for flow therethrough, means to connect the steam outlets of the tubes of the first row to the steam inlets of the tubes of the second row, and separate first and second trap means to prevent escape of steam but to discharge condensate, the tubes of the first row being connected to said first trap means and the tubes of the second row being connected to said second trap means.

2. Apparatus according to claim **1**, including a first header to which the steam inlets of the first row of tubes are connected and a second header to which the steam inlets of the second row of tubes are connected.

3 Apparatus for passing steam in heat exchange relation with air having an initial temperature below the freezing point of water, said apparatus comprising a plurality of vertically extending heat exchanger tubes arranged in first and second rows, the tubes of the second row being arranged behind the tubes of the first row and each tube having a steam inlet and a steam outlet, means to direct a stream of air substantially horizontally across the exterior surfaces of the tubes so that the air passes across the tubes of the first row before passing across the tubes of the second row, means to supply steam to the steam inlets of the tubes of the first row for flow therethrough, means interconnecting the steam outlets of the tubes of the first row with the steam inlets of the tubes of the second row, separate first and second condensate headers connected to the steam outlets of the tubes of the first row, and the tubes of the second row, respectively, the first and second condensate headers being isolated from one another, first and second traps to prevent escape of steam but to discharge condensate, first conduit means interconnecting the first condensate header and the first trap, and second conduit means interconnecting the second condensate header and the second trap, said first and second conduit means being isolated from one another.

4 Apparatus according to claim **3**, including a first header to which the steam inlets of the first row of tubes are connected and a second header to which the steam inlets of the second row of tubes are connected.

5 Apparatus according to claim **1**, in which the tubes are horizontal and are stacked vertically one upon the other in each row, the tubes extending between a first vertically extending header, to which the steam outlets of the first row of tubes and the steam inlets of the second row of tubes are connected, and second and third vertically extending headers to which the steam inlets of the first row of tubes and the steam outlets of the second row of tubes are respectively connected, said first trap means being connected to said first header, and said second trap means being connected to said third header.