13306 Johnson

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

MAR 14 1975

REPLY TO ATTN OF: GP

TO: KSI/Scientific & Technical Information Division
Attn: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,868,830

Government or Corporate Employee : Hamilton Standard Div. United Aircraft Corp., Windsor Locks, CT

Supplementary Corporate Source (if applicable) : ———

NASA Patent Case No. : MSC-14,143-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

YES /X/ NO / /

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words "... with respect to an invention of ..."

Bonnie L. Woerner

Bonnie L. Woerner
Enclosure

(NASA-Case-MSC-14143-1) CONDENSATE REMOVAL DEVICE FOR HEAT EXCHANGER Patent (NASA) 9 p CSCL 20M

N75-20139

Unclas 00/77 13306

MSC-14,143-1

United States Patent [19]

Fletcher et al.

[11] 3,868,830

[45] Mar. 4, 1975

[54] CONDENSATE REMOVAL DEVICE FOR HEAT EXCHANGER

[76] Inventors: **James C. Fletcher**, Administrator of the National Aeronautics and Space Administration with respect to an invention of; **Raymond B. Trusch**, South Windsor; **Edward W. O'Connor**, Simsbury, both of Conn.

[22] Filed: **Aug. 31, 1973**

[21] Appl. No.: **393,526**

[52] **U.S. Cl.** **62/290**, 62/93, 62/285, 62/288, 62/289, 62/317, 165/110, 165/111

[51] **Int. Cl.** **F23b 9/08**

[58] **Field of Search** 165/110, 111; 62/285, 317, 62/288, 289, 290

[56] **References Cited**

UNITED STATES PATENTS

2,218,407	10/1940	Meyerhoefer	62/307
3,089,314	5/1963	Speaker	62/288
3,199,307	8/1965	Willis	62/285
3,304,696	2/1967	McKenna	62/290
3,383,878	5/1968	Booth	62/317

Primary Examiner—Albert W. Davis, Jr.
Assistant Examiner—S. J. Richter
Attorney, Agent, or Firm—Carl O. McClenny; Marvin F. Matthews; John R. Manning

[57] **ABSTRACT**

The invention takes the form of a set of perforated tubes disposed at the gas output side of a heat exchanger, in a position not to appreciably affect the rate of flow of the air or other gas. The tubes are connected to a common manifold which, in turn, is connected to a sucking device such as a vacuum pump. Where it is necessary to conserve and recirculate the air sucked through the tubes, the output of the manifold is run through a separator to remove the condensate from the gas.

The perforations in the slurper tubes are quite small, lying in the range of 0.010 inch to 0.100 inch. The tubes are disposed in contact with the surfaces of the heat exchanger on which the condensate is precipitated, whether fins or plates, so that the water may be directed to the tube openings by means of surface effects, together with the assistance of the air flow. Only about 5 percent of the air output need be thus diverted, and it effectively removes virtually all of the condensate.

18 Claims, 9 Drawing Figures

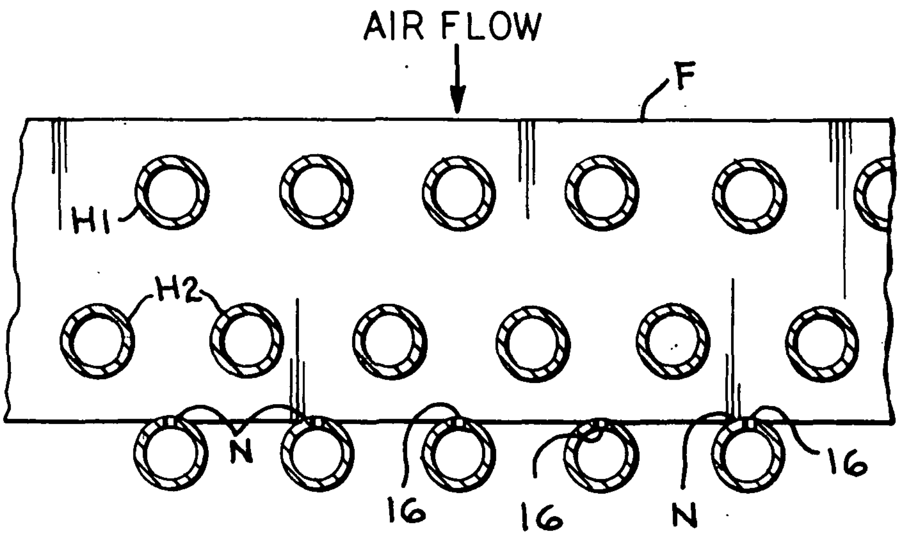


Fig. 1

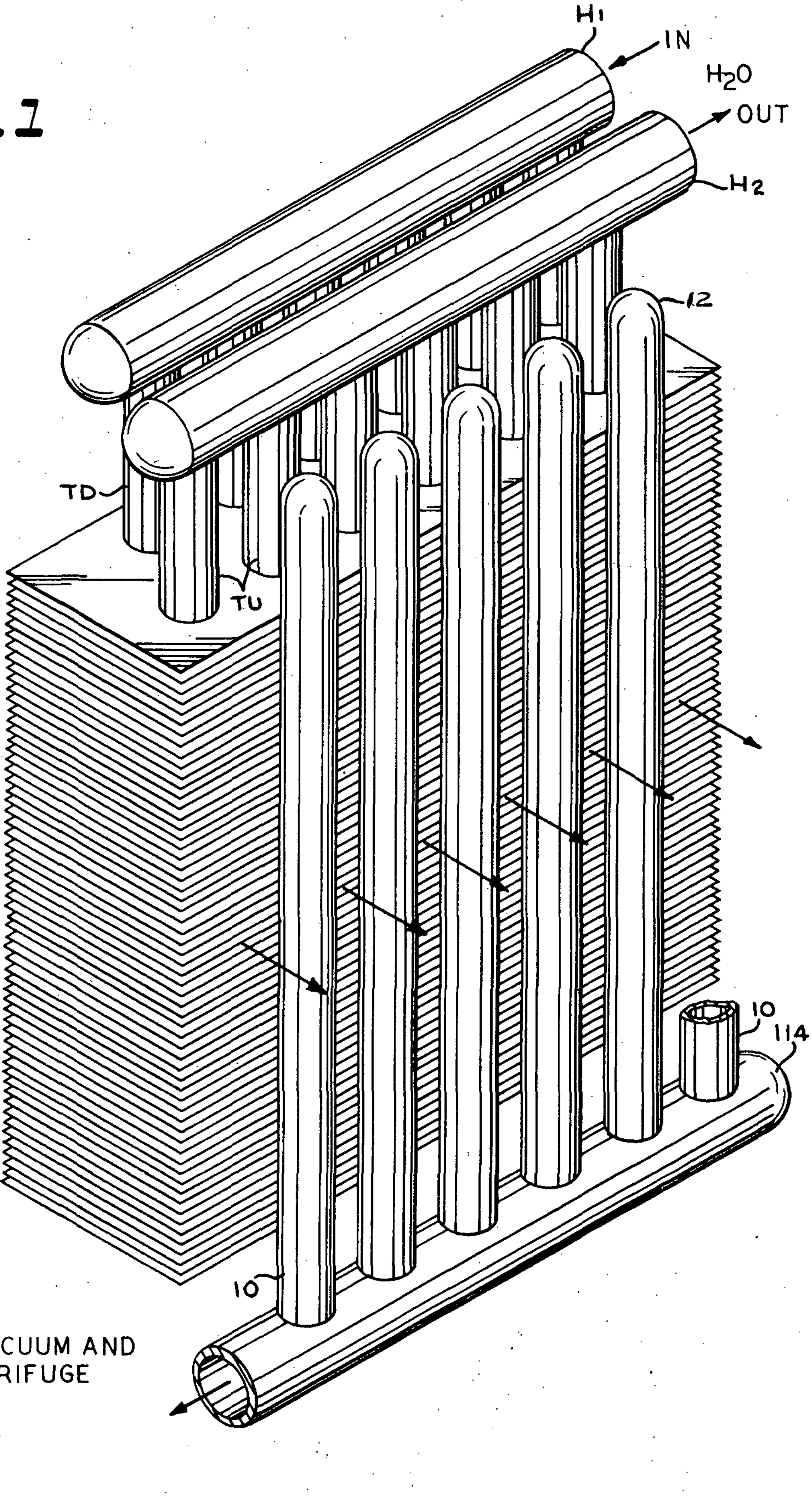

H1
IN
H2O
OUT
H2
12
TD
TU
AIR
FLOW
10
114
10
TO VACUUM AND
CENTRIFUGE

Fig. 2

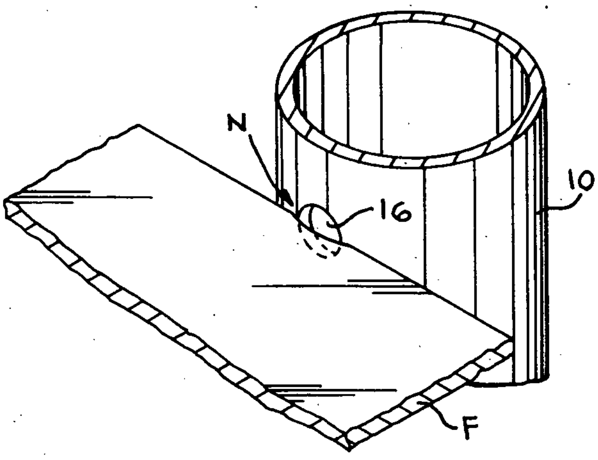


Fig. 3

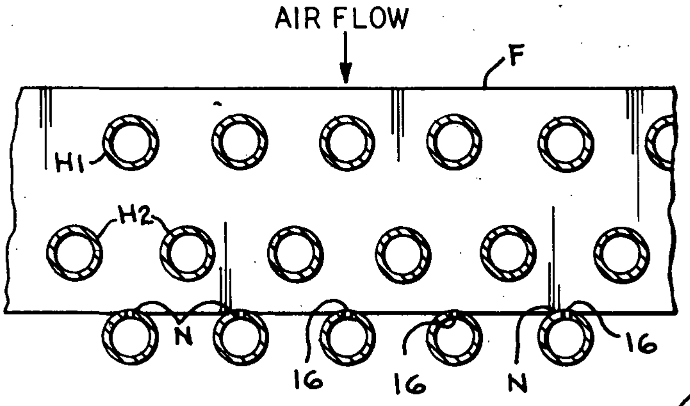
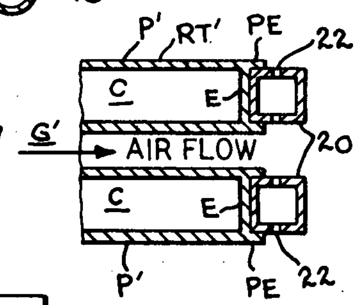


Fig. 7



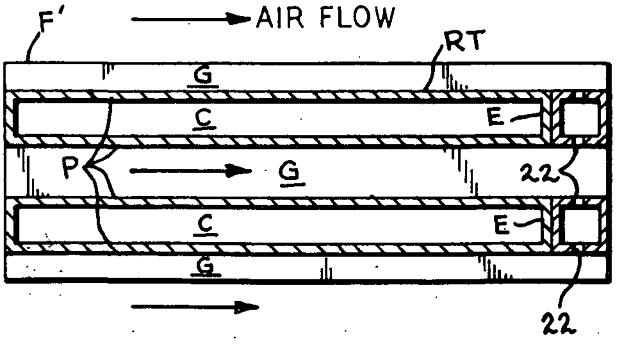
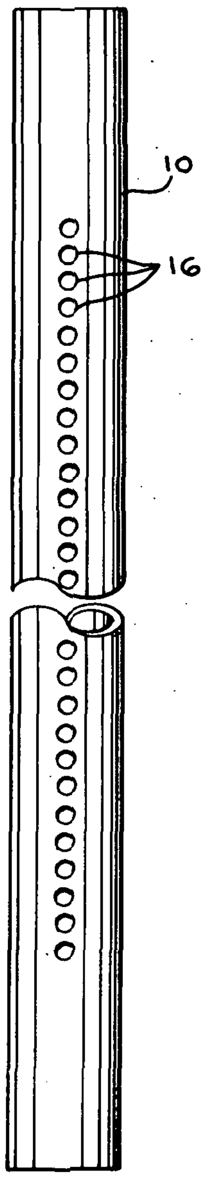


Fig. 6

Fig-4



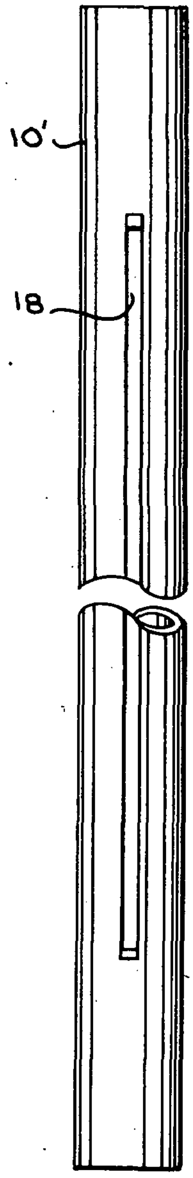
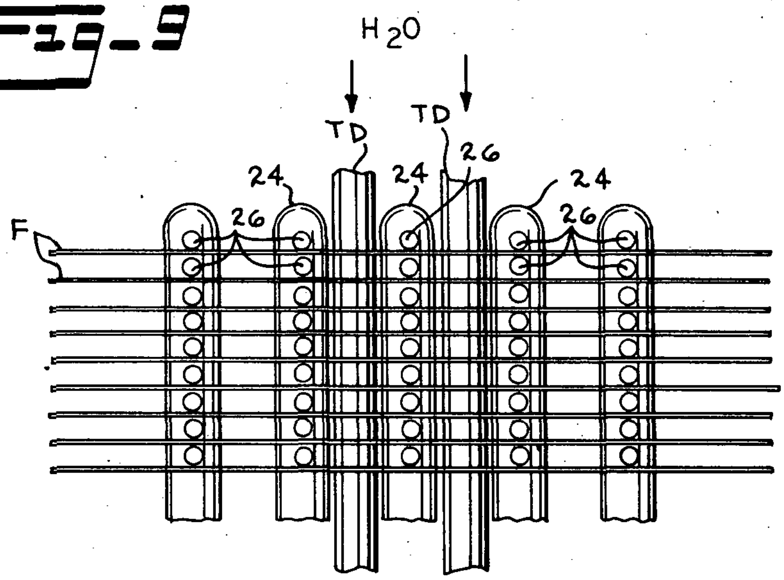


Fig-5

FIG. 9


H2O
TD
TD
26
24
24
24
26
26
F

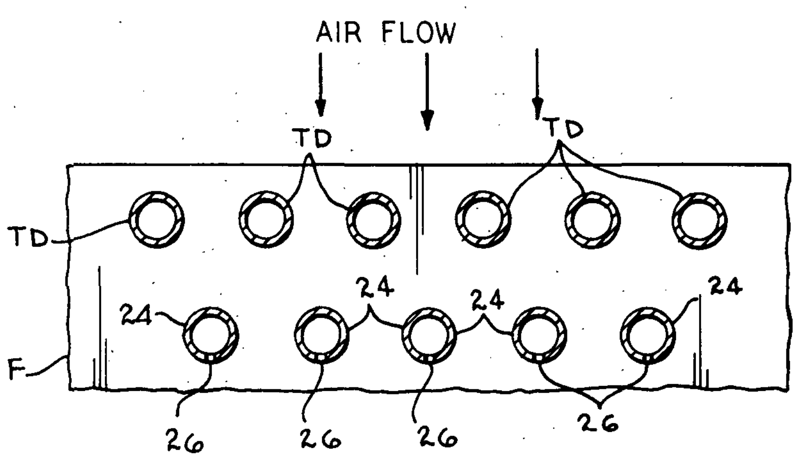

AIR FLOW
TD
TD
TD
24
24
24
24
F
26
26
26
26

FIG. 8

CONDENSATE REMOVAL DEVICE FOR HEAT EXCHANGER

ORIGIN OR THE INVENTION

The invention described herein was made in the performance of work under a NASA Contract and is subject to the provisions of Section 305 of the National Aeronautics ans Space Act of 1958, Public Law 85-568 (72 Stat. 435; ;45 USC 2547).

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to heat exchangers and humidity control. More particularly, it is a device added to a condensing-type heat exchanger to remove the condensed liquid therefrom.

2. Description of the Prior Art

The only prior art known to applicants for condensate removal from a condensing heat exchanger is exemplified in the U.S. Patent to Meyerhoefer, No. 2,218,407. In this the inventor discloses what might be called the "integral wick" concept, one in which the condensate is absorbed by a hydrophilic facing on the other side of the plates from the side on which condensation occurs. The liquid condensing on the plates is allowed to drip down into a tank in which the lower ends of the plates (with facing material) extend, and it then runs up the facing material by capillary action. This condensate in the facing material is then transported out of the heat exchanger by a separate gas stream, whether by blower or suction. While this approach may be workable, it is apparent that a much higher cost is involved in the use of a faced plate than a simple plain one. Furthermore, the facing material (wicks) are expendable and must be replaced periodically; on a long space flight this implies carrying extra weight.

Not all condensing heat exchangers require a condensate removal device, even when being used to cool air for an environmental system; it is sometimes sufficient simply to allow the condensed moisture to flow out of the heat exhanger by gravity. However, such a system does not allow for accurate control of the relative humidity of the air, and there are limits on the extent to which the air may be dehumidified. Further, such systems are objectionable in that the moisture collecting at the air output side of the heat exchanger will be "spitted" into the environment by the air stream itself; some of these droplets will be reabsorbed in the ambient air, and others will be sprayed about and fall on whatever surfaces happen to be present, sometimes creating a corrosion or similar problem. For one thing, the droplets sprayed out of the heat exchanger may fall on external surfaces to create something of a mess or and undesirably slippery surface; the droplets may also be reabsorbed in the ambient atmosphere to increase the relative humidity to an undesirably high level.

Of course, a large amount of the spitting from the heat exchanger can be avoided by forcing the gas which carries the vapor to follow a tortuous course, either bending it around completely or causing it to run through on or more baffles. While such solutions may be feasible in some instances, it is apparent that they require additional structure for the air passages. Furthermore, they are objectionable in that more horsepower is required in the blowers which force the gas through the heat exchanger to achieve the same flow rate.

SUMMARY OF THE INVENTION

Accordingly, it is the principal object of the present invention to provide a slurper for condensing heat exchangers which avoids the disadvantages of prior art structures. Stated another way, the principal object of the present invention is to provide a condensate removal device for condensing heat exchangers which utilizes a structure not requiring the use of a liquid absorbing material and which can be used on heat exchangers of the type having a straight-through gas flow to reduce or completely eliminate the spitting or condensate which otherwise would occur.

Briefly stated, the present invention comprises an array of perforated tubes manifolded together and connected to a suction device which creates a vacuum within the slurper tubes to pull a mixture of condensate and the effluent gas through the perforations and along the length of the tubes to a discharge device. When the heat exchanger is being used to control the air in a life support system in a manned space vehicle, the discharge device is preferably a separator which will separate water vapor from the effluent air and allow recirculation of both of them.

When the gas being discharged from the heat exchanger flows out of a number of discrete, separated paths, the slurper tubes are disposed so that there is at least one tube extending transversely of each air path, either directly in the path or adjacent thereto. Each tube is also disposed in contact with parts of heat exchanger on which condensate is formed, whether these be plates or fins. The perforations in the slurper tubes are disposed so that a part of the effluent gas may be sucked through the perforations, together with droplets of condensate flowing to the perforations by a combination of surface effects and the pushing of the gas stream. In the most preferred form, the slurper tubes are incorporated in the core of the heat exchanger by disposing them near the gas outlet side of the heat exchanger so that the tubes contact and are surrounded by the heat exchanger fins, with the perforations facing downstream, in the same direction as the air flow. The perforations may take the form of longitudinal slots or a series of holes spaced along the length of the tubes. When holes are used, it is preferable that they be located between the fins, such disposition together with the downstream orientation promoting ready inspection and cleaning of the holes.

In another form of the invention wherein the heat exchanger includes fins extending out of the heat exchanger core, the perforations and tubes are disposed so that the fins partially penetrate the perforations in the tubes, whether these be spaced-apart holes or extended slots. In either form the width of the holes or slots is kept relatively small, small enough to ensure a sizeable pressure drop from the outside of the tube to its vacuumed interior, but not so small that droplets of condensate will lodge in the openings to block the same. In the slurpers reduced to practice, it was found that the width of the holes or slots should lie somewhere in the range of 0.010 inch to 0.100 inch. The smallness of these openings also prevents too large a fraction of the effluent gas from being passed through the slurper; if an overly large fraction were thus diverted, it would probably be more feasible to run the entire output through a separator.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

The structure of the invention may perhaps be more readily comprehended by reference to the accompanying drawing, in which:

FIG. 1 is a perspective view of one embodiment of the invention and so much of the heat exchanger with which it is used as is necessary to an understanding of the invention.

FIG. 2 is a perspective detail showing a fit of one of the slurper tubes to a fin of the heat exchanger.

FIG. 3 is a horizontal section taken below the coolant headers and looking down on the uppermost fin of the assembly of FIG. 1.

FIG. 4 is an elevation of one of the slurper tubes of the FIG. 1 embodiment, showing the array of holes within the tube.

FIG. 5 is an elevation showing an alternate form of opening in th slurper tube, this type being an elongated slot rather than a series of holes.

FIG. 6 is a horizontal section similar to FIG. 3 but showing an alternate form of the invention applied to a plate and fin-type heat exchanger.

FIG. 7 is a partial horizontal section similar to that of FIG. 6, showing a slightly modified heat exhanger used with the same form of the invention.

FIG. 8 is a partial horizontal section, similar to that of FIG. 3, showing the preferred form of the invention.

FIG. 9 is an end view of the preferred embodiment of FIG. 8, showing the spacing of the slurper tube openings relative to the fins of the heat exchanger.

DETAILED DESCRIPTION OF THE DRAWING FIGURES

In the embodiment illustrated in FIGS. **1–5**, the parts of the heat exchanger pictured include the inflowing coolant header Hl, the descending coolant tubes TD, the coolant riser tubes TU manifolded to the outflcwing coolant header **H2**, and the stack of horizontal fins F. At their lower ends, the coolant tubes TD and TU are fastened together by appropriate elbow connections (not shown) so that coolant passing down through tubes TD is caused to flow upwardly throught tubes TU. The fins F are made of a metal and are quite thin, of the order of 0.006 inch, being evenly spaced so that there are, for example, 12 of them per inch. Air is forced through the fins in the direction parallel to their surfaces, or from upper left to lower right as indicated in the drawing figure. By way of example, the coolant tubes shown in the figures may be   inch in outside diameter and may be spaced in any one row on ¾ inch centers. The two rows are offset with respect to each other so that any one tube in the back row forms an equilateral traingle with the adjacent pair of tubes in the forward row. To provide good surface contact with the slurper tubes, it is desirable to very slightly notch the air exit edges of the fins F, as indicated by the reference character N.

The slurper itself comprises the array of vertical tubes **10**, closed at their upper ends **12** and joined to the horizontal manifold **14** at their lower ends. As indicated in FIG. **3**, each of the slurper tubes **10** is disposed in the air stream flowing between the nearest pair of heat exchanger tubes **H2**, and with each tube **10** oriented so that the opening or openings **16** (or **18**) therein face directly into the gas stream. The slight notches N provided in the fins F permit the slurper tubes **10** to interengage with the fins to ensure a good surface contact and readly avilability of the openings **16** to the flow of condensate along the surface of the fins. In this embodiment of the invention the holes are spaced along slurper tube **10** to register with the fins F, so that each fin F partially intrudes into a hole **16**, as indicated in FIG. **2**.

FIG. **5** illustrates an alternate form of slurper tube **10'** which can be used in lieu of slurper tube **10** in the FIG. **1** embodiment, or with the preferred embodiment of FIGS. **8–9** described below. The two types of tube are alike except that in slurper tube **10'** an elongated slot **18** is used in lieu of a series of holes. To obtain the same rate of removal of condensate and gas, it was found necessary to reduce the width of the slot **18** to a smaller dimension than the diameter of the holes **16**. In other respects the two tubes are identical, and it should be noted that the slot form of tube has the advantage that it obviates the necessity for accurate alignment of fins and holes. This is accompanied by the similar advantage of a reduction in the amount of accurate machine work required.

In FIG. **6** the concept of the present invention is shown applied to a plate-and-fin type of heat exchanger. In this type a series of plates P are disposed in spaced, parallel fashion, and alternate pairs of plates are connected by the transverse closures or end members E which define liquid passageways or chambers C. The chambers C are interconnected with manifolds or supply mains (not shown) so that the liquid or coolant circultes through the various chambers C in the same manner that liquid is circulated through the tubes TU and TD of the FIG. **1** embodiment. The plates P and end closures E together define rectangular tubing RT, separated by gas flow passge g. The gas flow passages are also divided, in the direction normal to the gas flow direction indicated by the arrows in the figure, into discrete strata separated by the fins F', in the same meanner as shown in FIG. **1**. These fins F' preferably extend, at the gas exit end of the heat exchanger, beyond end closures E.

With this form of heat exchanger, it is preferred to use slurper tubes **20** which are also of rectangular form and have openings **22** on each side face, thus providing at least two openings available to each discrete air stream. In the direction transverse to the flow of gas, the slurper tubes **20** are preferably disposed at the end of each liquid flow tube RT, although they could be spaced outwardly therefrom (to the right in FIG. **6**) and spaced to lie between the tubes RT, directly confronting the air stream. As in the FIGS. **1–5** embodiments, the openings **22** may be either rectangular slots or a series of holes; when holes are used, they may be disposed along the length of the slurper tubes **20** so that each fin F' directly confronts a hole **22**, or the holes may be disposed between fins, as in the preferred embodiment of FIG. **8–9**.

FIG. **7** shows the same slurper tubes **20** with openings **22** used with a slighly different form of heat exchanger, one having no separate fins. This heat exchanger uses spaced apart coolant tubes RT' formed of metal plates P' and end closures E defining the chambers C through which the coolant flows, but differs from the FIG. **6** form in that plates P' extend somewhat beyond end closures E at the various outlets of the heat exchanger. The rectangular slurper tubes **20** are then disposed between the projecting ends PE of plates P'. It will be apparent that in this form of the invention the gas passages G' are not only elongated in the direction parallel to the direction of the gas flow, but in the direction normal thereto which is parallel to plates P', the only short dimension being that which is normal to both the gas flow direction and end plaes P'. It will also be apparent that the condensate formed on plates P' in the course of operation flows along plates P' under urging of the gas stream until it reaches the walls of the slurper tubes **20**, after which it flows into the openings **22** as a result of the pressure difference between the outside of the tubes and the vacuumed interior thereof.

FIGS. **8** and **9** illustrate the most preferred embodiment, one in which the row of coolant tubes TU of FIGS. **1–5** nearest the gas discharge are eliminated and replaced by the row of slurper tubes **24**. This converts the heat exchanger to a single pass type of coolant circuitry, but of course more rows of coolant tubes may be added, as desired. With the coolant tubes supplanted by slurper tubes **24** of the same outside diameter, the latter are surrounded by and contact fins F of the heat exchanger.

Two other differences should be noted in comparing the preferred embodiments of FIGS. **8–9** with the earlier tested embodiment of FIGS. **1–5**. Whereas in the later the holes **16** face into the air stream and are aligned to register with the fins F, in the FIGS. **8–9** embodiment the slurper tubes **24** are disposed so that holes **26** face in the same direction as the air stream, and are disposed between the fins F. This configuration not only produces superior results in terms of condensate removal, but has the additional advantage of making the holes more readily available for inspection and cleaning.

REDUCTION TO PRACTICE

A. FIGS. 1–5 EMBODIMENT

The form of invention illustrated in FIGS. **1–5** was tested with the heat exchanger also therein depicted, using a Lytron Model 5110 tube-fin heat exchanger. Pertinent data on this heat exchanger are as follows:

Face Flow Area:	5 × 3 = 25 square inches
Fins Per Inch:	12
Fin Thickness:	.006 inch
Fin Material:	Aluminum
Tube O.D.:	⅝ inch
Tube Spacing:	¾ inch center line spacing
Tube Pattern:	Equilateral triangle
Tube Material:	Aluminum
Tube Rows:	2
Coolant Circuitry:	2 pass cross-counterflow

The fins of the heat exchanger were slightly notched, as indicated above, to obtain good contact with the slurper tubes. The heat exchanger was cleaned and treated with a hydrophilic compound, specifically Minnesota Mining & Manufacturing Corportation's FX 181. The slurper tubes were assembled to the heat exchanger with two cross bars secured with threaded fasteners (not shown).

During testing, instrumentation was provided to measure the pressure, temperature, flow rate and dew point of air blown through the heat exchanger, and the temperature of the air leaving the heat exchanger and slurper, i.e., the air not taken into the slurper tubes. Also measured were the input coolant temperature and, for the slurper, the pressure in the slurper tubes, the flow rate of air passing through the tubes, and the weight of collection of condensate (water) in the slurper tubes. The air flow through the heat exchanger was held constant at sixty cubic feet per minute for all tests. The temperature of the incoming coolant was held at approximately 40° F., but the inlet air temperature and dew point of the air were modulated to obtain a condensate flow rate of approximately 360 cc/hr.

With such inputs and control, the adjustable variables became the slurper tube geometry and the vacuum within the slurper tubes. The tubes were all of the same overall configuration and size, ⅝ inch outside diameter, 6061-0 aluminum alloy for the tubes with round holes and 316 SS for the slotted tubes. There were disposed as shown in the drawing, with two different hole sizes tested, 0.023 inch diameter and 0.032 inch diameter, with 61 holes spaced at **12** holes per inch to register with the disposition of the fins. Two different sizes of slots, as indicated in FIG. **5**, were also tested; each was 5.0 inches long, and the two widths were 0.010 inch and 0.020 inch.

For each of these configurations, it was found that the slurper concept provides an effective way for removing condensate from the heat exchanger. The condensate build-up throughout the heat exchanger can be maintained at an acceptably low level. Spitting of water droplets from the face of the heat exchanger was completely eliminated. The air flow rate required to effectively operate the slurper is approximately 5 percent of the air flow through the heat exchanger. The suction required for effective operation is approximately two inches of water vacuum.

Performance is to some extent affected by the surface properties of the heat exchanger and slurper tubes exposed to the condensate; it is desirable that these surfaces be as hydrophilic as possible. Round holes and slots are believed to be equally effective, but it is also believed that aluminum is a more appropriate material than stainless steel because stainless steel tends to be somewhat hydrophobic.

B. FIGS. 8–9 EMBODIMENT

With the exceptions already noted (one pass coolant circuitry and coolant tubes in a single line, with second row replaced by the slurper tubes), the same Lytron Model 5110 tube-fin heat exchanger was employed in testing the configuration of the FIGS. **8–9** embodiment. The instrumentation and test procedures were the same as described above. The test results were superior, as with holes of 0.022 inch diameter and the same vacuum applied to the slurper tubes, only aobut 3 percent of the air flow was diverted into the tubes to effect the same rate of condensate removal. Thus the holes in the slurper tubes can face in any desired direction relative to the gas stream.

Additional tests were conducted to determine the importance of a) heat exchanger attitude and b) the hydrophilic coating. With the heat exchanger rotated 90° from the position illustrated, so that the fins F of the FIGS. **8–9** were vertical and the air flow was directed downwardly, the slurper was found to operate satisfactorily, with no spitting or dripping.

To test the effect of degradation of the hydrophilic coating, a low viscosity lubricating oil was sprayed on the fins. Operation of the heat exchanger-slurper combination with such a hydrophobic coating resulted in only a small decrease in performance, in the form of more water build-up on the fins. There was no spitting or misting from the outlet face, and the net performance was considered acceptable.

What is claimed is:

1. In a slurper in a heat exchanger of the type including a set of coolant tubes and an array of parallel plates or fins, said coolant tubes passing through said fins and being disposed for circulation therein of a liquid cooling medium while a gas flow is maintained between said coolant tubes and through said array of fins, vapors carried by said gas flow being precipitated onto said coolant tubes and fins in the process, the improvement comprising a set of slurper tubes disposed in contact with the gas outlet portions of said fins, each of said slurper tubes containing a plurality of small openings and being adapted for common connection to means for sucking fluids through said openings and passing them through said slurper tubes to an external discharge.

2. The slurper of claim 1 in which said slurper tubes are disposed with said small openings therein facing in the same direction as said gas flow.

3. The slurper of claim 1 in which said slurper tube openings are a plurality of small holes spaced along the length of said tubes and disposed between said fins, said holes being of a diameter in the range of 0.010 to 0.100 inch.

4. The slurper of claim 3 in which said slurper tubes are disposed so that said openings face in the same direction as said gas flow.

5. The slurper of claim 3 in which the number of holes is about equal to the number of fins and the slurper tubes are disposed so that the fins partially enter said holes.

6. The slurper of claim 5 in which said holes are of a diameter in the range of 0.010 to 0.100 inch.

7. The slurper of claim 1 in which said slurper tubes are disposed in contact with surrounded by said fins.

8. The slurper of claim 7 in which said openings in said slurper tubes are small holes disposed between said fins, said holes being of a diameter in the range of 0.010 to 0.100 inch.

9. The slurper of claim 8 in which said small holes face in the same direction as said gas flow.

10. The slurper of claim 1 in which said slurper tubes are disposed with said small openings therein facing in the direction opposite that of said gas flow.

11. The slurper of claim 1 in which said slurper tubes are disposed so that some of said fins partially enter said small openings.

12. The slurper of claim 1 in which said small width openings are slots elongated along the length of the slurper tubes.

13. The slurper of claim 12 in which said slots have a length substantially equal to the distance between the uppermost and lowermost fins in the array of fins.

14. The slurper of claim 13 in which said slots have

a width in the range of from about 0.010 inch to about 0.100 inch.

15. *In a slurper or condensate removal device in heat* exchangers of the type having a plurality of liquid flow conduits therein for the circulation of a liquid cooling medium, said liquid flow conduits being spaced from each other to define at least one open-ended passage for accommodating an air or other gas flow therethrough, said heat exchanger having in contact with said gas passages a plurality of surfaces, such as the outer surfaces of said liquid flow conduits, for facilitating the condensation of vapors carried by said gas flow, and also having extensions of said surfaces, as in the form of fins, extending beyond said liquid conduits at the gas flow exit face of said heat exchanger, the improvement comprising a plurality of tubes in contact with said extensions or fins, each of said tubes having a plurality of narrow openings therein and being adapted for connection to means for sucking fluids through said openings and through said tubes to an external discharge.

16. The slurper of claim 15 in which said openings in said slurper tubes are a plurality of small holes spaced along the length of said slurper tubes.

17. A slurper in a heat exchanger of the type having elongated liquid flow passages defined by enclosing plates, said plates being spaced from one another so that their outer surfaces (those facing away from the liquid flow passages) define gas flow channels, an array of parallel fins disposed in such gas flow channels extending across the width thereof and elongated in the same direction as the plates and extending beyond the plates at the gas exit end of the heat exchanger, said slurper comprising a set of tubes disposed at the end of the liquid flow channels between the projecting ends of said fins and in contact therewith, said slurper tubes having a multiplicity of small width openings therein and being adapted for connection to a suction device for pulling fluids through the openings and passing them along said tubes to an external discharge.

18. A slurper in a heat exchanger of the type having a number of elongated parallel plates, adjacent pairs of such plates being provided with transverse closure members to define liquid flow passages and leaving unobstructed air flow passages between such pairs, such plates extending beyond the closure members to define fins, said slurper comprising a set of tubes disposed adjacent the closure member at one end of the liquid flow passages and between said fins in contact therewith, said slurper tubes having a portion within the fins and a portion projecting beyond the fins, said projecting poriton having a number of small width openings therein and being adapted for connection to a means for sucking fluids through the openings and tubes to an external discharge.

* * * * *