Dec. 6, 1966 J. ENGALITCHEFF, JR 3,290,025

TROUGH SYSTEM FOR EVAPORATIVE HEAT EXCHANGERS

Filed Nov. 19, 1965 6 Sheets-Sheet 1

Fig. 2.

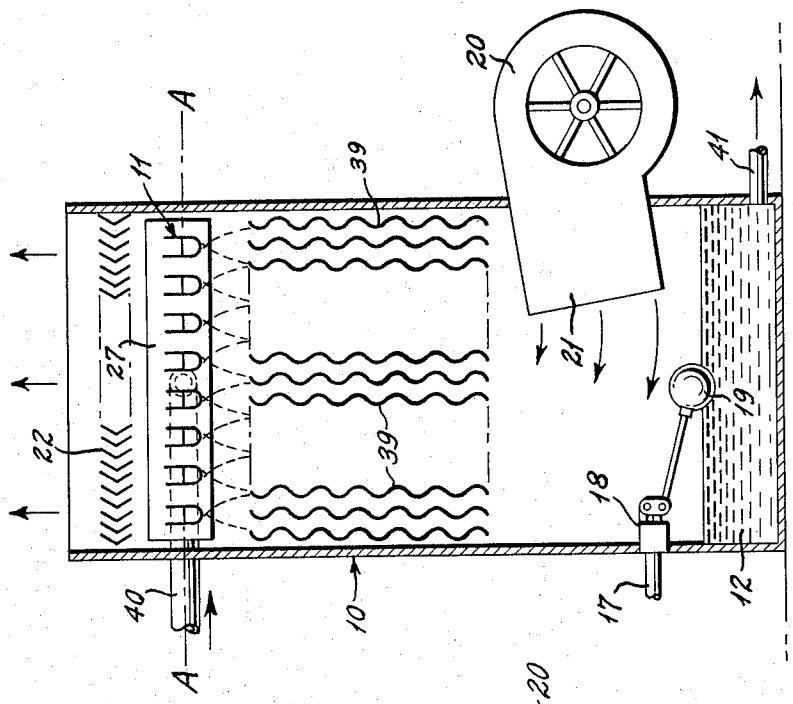
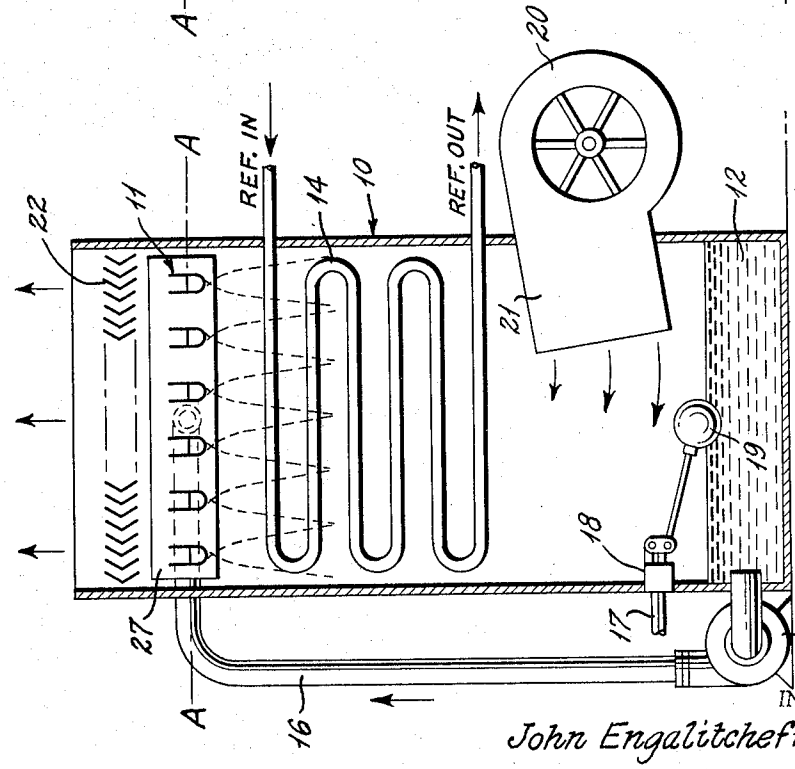


Fig. 1.



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Dec. 6, 1966 J. ENGALITCHEFF, JR 3,290,025

TROUGH SYSTEM FOR EVAPORATIVE HEAT EXCHANGERS

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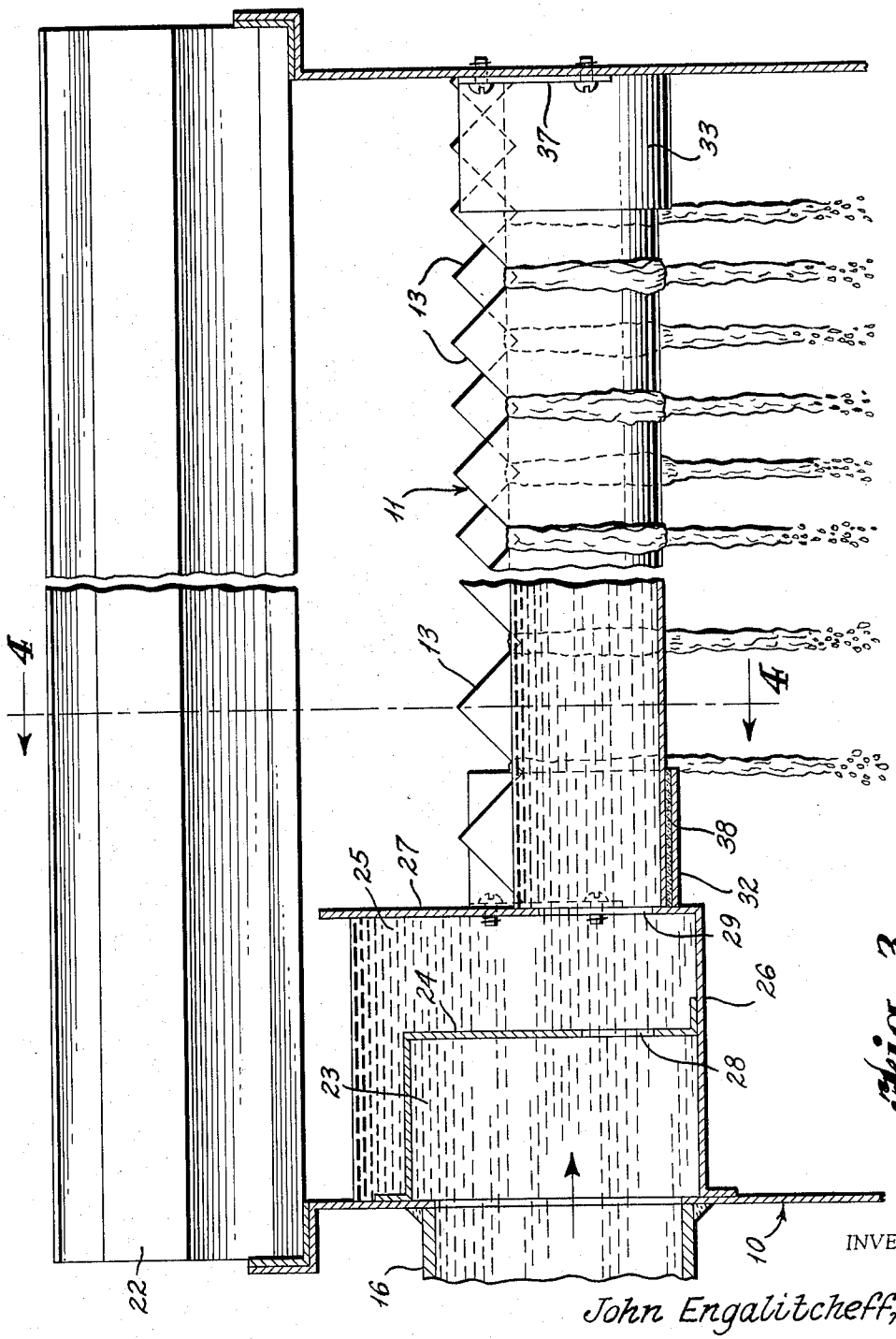


Fig. 3.

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TROUGH SYSTEM FOR EVAPORATIVE HEAT EXCHANGERS

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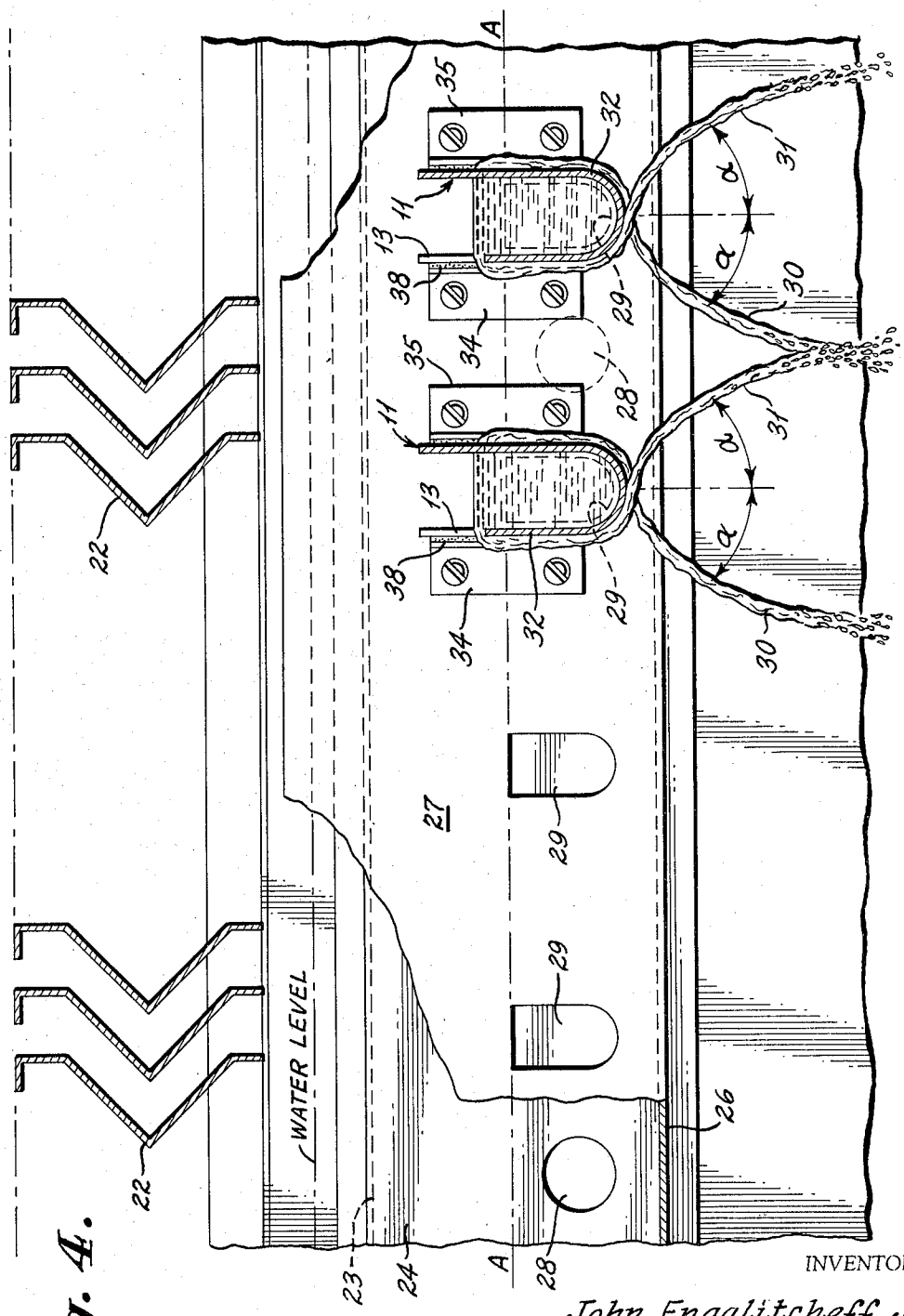


Fig. 4.

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TROUGH SYSTEM FOR EVAPORATIVE HEAT EXCHANGERS

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Fig. 5.

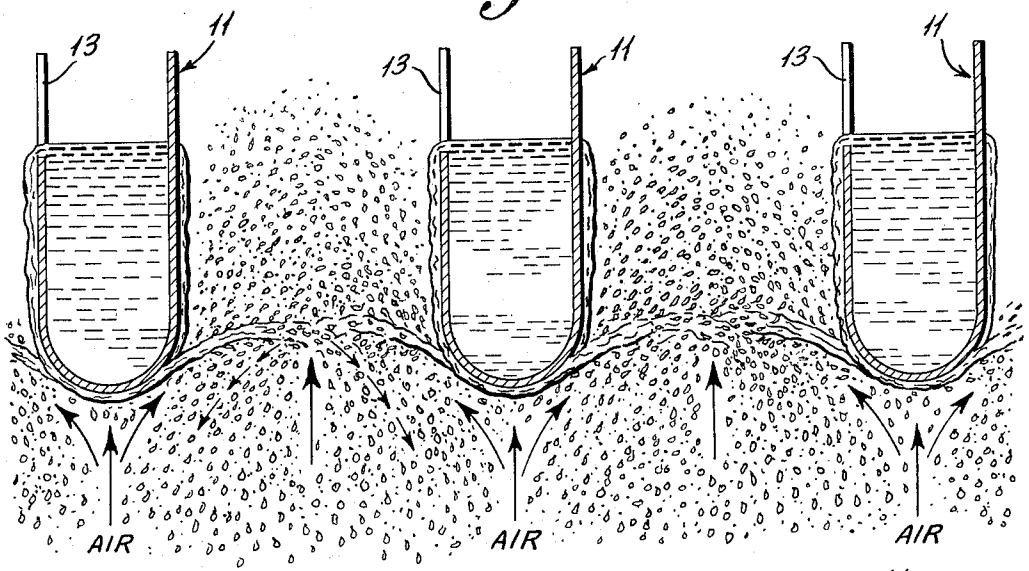


Fig. 6.

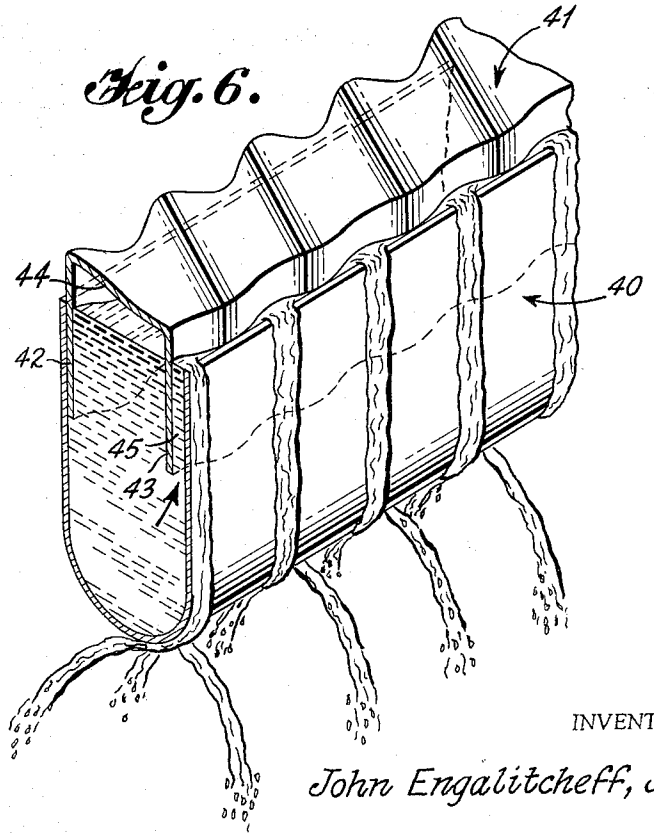
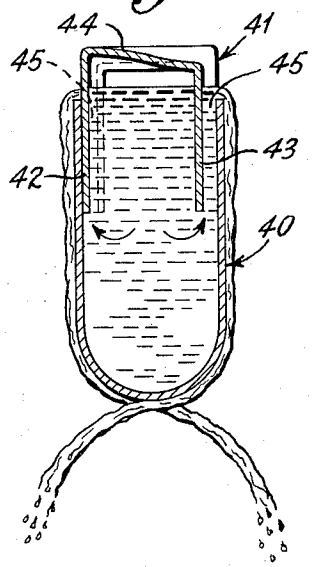


Fig. 7.



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TROUGH SYSTEM FOR EVAPORATIVE HEAT EXCHANGERS

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Fig. 8.

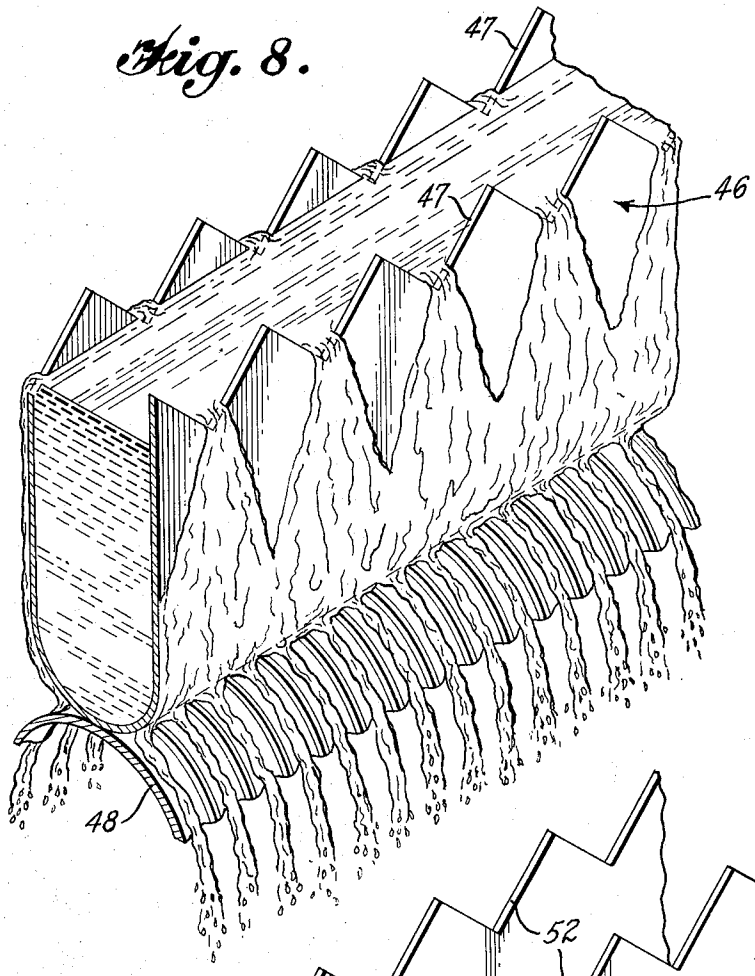
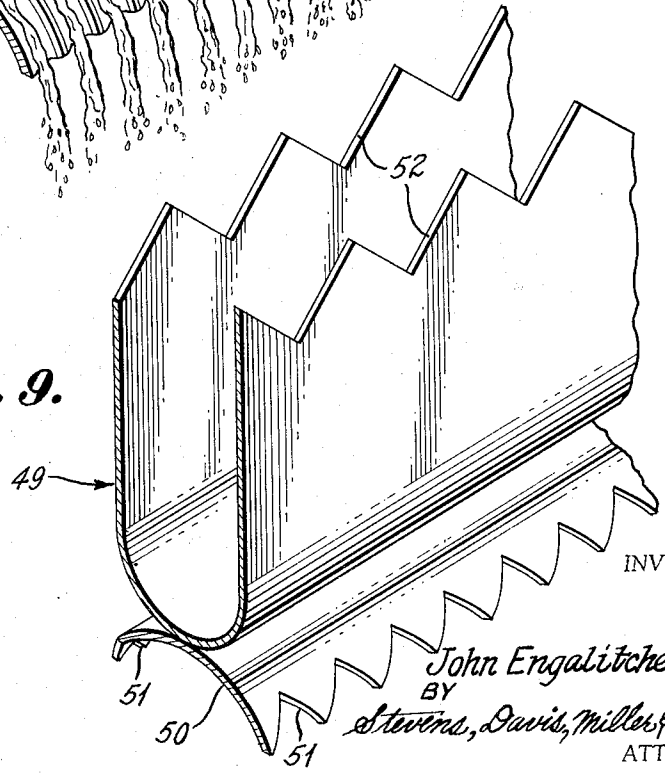


Fig. 9.



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TROUGH SYSTEM FOR EVAPORATIVE HEAT EXCHANGERS

Filed Nov. 19, 1965 6 Sheets-Sheet 6

Fig. 10.

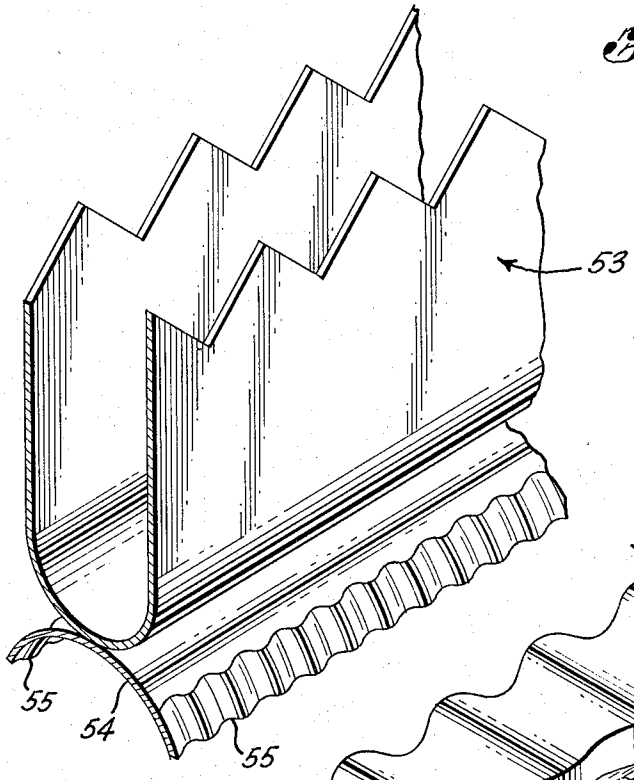
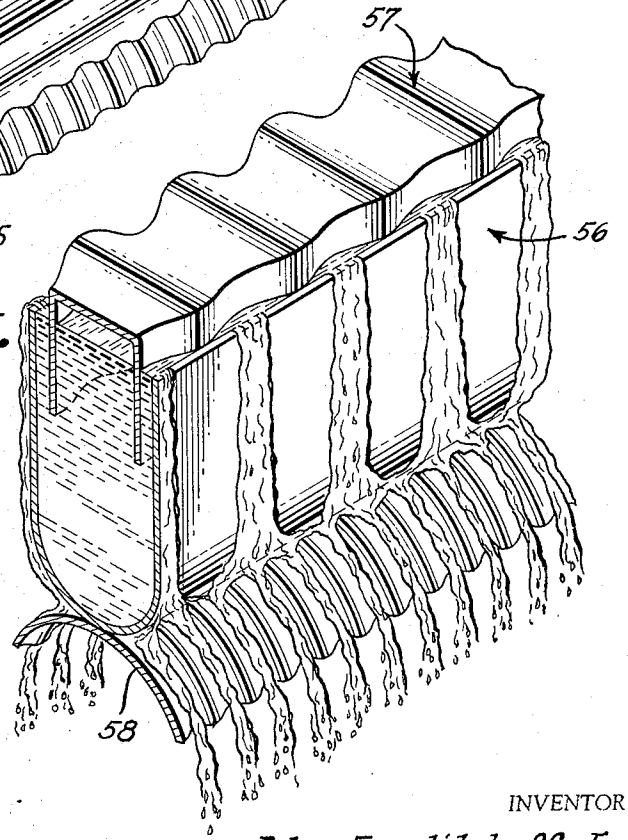


Fig. 11.



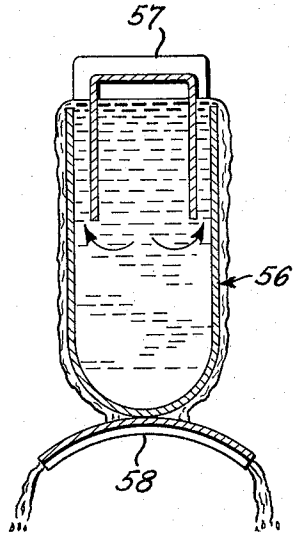


Fig. 12.

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United States Patent Office 3,290,025
Patented Dec. 6, 1966

3,290,025

TROUGH SYSTEM FOR EVAPORATIVE HEAT EXCHANGERS

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Filed Nov. 19, 1965, Ser. No. 508,815
12 Claims. (Cl. 261—140)

This invention relates to evaporative heat exchangers and in particular to improved apparatus for the distribution of water over a heat exchange surface. This application is a continuation-in-part of application Serial No. 425,785 filed January 15, 1965, now abandoned.

Evaporative type heat exchangers can generally be classified into two groups:

(*1*) *Open type.*—Where the fluid to be cooled is directly exposed to the air. A common example of this type is a water cooling tower.

(2) *Closed type.*—Where the fluid to be cooled or condensed, or both, is confined in a restricted space such as a coil and air and water flow over the outside of the coil. An example of this type is a refrigerant evaporative condenser.

In the case of the cooling tower (open type), a portion of the circulated water is evaporated, the heat of vaporization being supplied by the remaining water. In the closed type such as the refrigerant evaporative condenser, a portion of the water which continually flows over the outside of the coil is evaporated, the heat of vaporization being supplied by the refrigerant or fluid within the coil which is being condensed or cooled.

In either type of evaporative heat exchanger the distribution of the water over the heat exchanger section is importantly related to the capacity of the unit. In the design of any evaporative type heat exchanger, it is important to subdivide the water in the finest particles possible so that maximum air-water interface is achieved.

A very early version of an evaporative heat exchanger is shown in the Burhorn Patent 1,118,267 issued in 1914. According to the teachings of the Burhorn patent, water is supplied to troughs having notched side walls and the water overflows these troughs in the form of a plurality of streams. It is clear from the disclosure of the Burhorn patent that evaporation of some of this water is intended to be brought about by the natural circulation of the ambient air. In addition, it is obvious from the disclosure that the troughs are so arranged that air does not flow countercurrent to the water leaving the troughs, but contacts the water in a crossflow manner. This results in little or no "breakup" of the water leaving the troughs, and hence, a very small air-water interface. In addition, this type of heat exchanger never enjoyed much commercial success because its capacity was solely dependent on the prevailing winds, and the ratio of floor space occupied to the capacity output was large.

In an effort to increase air-water interface, the art discontinued the use of troughs, for the most part, in favor of the use of counterflow evaporative type heat exchangers which were usually designed with spray nozzles for the purpose of distributing the water in rain-like form over the heat exchanger section. The spray water falls by gravity over the heat exchanger section and flows conutercurrent to the upwardly flowing air which is propelled by a fan.

However, there are some disadvantages of an evaporative type heat exchanger utilizing spray nozzles for water distribution. The nozzles will clog with foreign material found in the circulation system, causing "dry spots" on the heat exchanger surface resulting in a loss of capacity. Frequent periodic maintenance is required to keep the

spray system clean at all times. In addition, there is considerable manufacturing cost in the fabrication of a spray tree and nozzle system. Also, in comparison to a gravity type water distribution system of the trough type, the pumping head required on the spray system is higher by the amount of the spray nozzle pressure requirement, thereby resulting in a more expensive and higher horsepower circulating pump.

It is an object of this invention to overcome the disadvantages of the prior art and to provide a water-air counterflow system economical to install and maintain and yet characterized by very large air-water interface, very rapid heat exchange, and very high cooling capacity for the space occupied.

The present invention comprises a trough-type evaporative heat dissipation system in which water overflowing from the troughs is so directed into counterflowing air as to cause the generation of a mist or spray of finely divided droplets with large air-water interface.

Further objects of the present invention include the maintenance of an even distribution of water throughout the length of the troughs and multiple subdivisions of the water spilling from these troughs further to enhance the production of mist when the water streams and counterflowing air mutually react.

Other objects and advantages of this invention will be apparent upon consideration of the following detailed description of several embodiments of heat exchange equipment incorporating this invention and disclosing, as well, the invention of the application of Thomas F. Facius, filed January 15, 1965, in conjunction with the annexed drawings in which:

FIG. 1 is a schematic view in vertical section of an evaporative condenser of fluid cooler incorporating the water distribution troughs and counterflow air system of the present invention;

FIG. 2 is a schematic view in vertical section of an open type, evaporative cooler (cooling tower) incorporating the water distribution troughs and counterflow air system of the present invention;

FIG. 3 is a view to an enlarged scale of a single trough constructed in accordance with the teachings of the present invention, part of the trough being shown in vertical section and part in elevation, the water supply system for feeding the trough being included in the illustration;

FIG. 4 is a view partly in section and partly in elevation taken along the line **4—4** of FIG. 3 and illustrating the manner of flow of water from the troughs in the absence of counterflowing air;

FIG. 5 is a fragmentary sectional view of three troughs of the type shown in FIG. 4 but showing the effect of counter-flowing air on the streams of water issuing from the troughs;

FIG 6 is a fragmentary perspective view of a modified form of trough adapted to produce a plurality of spaced streams;

FIG. 7 is a transverse sectional view of a trough of the type illustrated in FIG. 6;

FIG. 8 is a fragmentary perspective view of a notched trough having tangent to the bottom thereof an inverted, corrugated crescent section baffle for directing a large number of streams into the counterflowing air;

FIG. 9 is a view similar to FIG. 8 but showing a form of crescent section baffle having notches instead of corrugations;

FIG. 10 is a view similar to FIG. 8 but illustrating a form of crescent section baffle which is corrugated only at its margins;

FIG. 11 is a fragmentary perspective view of a trough of the type shown in FIG. 6 equipped with a subdividing member of the type shown in FIG. 8; and

FIG. 12 is a view in cross section of the form of the invention illustrated in FIG. 11.

Referring now to the drawings in greater detail and in particular to the FIG. 1 thereof, it will be noted that chamber **10** is provided at its upper end with a group of troughs **11** and at its lower end with a sump **12**. Each trough has V notches **13** in its side walls (see FIG. 3), those in one side wall being staggered in relation to those in the other side wall. Water spilling from the notches **13** of the troughs **11** passes through heat exchanger tubes **14** in the form of rain or droplets and is collected in the sump **12** from which it is recirculated by a pump **15** through a conduit **16** to the troughs **11**. Makeup water enters through a conduit **17** under the control of a float valve **18** operated by a float **19** disposed in the sump **12**.

A centrifugal fan **20** pumps air through ducting **21**, and this air flows upwardly through the chamber **10** countercurrently to the water issuing from the troughs **11**. The air, after passage through the heat exchanger **14**, passes between the troughs **11** and through mist eliminators **22** to atmosphere. A fluid to have heat extracted from it is circulated through the heat exchanger tubes **14**, and heat is extracted by vaporization of the water wetting the exterior of the tubes **14**, this water having spilled from the notches **13** of the troughs **11**.

The foregoing is a brief description of an evaporative heat exchanger which is conventional in structure and operation except for the water distribution system of the concurrently filed application of Thomas F. Facius and the trough system of the present invention.

It will be appreciated that if the heat exchanger **14** is used for a purpose such as condensing a refrigerant, the amount of water necessary to be supplied is only that amount required to keep the exterior of the tubes wet at all times. According to the present invention, by the use of rounded bottom troughs the curvature of which is clearly apparent from FIG. 4, it is possible so to distribute the water issuing from these troughs that they may be spaced wide apart and, indeed, occupy only about 25–30 percent of the cross section of the chamber **10** at the plane A—A and, yet, insure that the tubes **14** are maintained wet at all times. The structure by which this is accomplished is best understood by reference to FIGS. 3 and 4.

A chamber **23** is located near the top of chamber **10** which could be installed either internally or externally and is fed centrally from conduit **16**. This chamber **23** is partially defined by a wall **24** which separates it from and is common to a reservoir **25**. Reservoir **25** is defined by the partition **24**, a common bottom wall **26** and a wall **27**, which is the wall which one sees in FIG. 1. The wall **24** defines a series of spaced, round holes **28** which provide a path of liquid communication between chamber **23** and reservoir **25**. The wall **27** defines a group of discharge apertures, one for each trough **11**, and these discharge apertures bear reference numeral **29**. Four of them can be seen in FIG. 4. The apertures **29** generally conform to the cross section of the trough but they terminate below the steady water level in the troughs **11**. The water issuing from the conduit **16** enters the chamber **23** near the center thereof, flows through holes **28** in partition **24** and establishes a stable liquid level in reservoir **25**. Note that there is a hole at **28** in wall **27** for each of the three troughs served. Chamber **23** is actually of about the same height as the diameter of pipe **16** so that the flow from the pipe to the chamber is about the same as the flow from the stem into a T joint. Reservoir **25** drains through apertures **29** into the respective troughs and from the V notches in the troughs the water spills into the heat exchange region. In so spilling, the streams have a tendency to adhere to the side wall of the trough below their originating notch and to leave the trough well beyond the vertical center line on the side of the trough opposite to the notch of origination. These streams, in the absence of counterflowing air,

have a tendency to fall as illustrated in FIGS. 1, 2, 3 and 4. Thus, the stream **30** issues from a notch in the right-hand side of the trough **11** as it is viewed in FIG. 4, and the stream **31** issues from a notch in the left-hand side of the trough **11** as it is viewed in FIG. 4. The notches **13** of the troughs **11** are staggered, as is quite apparent from FIG. 3, so that notches on opposite sides of each trough are mutually axially offset, with the result that streams such as **30** and **31** are axially offset and do not touch one another. When the air is turned on, the pattern of the streams undergoes a marked change, which is illustrated in FIG. 5. The stream spilling down the side wall of a trough has a tendency to flatten somewhat as it nears the bottom of the trough. When the air is turned on, the stream tends first to flatten and then to round again as it goes past the bottom center line of the trough to be swept away from the trough by the counterflowing air. At the moment the stream finally leaves the trough, it literally explodes into droplets and FIG. 5 represents an effort to depict these phenomena.

When the air is not displacing them, there is defined between the streams **30** and **31** and the vertical center line of the trough an angle alpha, and it has been discovered, as a part of this invention, that this angle alpha is related to the curvature at the base of each trough. As can be seen in FIG. 4, the troughs illustrated in this application have nearly parallel sides connected by an arc of uniform radius. Whether such an arc is used as the radius of curvature of the bottom of the troughs is a matter of what is sought to be accomplished. If the troughs are in the form of a sharp V at the bottom, then the respective angle alpha will be quite small and the spacing between the troughs will have to be small in order to get good water coverage. Where good water coverage is sought with minimum obstruction of the air flow space, it has been found that the troughs, as illustrated in FIG. 4, are effective. The troughs of FIG. 4 are shown as rather widely spaced in FIG. 1 and occupy only about 25–30 percent of the cross-sectional area of the chamber **10** at the plane A—A. This arrangement has been found to offer good wetting characteristics for evaporative condenser tubes.

The troughs **11** are supported in brackets **32** and **33**. Each bracket **32** is provided with integral flanges at **34** and **35** which are bolted or fastened by self-tapping screws to the partition **27** with the trough in registry with the respective aperture (see FIG. 4). Bracket **33** is similarly held by flanges **37**, only one of which shows in the drawings. A matrix of sealing material indicated at **38** seals each end of each trough into the respective hanger bracket.

The water distribution system of the cooling tower illustrated in FIG. 2 is much like that shown in FIG. 1 except that, because of the higher flow rates required, the troughs **11** are spaced much closer together and, in the illustrated form of the invention, occupy about 45 percent of the cross section of the chamber **10** at the plane A—A. Like parts in FIGS. 1 and 2 bear like reference numerals but, of course, in FIG. 2 heat exchange tubes are absent and instead the heat exchange region is occupied by undulatory plates **39**. A plurality of these plates **39** are provided to afford a larger surface to be kept wet with water and, hence, a large air-water interface.

In the arrangement of FIG. 2, water, to have heat extracted from it, is delivered by pipe **40** and is discharged from the troughs **11** much as described in conjunction with FIGS. 1, 3, 4 and 5. Some of this water evaporates and this has the effect of cooling the rest of the water so that the hot water supplied through conduit **40** is cooled by the time it reaches the sump **12**. The cool water is withdrawn from the sump **12** through a conduit **41**.

In FIGS. 6 and 7 there are illustrated fragments of a straight-edged trough **40** which may be used in lieu of or in conjunction with troughs such as are designated by reference numeral **11** in FIGS. 1 to 5, inclusive. Since

troughs **40** are intended to be installed and used much in the manner of troughs **11**, only the differences in trough structure are described. Within each trough **40** there is mounted a corrugated channel **41** with its side walls **42** and **43** pressed with their convex corrugations tangentially against the inner respective faces of the side walls of the trough **40** and so held by the integral bight **44** of the channel. Because the corrugations of channel **41** run diagonally, the corrugations of side wall **42** of the channel **41** are offset with respect to those of side wall **43** so that the concave corrugations provide with the trough side wall a plurality of vertical channels **45** extending from the top edges of the trough **40** to the free lower edge of the respective side walls **42** or **43**. Thus, when the trough **40** overflows, a plurality of streams flow from it much like those which issue from a trough such as **11**.

In a water distribution system for evaporative type heat exchangers, it is desirable to supply the water in the smallest streams possible in order to provide for maximum air-to-water interface. In the case of troughs such as troughs **11**, the notches in each side wall are in staggered relationship to those of the other side wall so that the water issuing from each notch leaves the trough in a separate stream. See FIGS. 1 to 5, inclusive. Very much the same stream effect is obtained with the modified form of the invention shown in FIGS. 6 and 7. However, these methods of providing individual streams spilling from the edge of the trough are suitable to relatively low flow rates, such as are required in evaporative condensers or fluid coolers and in cooling towers of relatively low water flow per unit face area. When higher water flow rates are needed, the water has a tendency to sheet as it leaves the notches of the troughs such as are shown in FIGS. 1 to 7, inclusive. This effect, if not counteracted, reduces the atomization of the water, thereby reducing the efficiency of the tower because of a resulting failure to produce a maximum air-water interface. In FIG. 8 there is disclosed an improved trough which is found to be very effective for handling high water flow rates.

The troughs of FIG. 8, as well as the troughs of FIGS. 9, 10, 11 and 12, are intended to be used in an evaporative heat exchanger and intended to be mounted in the assembly in the manner described in connection with FIGS. 1 and 5. For this reason, all of FIGS. 8 to 12 inclusive, are merely fragmentary views of a portion of a trough for the purpose of illustrating various modifications which have been found efficacious to deal with high water flow rates.

In FIG. 8 the trough is designated by reference numeral **46**, and it has notches **47** in its free edges similar in structure and function to the notches **13** earlier described. However, the trough **46** has a crescent section corrugated baffle **48** attached tangentially at the bottom thereof. This baffle has a number of corrugations considerably exceeding the number of notches **47**, and the water spilling down the side of the trough **46** is subdivided by the corrugations and discharged into the counterflowing air in the form of a large number of very small streams. This system has been found to be highly efficient for producing high air-water interfaces under high water flow conditions. While the notches **47** in the side wall of trough **46** are illustrated as staggered and less numerous per unit length than the corrugations of baffle **48**, the baffle **48** is so effective that shallow numerous notches not offset will produce an entirely satisfactory result.

In FIG. 9 the trough is designated by reference numeral **49** and it is, in all respects, similar to trough **46**. In FIG. 9, however, the crescent section baffle **50** is not corrugated but, instead, is provided with V notches **51** along its opposite edges. These notches **51** are more numerous and more shallow than the notches **52** through which the water overflows from the trough. In FIG. 9 there has been no attempt to illustrate the flow of the water from baffle **50**. However, it leaves in the form of streams falling off of the points which define the notches **51**.

In FIG. 10 there is shown a trough **53**, again entirely similar to trough **46**. In this case, the crescent section baffle **54** is corrugated only at its opposite edges **55**. The spill of water from these edges is the same as shown in FIG. 8. The corrugations **55** and the notches **51** of FIG. 9 are both more numerous per unit length than the main spill notches of the trough so that numerous small streams are fed into the air flow, although the number and depth of notches in the side wall of any trough used with a crescent baffle of a type such as is illustrated in any of FIGS. 8, 9 and 10 is a matter of maintaining an even spill for the length of the trough, since the number and size of the corrugations or teeth on the crescent baffle controls the spacing of streams of water fed into the counterflowing air.

The baffles **48**, **50** or **54** may be attached to the bottom of the respective troughs by welding or by sheet metal screws.

In FIGS. 11 and 12 there is illustrated a trough essentially of the type shown in FIGS. 6 and 7 but provided with a corrugated crescent section baffle tangential to the base.

In FIG. 11 the trough bears reference character **56** and the interior corrugated member which produces the streams which spill over the straight edge of the trough **56** bears reference numeral **57**. It is similar in structure and function to the channel **41** shown in FIGS. 6 and 7. The corrugated baffle **58** is similar in structure and function to the baffle **48**, but the corrugations need not be offset.

In all of FIGS. 6, 7, 8 and 11, the streams issuing from the respective troughs or crescent section baffles are illustrated in the no-air position, but it is intended that these troughs will be used in a counterflowing air situation and that the streams will be subdivided by the counterflowing air much in the manner described in FIG. 5.

What is claimed is:

1. A trough for supplying water to an evaporative heat exchanger comprising an integral sheet metal structure having parallel side walls mutually spaced and interconnected by a regularly curved portion extending for 180°, said side walls presenting two free edges, said side walls each defining regularly spaced deep V notches therein, the mouths of said notches coinciding with the free edges of the side walls, the depth of the side wall between the beginning of the curved portion and the bottom of the notches being about equal to the space between the side walls.

2. Apparatus for supplying water to an evaporative heat exchanger comprising a trough, means to supply water to said trough, a corrugated wall, means to hold said corrugated wall against the inner face of a side wall of said trough in a position to define therewith spaced channels through which water overflowing the trough is led to the trough edge in a series of spaced streams.

3. Apparatus for supplying water to an evaporative heat exchanger comprising a trough, means to supply water to said trough, a corrugated wall, means to hold one of said corrugated walls against the inner face of each side wall of said trough in a position to define therewith spaced channels through which water overflowing the trough is led to the trough edge in a series of spaced streams.

4. Apparatus for supplying water to an evaporative heat exchanger comprising a trough, means to supply water to said trough, the free edges of said trough defining deep notches to cause water to overflow from the opposite edges of said trough in a series of spaced streams and means associated with said trough to divide the water from said streams into a larger number of divergent streams discharging into the heat exchange area in space defined by a vertical projection of the sides of the troughs.

5. Apparatus for supplying water to an evaporative heat exchanger comprising a trough, means to supply

water to said trough, a corrugated wall, means to hold said corrugated wall against the inner face of a side wall of the trough in a position to define therewith spaced channels through which water overflowing the trough is led to and flows from the trough edge in spaced streams, and means associated with said trough to divide the water from said streams into a larger number of streams discharging into the heat exchange area.

6. Apparatus for supplying water to an evaporative heat exchanger comprising a trough, means to supply water to said trough, means to cause water to overflow from the opposite edges of said trough in a series of spaced streams and a generally crescent section baffle tangent to the bottom of said trough in a position to receive the water overflowing the trough, the edges of said baffle defining a pattern of edge portions mutually offset in at least one plane.

7. Apparatus for supplying water to an evaporative heat exchanger comprising a trough, means to supply water to said trough, means to cause water to overflow from the opposite edges of said trough in a series of spaced streams and a generally crescent section baffle tangent to the bottom of said trough in a position to receive the water overflowing the trough, the edges of said baffle being corrugated and the corrugations being closer together than the spacing of the streams overflowing the trough.

8. Apparatus for supplying water to an evaporative heat exchanger comprising a trough, means to supply water to said trough, means to cause water to overflow from the opposite edges of said trough in a series of spaced streams and a generally crescent section baffle tangent to the bottom of said trough in a position to receive water overflowing the trough, the edges of said baffle being notched and the number of notches being greater than the number of streams overflowing the trough edge.

9. In an evaporative heat exchanger including a chamber having a heat exchange region therein, the improvement that comprises a plurality of generally U section troughs arranged in horizontally spaced relation throughout the cross section of said chamber above said region, means to cause water to overflow the opposite edges of said trough in a series of mutually spaced streams divergent from the sides of said troughs, and means to flow air upwardly through said region and between said troughs to atomize said separate streams.

10. Apparatus for supplying water to an evaporative heat exchanger comprising a trough, means to supply water to said trough, means to cause water to overflow from the opposite edges of said trough in a series of spaced streams, means associated with said trough to divide the water of said streams into a larger number of streams discharging downwardly into the heat exchange area in divergent relationship to the sides of the troughs, and means to flow air upwardly through said regions against said streams to atomize the water thereof.

11. In an evaporative heat exchanger including a chamber having a heat exchange region therein, the improvement that comprises a plurality of generally U section troughs arranged in horizontally spaced relation throughout the cross section of said chamber above said region, each trough having parallel sides with V notches therein and a regularly curved bottom portion, the side walls of said troughs having a mutually parallel portion between the bottom of the notches and the beginning of the curvature at the bottom thereof, means to flow water into said troughs to discharge from said notches and flow downwardly as separate streams, each stream leaving the trough from the side thereof opposite to the notch at which it originated, and means to flow air upwardly through said region and between said troughs to atomize the separate streams.

12. In an evaporative heat exchanger including a chamber having a condenser therein, the improvement that comprises a plurality of generally U section troughs arranged in horizontally spaced relation throughout the cross section of said chamber above said condenser, each trough having V notches in a side wall, said troughs occupying about 25–30 percent of the area of the chamber at the horizontal plane at which the troughs have their widest dimension, means to flow water into said troughs to discharge from said notches and flow downwardly as separate streams, each stream leaving the trough from the side thereof opposite to the notch at which it originated, and means to flow air upwardly through said region and between said troughs to atomize the separate streams.

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