Aug. 20, 1968 P. W. SCHIPPER 3,397,872

CASCADE TRAYS FOR AN EVAPORATOR AND A METHOD OF FILLING SUCH TRAYS

Filed Oct. 18, 1965 2 Sheets-Sheet 1

Fig. 1

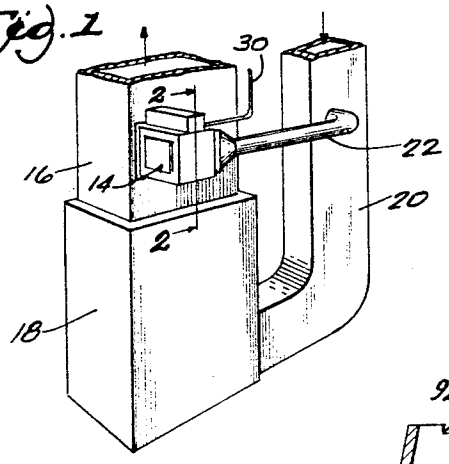
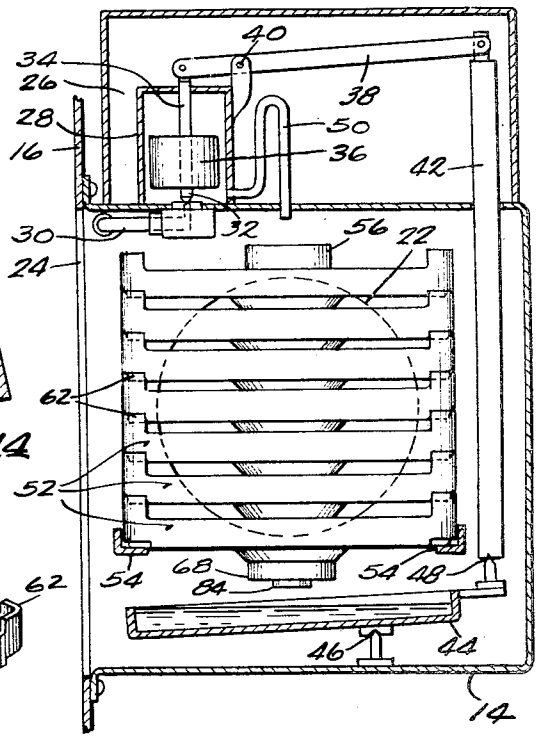



Fig. 2



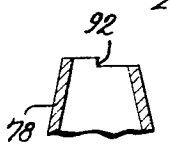




Fig. 14

Fig. 6

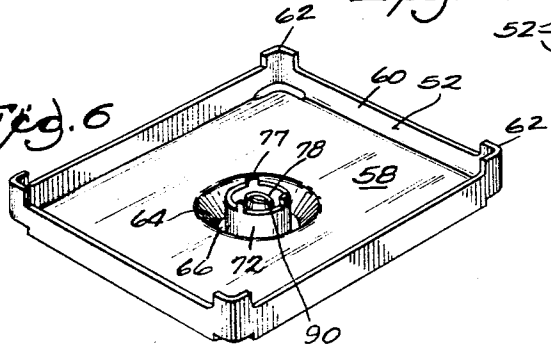
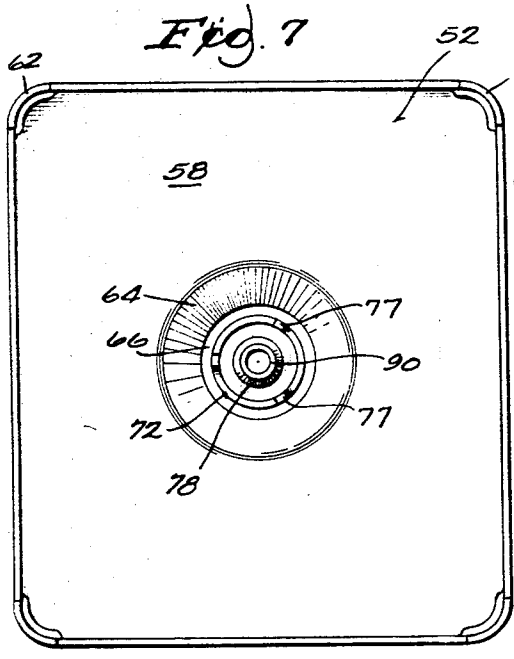



Fig. 7



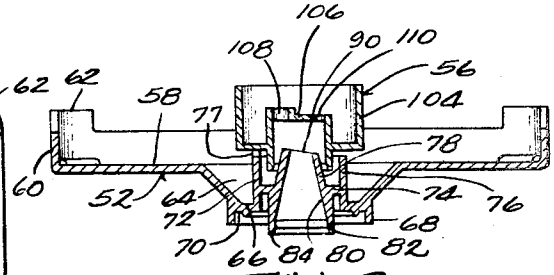




Fig. 3

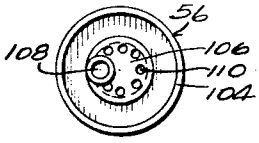



Fig. 4

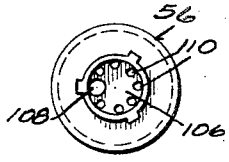



Fig. 5

INVENTOR
DIETER W. SCHIPPER
BY Wheeler, Wheeler & Wheeler
ATTORNEYS

Aug. 20, 1968 P. W. SCHIPPER 3,397,872

CASCADE TRAYS FOR AN EVAPORATOR AND A METHOD OF FILLING SUCH TRAYS

Filed Oct. 18, 1965 2 Sheets-Sheet 2

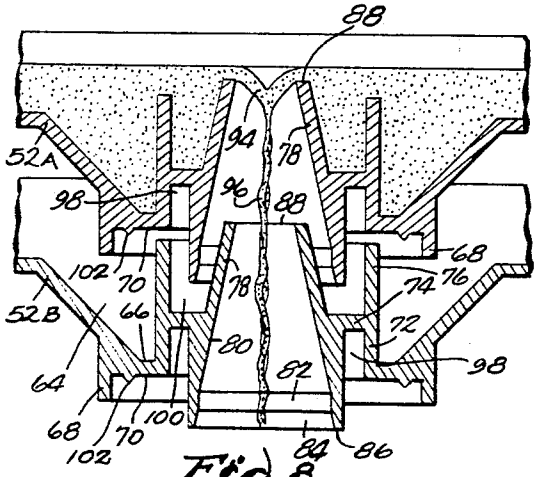



Fig. 8

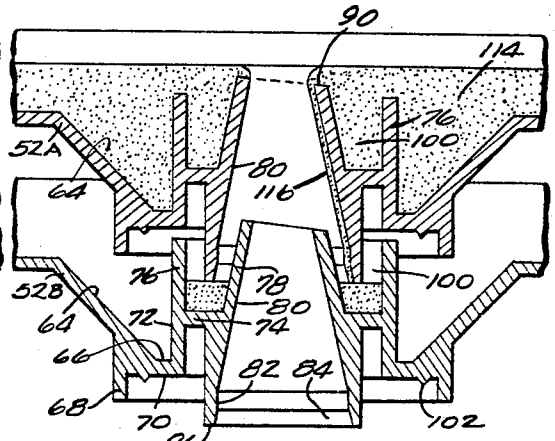



Fig. 9

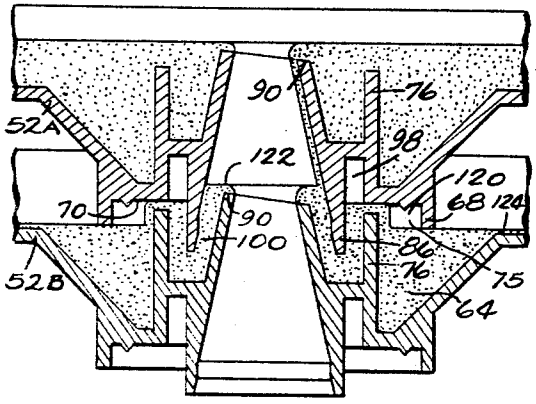



Fig. 10

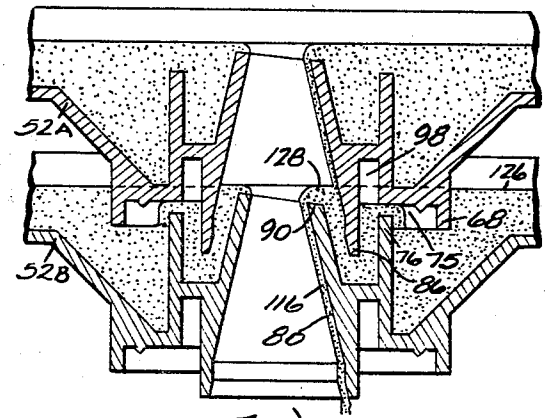



Fig. 11

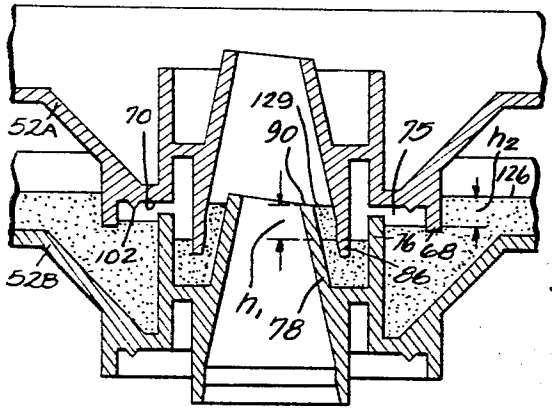



Fig. 12

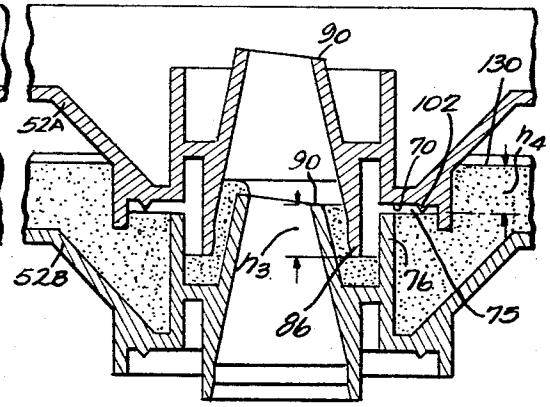



Fig. 13

INVENTOR
PIETER W. SCHIPPER
BY Wheeler, Wheeler & Wheeler
ATTORNEYS

United States Patent Office 3,397,872 Patented Aug. 20, 1968



3,397,872

# CASCADE TRAYS FOR AN EVAPORATOR AND A METHOD OF FILLING SUCH TRAYS

Pieter W. Schipper, Elm Grove, Wis., assignor, by mesne assignments, to Milwaukee Chaplet & Mfg. Company, Inc., Milwaukee, Wis., a corporation of Wisconsin

Filed Oct. 18, 1965, Ser. No. 496,909
9 Claims. (Cl. 261—110)

## ABSTRACT OF THE DISCLOSURE

A humidifier which has a vertically stacked series of cascade trays. The centers of the trays have interlocking annular depending skirts which act as overflow weirs to control the flow of water to the trays from a feed hopper mounted above the uppermost tray. The interlocked skirts also act as traps to prevent backflow of water from a tray through the skirts to the next lower tray.

This invention relates to cascade trays for an evaporator and a method for filling such trays. For convenience, the invention will be described with particular reference to a humidifier in which water is the liquid to be evaporated, it being understood that the invention has more general application.

In the evaporating system in which the trays are used, the water to be evaporated is introduced into the uppermost tray. As each successive tray is filled, the water flows to the next lower tray in the cascade series until, when the water fills the lowermost tray, it spills into a balanced pan which when filled to a certain level and by means of a lever system closes the inlet valve.

Cascade trays present problems. First, there is the problem of controlling the level of the liquid in the respective trays. When a given tray is full, the slightest disturbance will start the water flowing over its weir. Once the lip of a weir has been wetted, the flow will continue for considerable time. In the case of a single tray, little difficulty would be presented. In the case of a number of trays as herein illustrated, this after-drip will continue for perhaps twenty minutes.

Secondly, since replenishment of the water is dependent on the status of the water level in the balanced pan, the above described phenomenon tends to drain water from the trays into the balanced pan, with the result that, assuming all of the trays and balanced pan to be of like capacity and area, the trays will tend to evaporate dry before the water level in the balanced pan drops sufficiently to open the inlet valve. In an effort to solve this problem, cascade trays heretofore have been provided with excess water which has thereupon been permitted to drain away.

The present invention contemplates supplying only such water as is needed, and ensuring that all water is evaporated. To that end each tray is provided with an air lock which has the function of allowing water to pass to the trays but stops over-run by preventing discharge of water over the weirs except in the course of the desired filling process.

To achieve these objectives, it is preferred to use a stack of identical molded trays arranged in cascade relation upon a suitable support, the lowermost tray of the cascade series discharging into a counterbalanced pan which operates the intake valve. Each tray has a generally annular weir with a top margin which is not at uniform level for reasons hereinafter explained. The inner surface of the annular weir tapers outwardly at a slight conical angle so that water overflowing the weir will flow down the inner surface of the weir to a point of discharge which is outside of the weir of the next lower tray in the stack.

Surrounding each such weir there is a dam having its upper margins and surface somewhat lower than that of the weir. The water received from the next higher tray fills the annular space between the weir and the dam. A downward extension of the weir of the next higher tray extends into this space.

Surrounding the dam is an annular pocket which receives water overflowing the dam. This pocket opens into the storage area of the tray. However, a flange depending from the next higher tray encircles the top of the dam, extending to a level slightly lower than the top of the dam.

The contours of the respective trays provide air traps and "ceilings" as shown specifically in the drawings and hereinafter described, the object being to prevent discharge from the trays of water which would otherwise flow in a direction reverse to that of entry into the storage area.

In the drawings:

FIG. 1 is a general view in perspective of a typical humidifier installation selected for the purpose of exemplifying the invention.

FIG. 2 is a view partially in side elevation and partially in section showing a typical cascade tray arrangement.

FIG. 3 is a detail view of the top tray and a special filling hopper in transverse section.

FIG. 4 is a plan view of the filling hopper.

FIG. 5 is an inverted plan view of the hopper.

FIG. 6 is a view on a reduced scale showing one of the trays in perspective.

FIG. 7 is an enlarged plan view of the tray shown in FIG. 6.

FIGS. 8 to 13 are enlarged fragmentary detail views in diametrical cross section illustrating different conditions in the operation of cascade trays embodying the invention, each such view showing an upper tray and a lower tray in the series. To illustrate a point, the tray shown in FIG. 8 is slightly different mechanically from the other trays illustrated.

As already stated, the invention has to do with cascade trays in an evaporator of any sort. Therefore, in limiting this description to a humidifier, it will be understood that I am using the humidifier as a representative device and any reference to water is intended to comprehend any other liquid sought to be evaporated.

FIG. 1 shows the evaporator casing **14** applied to the side of a hot air plenum chamber **16** on a hot air furnace **18** which has a cold air return at **20**. Communication between the hot air plenum **16** and the cold air return **20** is provided by a conduit **22** and an opening **24** in the hot air plenum. The casing **14** is connected with the plenum about opening **24**.

On the top of the casing **14** is a valve chamber **26** in which a valve body **28** is disposed, being supplied with water through the supply line **30**. Movable to and from a seat in valve body **28** is a valve **32** having on its stem **34** a float **36**. A lever **38** fulcrumed at **40** is pivotally connected with the stem and with the link **42** which also serves as a counterweight for the balanced pan **44**. This pan is fulcrumed at **46** and has a knife edge pivotal connection at **48** with the counterweight **42**.

The arrangement is such that when the pan is full, it tilts downwardly upon its fulcrum as shown in FIG. 2, thereby lifting the counterweight to move the valve **32** to its seat. Thus when the water evaporates from the pan **44**, the counterweight oscillates the pan clockwise as in FIG. 2, thereby opening the water valve. The flow of water from the water valve into the valve casing **26** raises the level of water in the casing until the water overflows the gooseneck **50** and starts siphon action.

The general organization thus far described is not claimed herein, having been described by me in U.S. Patent 3,285,276.

The cascade trays **52** may all be identical. They are

preferably molded of synthetic resin and designed to stack one upon another. The lowermost cascade tray rests upon bracket seats **54** provided in the casing **14** as shown in FIG. 2. This tray discharges directly into the balanced pan **44** which controls the valve. The uppermost of these trays can be filled directly from the siphon tube **50** but in order to distribute the incoming water as desired it is preferred to introduce the water into the uppermost tray through a hopper **56** shown in FIGS. 3, 4 and 5. The bottom of this hopper is made to fit the tray parts in the same manner in which another superimposed tray would fit corresponding parts. This will hereinafter be described.

Each of the trays **52** comprises a bottom **58** and a side wall **60** which completely surrounds the bottom and provides an enclosed area to retain the water to be evaporated. The corners of the side wall **60** are built up as at **62** to provide posts upon which the next successive cascade tray is mounted. The posts provide clearance between trays for the circulation of air traversing the evaporator casing **14** between the plenum **16** and the pipe **22**.

Each of the cascade trays **52** is provided in accordance with the present invention with a series of integral weirs, dams, channels and cooperating surfaces for the control of water flow between successive upper and lower trays. FIGS. 8 through 13 are intended to show how this control is exercised. They also illustrate mechanical structure of the parts involved. Such parts are also shown in FIGS. 3, 6 and 7.

At some intermediate point on the bottom **58** of each tray there is an integral well **64**. The bottom **66** of this well is externally encircled by a flange **68** which extends a short distance below the under surface **70** of the bottom wall **66**. The lower surface of the well bottom **66** is so related to an underlying pan that it will hereinafter sometimes be referred to as "ceiling."

Rising centrally of the well above the bottom wall **66** is a tube **72** provided intermediate its height with a horizontal partition wall **74**. The portion **76** of the tube **72** which is above wall **74** is hereinafter referred to as a dam.

Integral with the partition **74** and rising above it is a conically tapered tubular strucure **78** wihch is hereinafer referred to as a weir. The interior of the weir **78** progressively decreases in cross section in an upward direction. The taper of its internal surface **80** is continued below the partition wall **74** to the point where it merges with a generally cylindrical band **82** below which the taper is resumed at **84** in approaching the lower extremity **86**. Extremity **86** is well below the level of the flange **68** as above described.

FIG. 8 shows a construction in which the top margin **88** of the weir **78** is horizontal. This is not preferred for reasons hereinafter to be explained. The preferred arrangement is shown in FIGS. 9 to 13 and in FIGS. 3, 6 and 7 where the upper margin **90** is slightly beveled. Alternatively, it may be notched or shouldered as indicated at **92** in FIG. 14, the object being to break the surface tension which, unless the opening through the dam were made abnormally large, might cause the dam to be bridged by the liquid to cause flow centrally through the dam instead of in the desired manner of flow down the interior surface. FIG. 8 shows the undesirable type of flow bridging the dam at **94** and trickling at **96** downwardly through the center of dam **78**.

As will be observed in FIGS. 8 through 13, the assembled position of the cascade trays is in a stack such that the lower margin **86** of the tube **78** of each upper tray surrounds the margin **88** of the dam of the next lower tray and is interposed between the dam **76** and the weir **78** of the next lower tray. In each case, the downwardly projecting flange **68** of the upper tray encircles the dam **76** of the next lower tray, the ceiling **70** of the upper tray lying closely spaced above the margin of the dam **76**. Although the upper trays are supported in each instance from the corresponding corners of the underlying tray, the spacing between trays in the trap area is important enough so that I may use spacing lugs as shown at **77** (FIGS. 6 and 7). These lugs are not shown in FIGS. 8 to 13 because the latter are intended to be diagrammatic and the lugs might obscure the intended operation. In each case, there is an inverted channel **98** in the upper tray which is just above the channel **100** of the next lower tray. The provision on ceiling **70** of an annular rib at **102** is a preferred arrangement.

The hopper **56** which receives water from siphon **50** and delivers it into the uppermost tray in the stack has a depending annular flange **104** extending into the channel **100** of the tray at the top of the stack. The water entering the hopper is baffled by a web **106** which has openings at **108** and **110** to so regulate the flow that the water enters the uppermost tray of the stack in substantially the same manner that the water enters each successively lower tray in the stack.

Describing now the operation of the system, reference will be made to FIGS. 8 to 13. Each of these figures illustrates two trays **52** which are identical with each other. For convenience, the uppermost tray in any given pair will be called **52A** and the lower tray in any pair will be called **52B**.

As already indicated, the desired control of the liquid to be evaporated can best be achieved if the liquid cascades from tray to tray. Since all of the openings of these identical trays are alike, it will be apparent that if the uppermost opening is bridged at the time the uppermost tray is filled (this being indicated at **94** in FIG. 8) the resulting trickle **96** will pass through the whole series of trays to the fulcrum pan **44** and the objective of distributing the liquid uniformly between the several trays will be defeated. This bridging cannot occur if the openings through the several weirs are sufficiently large in diameter. However, this would be an extravagant procedure since the size of the trays would then be excessive. The bridging can easily be avoided in trays of appropriate size by tilting the margin slightly as shown at **90** or by putting a notch or a step **92** in it (FIG. 14) to break up the continuity of surface tension around the edge.

Since FIG. 8 shows an undesirable contingency, the description of operation will commence with FIG. 9. The upper tray **52A** has had its water storage area filled with water **114** to a level which, by reason of surface tension, will be slightly above the lowest point of the upper margin **90** of the weir **78**. In reaching the weir, the water will have flowed over the dam **76** and filled the intervening channel **100**.

When the water wets the margin of the weir **78**, it will ultimately commence to flow downwardly in a stream **116** which will follow the conical inner surface **80**, thus being conveyed into channel **100** between the weir **78** and the dam **76** of the lower tray **52B** (FIG. 9).

As illustrated in FIG. 10, the water in channel **100** of the lower tray **52B** has increased to a point such that the water has begun to overflow the lower dam **76**. In so doing, it contacts the so-called ceiling **70** at the bottom of upper tray **52A**. The dimensions are so chosen with reference to the liquid involved that the liquid will actually contact the ceiling **70** as shown. Assuming that the liquid wets the ceiling, this actually aids the flow of liquid outwardly from channel **100** toward the storage area of the tray. Due to surface tension, water (for example) will stand one-eighth to three-sixteenths inch over the top of such a dam before spilling over. Assuming that water is the liquid handled, and assuming that the ceiling is brought down to a level such that it will be engaged by the water, the water will wet the ceiling and, by surface tension, will actually "pull" itself across the dam and start flowing into the channel **64** outside the dam.

The skirts **86**, **68** of the upper tray and the dam **76** of the lower tray together provide an annular inverted U-tube **75** with a longer inner leg between the skirt **86** and the dam **76** and a shorter outer leg between the dam **76** and the skirt **68**. The inverted channel **98** rises above the

inner leg and serves to trap air under the conditions shown in FIGS. 10 and 11.

In FIG. 10, air has been trapped in the inverted channel **98** of the upper tray and air has been trapped at **120** in the top of the shorter outer leg of the U-tube **75** between the dam **76** of the lower tray and the depending flange **68** of the upper tray of the stack. The back pressure produced by the trapped air has caused the water level to rise at **122** to a point such that only surface tension prevents it from rising over the top margin **90** of the weir **78** of the lower tray **52B**. The water is beginning to fill the storage and evaporation space in the lower tray as indicated at **124**.

FIG. 11 shows a situation which arises when the water level **126** in the lower tray is high enough to create a head which forces the water **128** to flow over the edge **90** of the weir **78** of lower tray **52B** to flow down at **116** along the outwardly tapering side wall **80** thereof and to enter the next successively lower tray in repetition of the sequence just described. The sequence will be repeated until all of the trays in the stack receive water. When the water begins to spill over the lip **90** of the weir of a given tray, practically all water received by that tray thereafter is passed on to the tray beneath it, none of it going through the U-tube into the tray just filled. This is the situation which exists in FIG. 11.

After the supply of water has been cut off by the closing of the valve at **32**, it is desired that all flow downwardly from the respective trays shall be promptly discontinued so that thereafter the water will evaporate from the trays instead of being discharged physically therefrom. FIGS. 12 and 13 show how the air locks above described prevent the water from continuing to flow over the weirs in the manner which has happened in cascade tray structures of the prior art.

The volume of air trapped in the U-tube in relation to the volume of the inner leg of the U-tube and the relative length of the outer and inner skirts **68** and **86** are all important. In the actual tray herein disclosed, which is designed for the vaporation of water, the dam **76** has a height which is one-eighth inch lower than that of the weir lip **90**. Constructed as shown, the operation of the U-tube is so effective that if water is introduced into the tray by external means (instead of arriving through the U-tube) it will flow over the side of the tray before spilling over the weir, despite the fact that the weir is three-eighths inches lower than the side. The reasons for this will be shown below in discussing FIG. 13.

The effective pressure on the inner leg of the annular U-tube **75** exceeds atmospheric pressure by the dimension shown at $h_1$ in FIG. 12. The pressure to which the outer leg of the annular U-tube **75** is subject is in excess of atmospheric by the dimension indicated at $h_2$ in FIG. 12. Surface tension is ignored in both instances. Equilibrium is reached when $h_1$ and $h_2$ are equal. As clearly appears in FIG. 12, this will occur when the liquid **126** in the tray outside of the tube is considerably above the level **129** that equals the level of the lip **90** of the weir **78**. Thus the U-tube holds the water level in the tray outside of the trap despite the fact that the wetted surface **90** at the edge of the weir drains off such water as has accumulated at the top of the weir inside the skirt **86**.

As shown in FIG. 13, the parts are so dimensioned that the outer leg of the annular U-tube **75** will be substantially completely purged of air before the water within the tray **52B** reaches the top of the dam **76**. $h_4$ represents the distance that the level **130** is above the level of dam **76**. $h_3$ represents the distance that the lip **90** of the weir **78** is above the level of the lower margin of the skirt **86**. Water level **130** cannot reach a level such that head $h_4$ is greater than head $h_3$. Thus reverse flow is impossible. In practice, $h_3$ is three-eighths of an inch and since the dam is one-eighth of an inch below the lip **90**, it never happens that the water can flow inwardly from the tray **52B** over the weir lip **90** of the next lower tray. (As in the previous examples, surface tension is being ignored.)

Due to surface tension, the liquid would actually have to be raised outside of the trap considerably higher than illustrated before flow could occur in an inward direction. Also liquid clinging to the ceiling **70** acts to resist flow. Tests show that water will actually run over the sides of the tray before spilling over the weir of the next lower tray.

The sharp ridge **102** depending from the ceiling **70** prevents the water from clinging to the ceiling when its movement is outward. If the liquid were other than water, or perhaps consisted in water having a wettting agent therein, or a material tending to adhere to a plastic tray, air might be driven from the air lock in the absence of a ridge such as that shown at **102**.

In actual practice, trays which have skirts and flanges interacting to establish the U-tube and air locks functioning as above described are effective to permit the trays to fill readily when supplied with water about the central weir, as above described, but resist loss of water over the weir after that portion of the water which wets the surface of the weir has been delivered downwardly. As a result of the arrangement described, it is possible to fill successive trays in the cascade series and yet to ensure that when the valve is closed no further water will escape from any of the trays except by evaporation. Thus the overflowing of the balanced control pan at the bottom of the series is prevented and the operation of the valve is positive and accurate without any necessity of supplying excess water which is wasted.

I claim:

**1.** A plurality of superimposed evaporator trays wherein an upper tray has inner and outer depending skirts, the inner skirt having its lower end at a lower level than the outer skirt, the next lower tray having an inner weir within the inner skirt of the upper tray and an outer dam intervening between the inner skirt and the outer skirt of the upper tray and in outwardly spaced relation to the weir, the height of the weir exceeding the height of the dam.

**2.** A plurality of trays in a stack according to claim **1** in which the weir has an inner surface which progressively expands downwardly.

**3.** A plurality of trays superimposed in a stack, the trays having substantially identical central trap portions which are interrelated in the stack, the trap portion of each ray including a central well, a generally annular dam extending upwardly from the center of the well, a partition intermediate the height of the dam, a weir carried by the partition and surrounded by the dam and projecting to a substantially higher level than the dam, said weir being continued below the dam as a depending skirt and having an inner surface which expands downwardly toward the bottom of the skirt, the skirt of an upper tray in said stack being interposed between the weir and the dam of the next lower tray in the stack, each tray further having below its said well a ceiling surface spaced above the dam of the next lower tray in the stack, and a second skirt depending to a level lower than the top of the dam of said next lower tray.

**4.** An evaporator comprising a stack of trays in superimposed relationship, and means for introducing into the uppermost tray a liquid to be evaporated, and for filling the trays with such liquid successively from the uppermost tray downwardly, means for shutting off the introduction of liquid when the lowermost tray in the stack has received a charge of liquid, and trap means with which each such tray is provided for opposing the discharge reversely through the trap of each tray of liquid introduced therein through the trap means for evaporation from the tray.

**5.** An evaporator according to claim **4** in which the trap means comprises a dam flange upstanding in the lower tray, a relatively long inner flange and a relatively short outer flange depending from a superimposed tray and dis-

posed at opposite sides of said dam flange, the superimposed tray being closed between the said depending flanges and having, with said depending and dam flanges the form of an inverted U-tube having a relatively longer inner leg and a relatively shorter outer leg, and means for guiding into the lower end of the relatively longer inner leg the liquid to be introduced into the respective tray, both legs having terminal portions immersed in the liquid so introduced.

6. An evaporator according to claim 5 in which the several flanges are annular, the lower tray having a central annular weir constituting a part of the means for guiding liquid into the longer leg of the U-tube for admission to the tray, said weir having a top margin at a level higher than the top of the dam flange and having an inner surface which flares conically in a downward direction, the top of the weir of one tray lying inside of the bottom of the weir of the next higher tray in the stack.

7. An evaporator according to claim 6 in which the top margin of the weir is non-uniform in height and the conical angle of its inner surface is sufficiently small so that liquid overflowing the weir will follow along such surface for delivery outside of the weir of the next lower tray.

8. An evaporator tray comprising unitarily a bottom having a central well and side walls for holding liquid to be evaporated and provided with inner and outer depending skirts of which the inner skirt terminates at a lower level than the outer skirt, and further being provided with an annular dam having a top margin above the level of the tray bottom, and an annular weir spaced inwardly from and surrounded by the dam and having



a top margin at an elevation higher than the level of the top of the dam, said tray being adapted to be stacked with similar trays with the inner skirt of a superimposed tray depending between the weir and the dam of the next lower tray, the dam of the lower tray intervening between the outer skirt of the upper tray and the weir of the lower tray, said skirts and weir and dam having the cross-sectional form of an inverted U-tube when so stacked.

9. A method of tray evaporation of liquid, said method comprising the cascade filling of a plurality of trays in succession, including self-initiating the flow of liquid from below the top margin of each tray into a successively lower tray by conducting the liquid downwardly through the centers of the trays and through a series of concentric weirs of concentric weirs depending from the trays, and trapping between the depending weirs in each tray the liquid filled into such trays, whereby to preclude reverse flow of such liquid from the tray and to require that such liquid be evaporated as its only means of egress.


**References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 329,115 | 10/1885 | Wurster | 261—110 |
| 474,630 | 5/1892 | Deckebach | 261—113 |
| 820,665 | 5/1906 | Moore | 261—113 |
| 1,765,087 | 6/1930 | Mase | 261—114 |
| 3,136,829 | 6/1964 | Skerritt. | |
| 3,282,575 | 11/1966 | Allcorn. | |



HARRY B. THORNTON, *Primary Examiner.*

E. H. RENNER, *Assistant Examiner.*