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Munters

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[54] **LIQUID AND GAS CONTACT APPARATUS**

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Related U.S. Application Data

[63] Continuation of Ser. No. 813,383, Feb. 28, 1969, abandoned, Continuation-in-part of Ser. No. 380,357, July 6, 1964, abandoned.

[30] **Foreign Application Priority Data**

July 4, 1963 Sweden 7455/63

[52] **U.S. Cl.** **261/112,** 261/DIG. 11, 55/241

[51] **Int. Cl.** **B01f 3/04**

[58] **Field of Search** ... 261/108, 109, 110, 111, 112, 261/DIG. 11; 55/240, 241

[56] **References Cited**

UNITED STATES PATENTS

2,252,242	8/1941	Wood	261/119
2,971,750	2/1961	Boling	261/DIG. 11
3,262,682	7/1966	Bredberg	261/112

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[57] **ABSTRACT**

A contact apparatus for liquid and gas, primarily used in air conditioning systems, which includes a contact body composed of first and second sets of corrugated sheets arranged with the sheets of the first set disposed alternately with the sheets of the second set. The corrugations of the sheets provide channels for passageways which penetrate the contact body from edge to edge, with both horizontal and vertical components of direction. A liquid distributing means is disposed over the top edge of the contact body. The channels thus formed are simultaneously passed by a flow of the gas in one direction and by the liquid in either counterflow or crossflow directions. The corrugations of the first set of sheets cross the corrugations of the second set of sheets, at an acute angle in the range of from 20° to 80°. The corrugations of the first set of sheets have a greater inclination to the horizontal plane of the contact apparatus than the corrugations of the second set of sheets; and the corrugations in the first set of sheets are inclined upwardly in the direction of the gas flow; the bisector of the angle of the corrugations of the respective sheets inclining downwardly opposite to the direction of gas flow with respect to the horizontal plane of the contact body; whereby to counteract an undesirable lateral displacement of the liquid stream caused by the gas flow, and causes the liquid to be distributed uniformly and causes evenly over the sheets.

6 Claims, 3 Drawing Figures

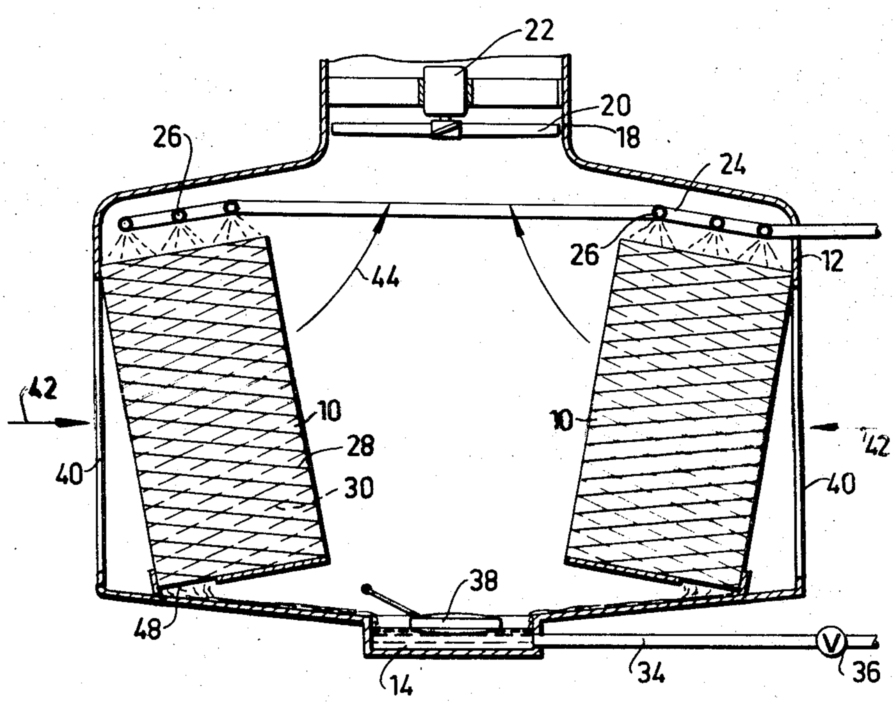

Fig. 1

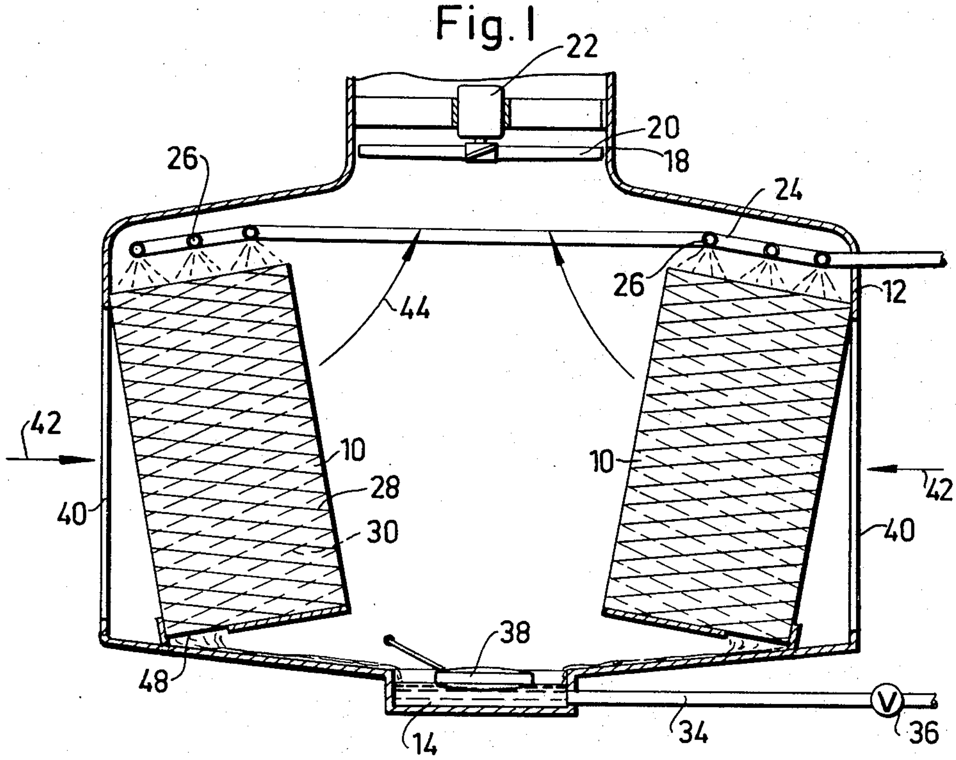

Fig. 2

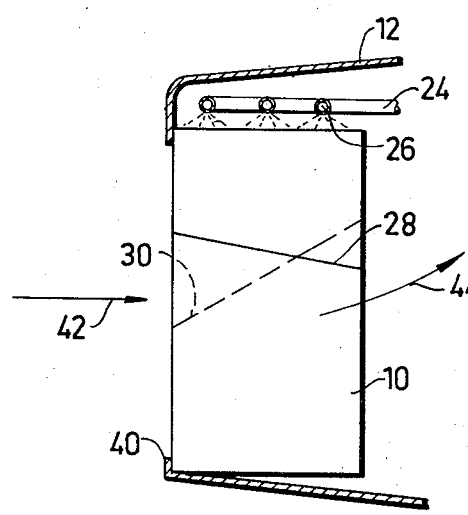

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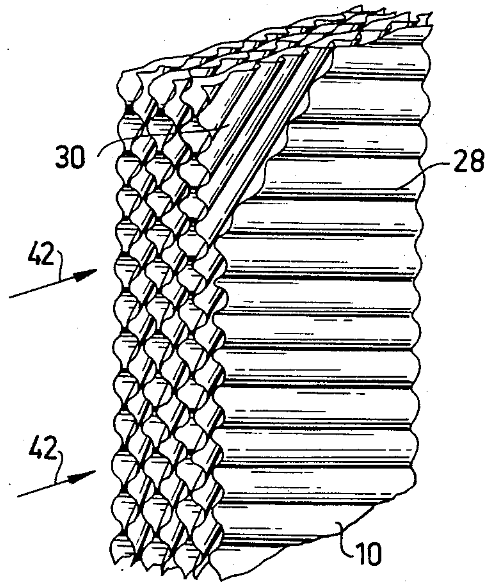
Fig. 3



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LIQUID AND GAS CONTACT APPARATUS

REFERENCE TO PRIOR APPLICATION

This application is a continuation of my copending application Ser. No. 813,383, filed Feb. 28, 1969, now abandoned, which in turn was a continuation-in-part of earlier copending application Ser. No. 380,357, filed July 6, 1964, now abandoned.

This invention relates to a gas and liquid contact apparatus comprising an exchanger packing or contact body disposed within a casing, said packing being composed of layers or sheets provided with folds or corrugations, said layers being passed by the two fluids simultaneously. These fluids may be water and air, one important field of application being constituted by cooling towers. In the following description, the invention will be explained in connection with cooling towers, although it is not limited thereto.

In copending patent application Ser. No. 290,422, filed June 25, 1963 by Sven Josef Henry Bredberg, now U.S. Pat. 3,262,682, a contact body or packing is described in which the folds of adjacent layers cross one another. The channels or interspaces between the layers are thereby given a continuously varying width, with the result that the flow direction of the fluids will repeatedly be changed during the passage through the packing. A packing of this type has a high efficiency in accomplishing the intended change of condition, such as the cooling of water.

One main object of the invention is to provide a further improvement of the contact apparatus of the type set forth.

A further more particular object of the invention is to provide a contact apparatus of the cross-flute type for use in cross flow cooling towers in which the angles of inclination between the folds or corrugations and the direction of the liquid flow are selected as to obtain an unexpected optimum of exchange between the fluids.

Due to the fact that two adjacent layers over the whole or the major part of the area, form the continuous interspace, an effect on the liquid is produced by a gas flow acting at a crosswise angle to the direction of flow of the liquid, which tends to produce lateral displacement of the liquid within the casing. Further, the liquid may be blown out of the packing, with the gas stream, in the form of droplets. Such lateral displacement of the liquid, increases substantially the resistance to the gas flow and causes the liquid to bubble and foam between the sheets and tends to blow it out from the fill.

Another object of the invention is to cause the liquid to follow the layers in a uniform distribution over the entire packing, which thereby attains maximum capacity and minimizes the pressure drop of the gas, with consequent saving of fan power and restriction of fan size. This distribution is of importance also from the point of view that, if the portion of the packing primarily impacted by the air is not wetted and rinsed by the water (as, for example, in a cooling tower) to a sufficient degree, precipitation of salts or like minerals on the surface of the layers may occur, which within a short time will block the channels of the packing.

Further objects and advantages of the invention will become apparent from the following description, considered in connection with the accompanying drawings which form part of this specification and of which:

FIG. **1** is a vertical longitudinal section through a cooling tower constructed according to the invention.

FIG. **2** is a fragmentary view showing a portion of a cooling tower in a vertical longitudinal section disclosing a modification.

FIG. **3** is a perspective view of a portion of a packing made according to the embodiment of FIG. **2.**

In all of the Figures, the same reference numerals have been used for equivalent parts.

In the embodiment shown in FIG. **1,** two packings or contact bodies **10** are surrounded by a casing **12,** which at its base forms a water collecting space **14.** Water is supplied to the packing from above through distributors **24,** which for ease of simple illustration have been indicated as stationary devices with escape holes **26** on their lower side but which also may be of a rotating or otherwise movable type.

The packing or contact bodies **10** consist of thin layers or sheets, which preferably are folded or corrugated, and which are positioned vertically. The folds or corrugations cross one another in adjacent layers, intersecting at an angle which applicant has discovered to be critical within certain ranges. They bear against one another and are bonded together at the points of contact by means of a suitable binding agent. The lines **28** denote the corrugations in every second layer, and the lines **30** in the layers therebetween. Channels or passageways penetrating from one edge to the other of the packing are thus obtained with both horizontal and vertical components of direction, said channels or passageways having a continuously varying width from zero at the points of the contact between the layers up to double the height of the corrugations. The height of corrugations preferably falls in a range of from 6 to 20 mm., but this may vary considerably according to design requirements.

The layers may to advantage be made of fibers of cellulose or inorganic material such as asbestos. Paper sheets of cellulose or asbestos are made to retain their strength when wet by impregnation with a substance suitable for this purpose, as, for instance, a resin such as a phenolic resin. The layers may also be interconnected at the points of contact by means of such resin. The layer may also be subjected to a treatment in a manner disclosed in my copending patent application, Ser. No. 254,131, filed Jan. 28, 1963 now U.S. Pat. No. 3,307,617 dated Mar. 7, 1967.

The water distributed from above over the entering area of the packing **10** flows downwardly along both sides of the layers as a film, following a kind of winding path, and there is accordingly obtained a very high rate of interaction between the fluids per unit of surface of the layers. While the water flows down in the form of a thin film along the layers in a substantially vertical direction of flow, the gas, such as air, enters through openings **40** located on the same level as one lateral edge of the packing and, as is indicated by the arrows **42, 44,** has a substantially horizontal direction of flow through the interspaces or channels existing between the packings. The air escapes through an outlet **18** within which a fan **20** with a driving motor **22** is provided. The cooled water is withdrawn from the collecting space **14** through a conduit **34,** controlled by a valve **36** disposed therein to be conveyed to a place of use from which it is recirculated in known manner to the distributors **24.** The level of the water in the collecting space is controlled by a float mechanism **38** causing fresh water to be supplied to replace the losses due, for example, to the evaporation within the contact body. In the embodiment of FIG. **1**, the packings have a rectangular contour and the folds or corrugations **28** in the one group of layers have the same angle of inclination as the corrugations or folds **30** in the other group of layers, relative to the gas stream entering edges of the sets of corrugated sheets. However, the packings are inclined by being supported by sloping supports **46** formed with openings **48** for the escape of the water to the collecting space **14**. In this manner the folds **30**, inclined upwardly viewed in the flow direction **42** of the air, are given a steeper angle of inclination in relation to a horizontal plane than if the planar surface of the supports coincide with the horizontal plane. Further, the inclination of the folds **28**, which extend downwardly as viewed in the direction of the air stream **42**, is reduced. The corrugations of the folds **30** are inclined upwardly in the direction of the gas flow. This arrangement has the result that means are provided within the packing which produce a retaining effect on the water during its downward flow so as to minimize any tendency of said water to be entrained with the air stream. Assuming that the air stream is interrupted, the above inclination of the packing has the result that the water would tend to flow in a direction towards that lateral edge of the packing which faces opening **40**. On the other hand, the air stream tends to blow the downwardly flowing water toward the air discharge side. These two factors will, according to the invention, counterbalance one another so as to insure a uniform distribution of the water over the whole packing.

In the embodiment illustrated in FIGS. **2** and **3**, the packing **10** is mounted so as to have its edges coincide with a horizontal and vertical plane respectively. Instead, the folds or corrugations have been given such inclination as to cause the folds **30** belonging to the one group of layers to form a larger angle to the horizontal plane than the folds **28** belonging to the layers crossing the first named group of layers. In this way, the same effect is obtained as with the preceding embodiment.

In the embodiments shown in FIGS. **1** through **3**, the angle of inclination of the corrugations respective seen from the intake side for the air or to the horizontal plane, is less than 45°, such as 20° to 35°. It should thus be understood that the angle between the corrugations of the respective folds **30** and **28** should be less than 90°. It also follows from the foregoing that the bisector of the angle between corrugations of the respective folds will slope downwardly toward the air intake side of the packing as clearly shown in FIG. **2**. In the latter view the angle between the corrugations of the folds **30** and **28** is shown as being 40°. Thus, the angle of inclination of the fold **30** is 30° to the horizontal plane of the packing, and the angle of inclination of the fold **28** is 10° thereto. It follows, therefore, that the bisector would have a downward slope relative to the horizontal plane of the packing of 10°.

On the other hand, referring to FIG. **2**, if the corrugations **28** and **30** should have a slope angle of 45° in opposite direction to the horizontal, the slope of the bisector will be 0°. Thus, the highest value for the bisector, consequently, will be obtained if the upwardly sloping angle of corrugations **30** is 45° while the downwardly sloping angle of corrugations **28** approximates 0°. It follows, therefore, that the upper limit for the bisector will be slightly more than 22.5°.

The retaining component of the force acting on the water will, of course, become greater the more the folds **30** incline upwardly and the less the folds **28** incline downwardly, viewed in the direction of flow of the air.

The liquid may be constituted by a salt solution such as a solution of a hygroscopic salt in water. Instead of water, other liquids having high vapor pressure may come into consideration. The invention may also be applied to a water heater, for instance, in order to utilize the exhaust heat in an air stream.

Careful test and performance data indicate that the selection of the proper angular geometry for cross-flute fill for use in cross-flow towers, as disclosed herein is of critical importance in order to attain the objects of the invention. Tests have verified that in a packing according to this invention the water flows as thin films along both sides of the individual sheets. Said films get a lateral component of flow which is greater for the corrugations **30** than for the corrugations **28** corresponding to the inclined bisector. When the film following one sheet in an inclined direction downwardly meets a contact point between said sheet and the adjacent sheet the flow of the film is changed to the opposite direction when being taken over by the crossing corrugations of said adjacent sheet. The effect will be that the films are maintained along the sheets when the horizontal wind draft exercises a lateral force on the films in opposite direction to the lateral component resulting from the inclined besector according to the invention. Over the structure shown in the Bredberg patent the unobvious result is obtained that the film flow will be undisturbed up to much higher water loads and air velocities. It should be noted that without the inclined besector the film is torn away from the sheets so that the water is collected to drops which momentarily more or less closes the spaces between the sheets and are then carried out by the air laterally of the packing while at the same time the pressure losses for the air flow becomes highly increased.

The invention has greatly increased the efficiency of the crossflow units of the type disclosed herein, which despite their compact size, show highly improved thermal and air pressure drop factors. In the lathe structure, as heretofore commonly used, the depth of filling bodies in the direction of movement of the air current varied between one meter up to several meters, while in the present crossflow structure of the invention the depth ranges from a few decimeters to a maximum of one to two meters.

In defining the critical range for the angle between the corrugations, it is noted that the angle must be an acute angle, taken in the direction of the gas flow. As shown in FIGS. **1** and **2**, the angle in question is the angle between the lines **28** and **30**, opening in the direction of the gas flow **42**.

What is claimed is:

1. A gas and liquid contact apparatus including a contact body in which the gas and the liquid flow in cross flow relationship to one another comprising:

a. a liquid distributing means disposed over the top edge of said contact body,

b. said contact body being composed of first and second sets of corrugated sheets having corrugations disposed in a direction transversely of the horizontal plane of said contact body,

c. said sheets of said first set being disposed alternately with the sheets of said second set with the corrugations of the said first set crossing the corrugations of said second set,

d. said crossed corrugations defining passageways penetrating from edge to edge of said body,

e. the corrugations of said corrugated sheets bearing against one another in such a way that the sheets touch where the crest of their respective corrugations cross,

f. the corrugations of said first set of sheets being inclined upwardly in the direction of the gas flow, the corrugations of said second set of sheets inclining downwardly in the direction of gas flow, the inclinations of said crossed corrugations being nonsymmetrical relative to a vertical plane extending perpendicular to the direction of the gas stream as it enters said sheets, the corrugations of said first set of sheets having a greater inclination to said horizontal plane than the corrugations in said second set of sheets and defining a bisector of the angle between said corrugations of said two sets of sheets inclining downwardly in a direction opposite to the direction of the air flow thereby counteracting a lateral displacement of the liquid stream over the sheets under action of the gas flow.

2. A gas and liquid contact apparatus including a contact body in which the gas and the liquid flow in cross flow relationship to one another comprising:

a. a liquid distributing means disposed over the top edge of said contact body,

b. said contact body being composed of first and second sets of corrugated sheets having corrugations disposed in a direction transversely of the horizontal plane of said contact body,

c. said sheets of said first set being disposed alternately with the sheets of said second set with the corrugations of the said first set crossing the corrugations of said second set,

d. said crossed corrugations defining passageways penetrating from edge to edge of said body,

e. the corrugations of said corrugated sheets bearing against one another in such a way that the sheets touch where the crest of their respective corrugations cross,

f. the corrugations of said first set of sheets being inclined upwardly in the direction of the gas flow, the corrugations of said second set of sheets inclining downwardly in the direction of gas flow, the inclinations of said crossed corrugations being nonsymmetrical relative to the gas stream entering edges of said sets of corrugated sheets, the corrugations of said first set of sheets having a greater inclination to said horizontal plane than the corrugations in said second set of sheets and defining a bisector of the angle between said corrugations of said two sets of sheets inclining downwardly in a direction opposite to the direction of the air flow thereby counteracting a lateral displacement of the liquid stream over the sheets under action of the gas flow.

3. A structure as set forth in claim **2** in which the angle between the crossed corrugations of said adjacent sets, taken in the direction of gas flow, is in the range of from 20° to 80°.

4. A structure according to claim **2** in which the angle of inclination of the bisector is less than 22.5°.

5. A structure as set forth in claim **2** wherein the gas entering edges of said sheets are substantially vertical.

6. A structure as set forth in claim **2** wherein the gas entering edges of said sheets are inclined forwardly from the vertical toward the gas flow, whereby the said different inclinations of said corrugations relative to the horizontal plane are achieved.

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