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Phelps

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[54] **CROSS FLOW TOWER FILL OF CELLULAR CONSTRUCTION**

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[21] Appl. No.: **32,995**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 13,875, Feb. 25, 1970, abandoned.

[52] **U.S. Cl.** **261/111,** 261/DIG. 11

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

[58] **Field of Search** ..... 261/111, 112, DIG. 11

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[57] **ABSTRACT**

A crossflow tower (e.g., for water cooling) which incorporates packing formed by a number of superposed adjacent cellular units. The principal planes of each unit are generally parallel and inclined at a substantial angle, such as 5° to 70° to the horizontal. Each unit includes a gridwork of horizontally open stacked cells forming substantially horizontal liquid splash plates. The above inclined units are stacked against each other substantially throughout the fill assembly. Each plate is vertically offset from proximal plates so that the open edges of an upper plate overhang intermediate portions of lower plates. Liquid gravitating onto the lower plates forms a film which is contacted by crossflowing air for efficient air-liquid contact.

1 Claim, 7 Drawing Figures

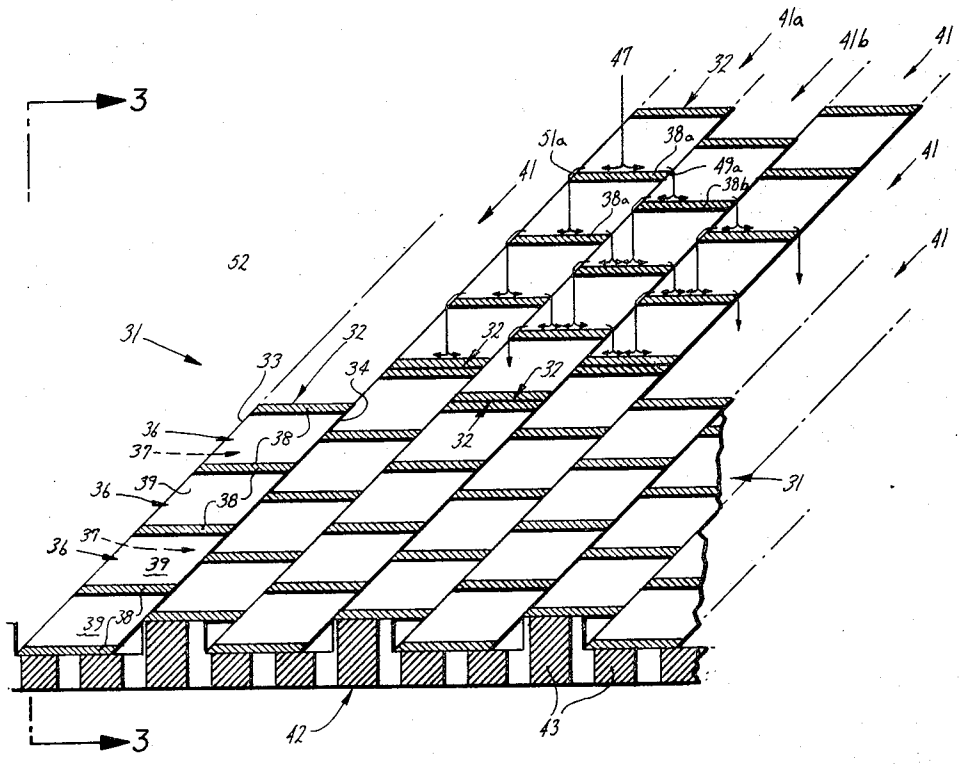


Fig. 1

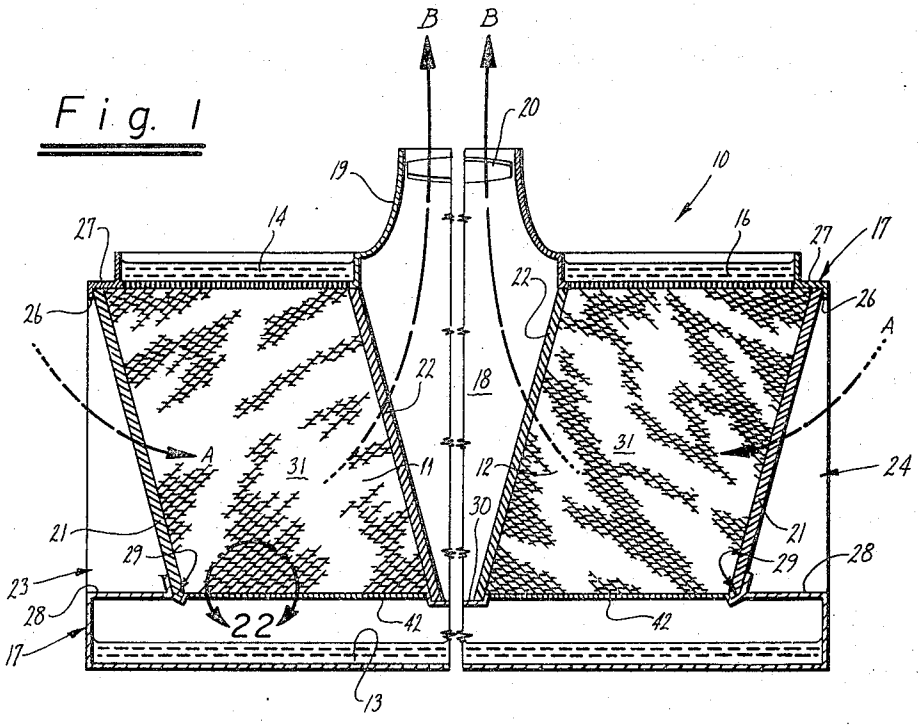
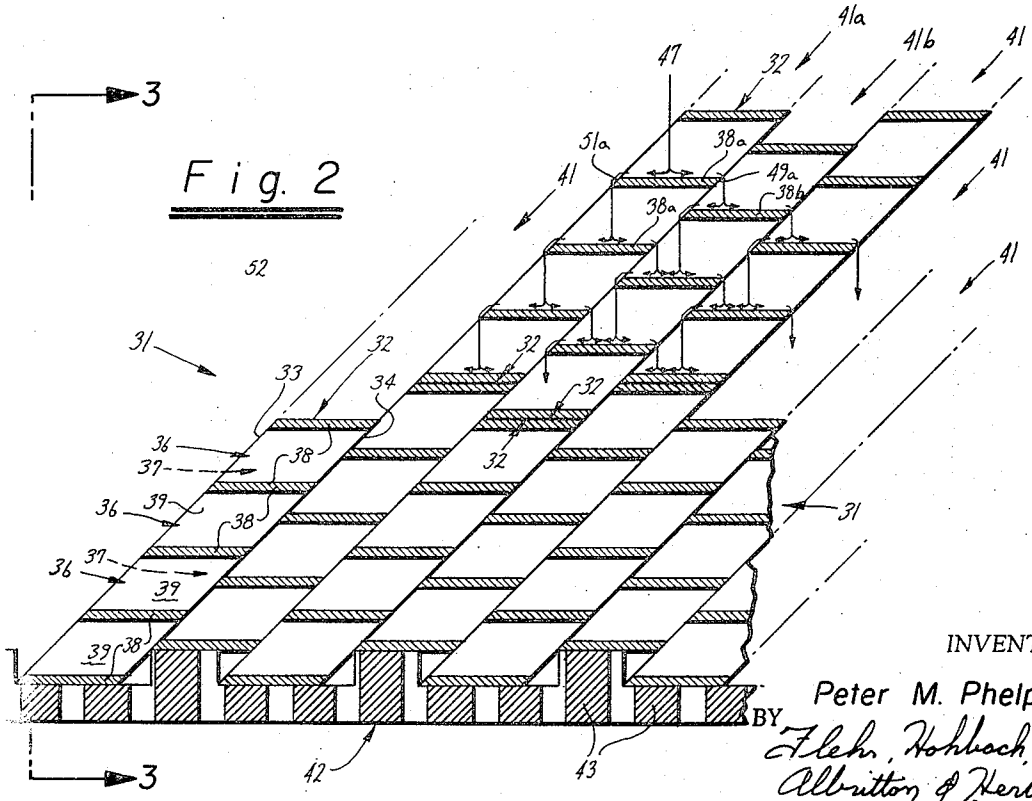
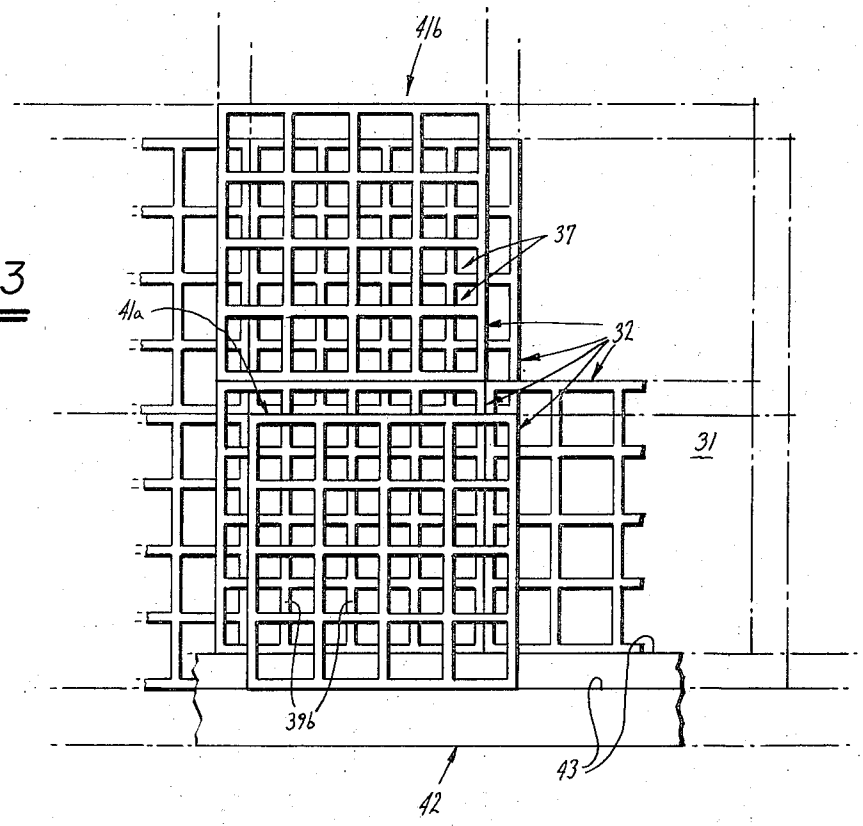


Fig. 2



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Fig. 3



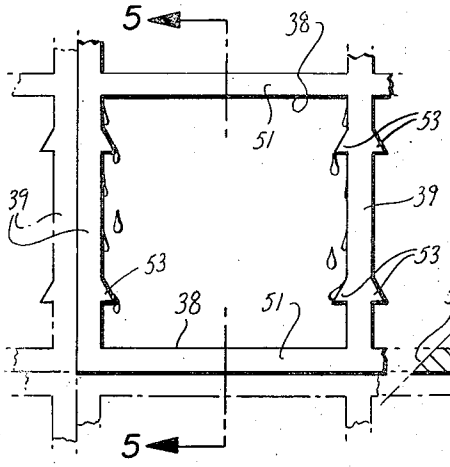


Fig. 4

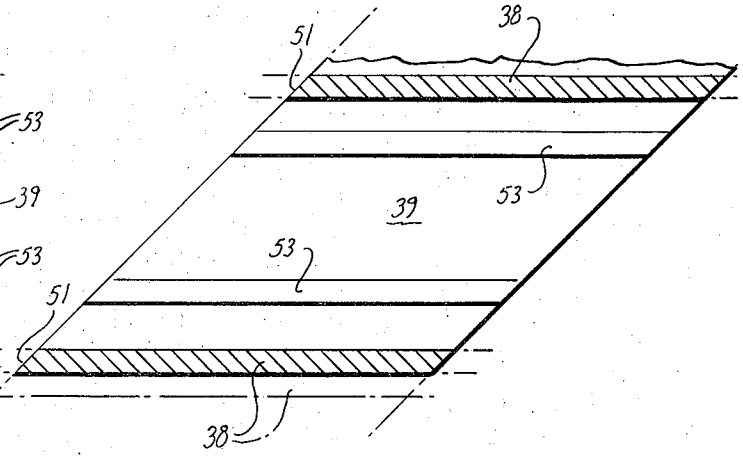


Fig. 5

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Fig. 6

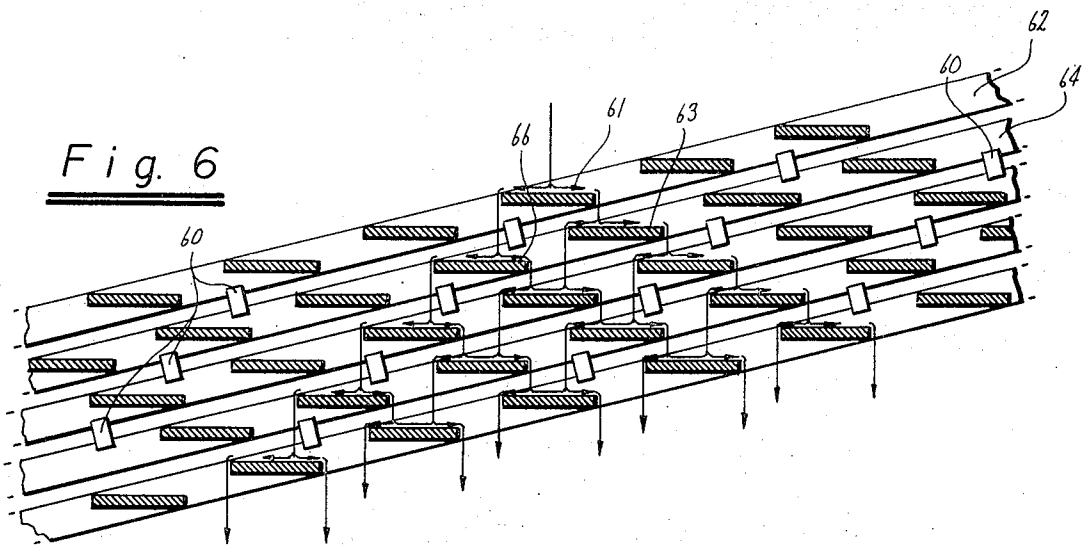
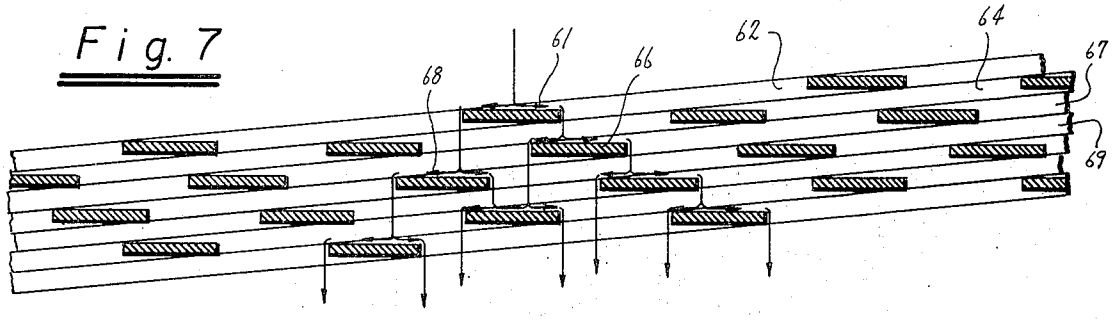


Fig. 7



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CROSS FLOW TOWER FILL OF CELLULAR CONSTRUCTION

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of U. S. application Ser. No. 13,875, now abandoned, in the name of Peter M. Phelps filed on Feb. 25, 1970.

BACKGROUND OF THE INVENTION

This invention relates generally to crossflow liquid towers wherein the liquid (e.g., water) is contacted on gravitating through a fill assembly with air flowing across the liquid. In a particular embodiment, the invention concerns a cross-flow water cooling tower wherein gravitating water is cooled by cross-flowing air for use in other heat exchange operations, such as the cooling means for air conditioning equipment.

Cooling towers of the above type normally contain an outer housing encasing the fill assembly, a hot liquid distribution basin overlying the fill, and a cold liquid basin disposed below the fill assembly. In a conventional construction, a central open topped exhaust plenum chamber is flanked by at least two fill assemblies. In a natural draft tower, air is induced by natural convection of the warm air exhaust stream to travel from the surroundings through the fill assembly and out the open top of the central chamber. Alternatively, in a mechanical draft cooling tower a fan is located at the top of the chamber to induce the air to travel in the same path.

Various types of packing are available for use as fill for crossflow cooling towers. In one conventional tower, a number of horizontally disposed slats are secured by wires into a series of staggered rows one above the other. The slats function to assist heat transfer between gravitating liquid and transversely flowing air by the formation of liquid droplet heat transfer surfaces each time the liquid splashes on random slats. However, there is little opportunity in the slatted structure for the liquid to form a high film surface area for air contact in addition to the splash droplet surface area. Furthermore, the installation of such slatted fill assemblies is quite expensive and time consuming since, conventionally, it is performed manually on a slat to slat basis.

Cellular film-forming packing has been used in counterflow structures. Such packing is formed of stacked units having vertical openings and horizontal principal planes and so are not suitable for transverse air flow in a crossflow structure. Even if rotated to a vertical principal plane, these cellular units would be ineffective for use as crossflow packing since liquid gravitating thereon would tend to flow down the vertical faces of the units without significant contact with the interior of the cells resulting in a minimal film formation.

SUMMARY OF THE INVENTION AND OBJECTS

According to the invention, an improved, convenient and economical type of packing has been provided for the fill assemblies of crossflow cooling tower. This packing is formed of a number of superposed integral cellular units. The principal planes of each unit are generally parallel and inclined at a substantial angle (e.g., 5° to 70° from the horizontal). Each unit has a gridwork of horizontally open stacked cells framed by air partitioning spaced upstanding support sidewalls and by spaced substantially horizontal liquid splash plates. These inclined units are stacked against each other throughout the fill assembly. Alternatively, the units could be nested in spaced apart relationship as by use of spacers.

Each splash plate is vertically offset from other proximal splash plates. The open edges of a first plate in a first unit overhang both an intermediate portion of a second plate and also a third plate. As defined herein, "intermediate portion" means that portion between the open edges of a plate. The second plate may form a portion of a second unit below the first unit or of a third or lower unit below the first unit. The third plate may form part of the first or second units or of a third or lower unit below the second unit. In any of the aforementioned arrangements, liquid flowing over both edges of the first plates splashes onto an intermediate portion of the second and third plates to form a thin water layer. The second, third and lower plates then function in the manner of the first plate to continue the distribution of liquid over each open end. This combination of vertical offset and overhang creates a highly efficient air-liquid contact for effective heat transfer in the tower.

The upstanding sidewall may be provided with ribbing to more efficiently distribute liquid gravitating thereon.

Each cellular unit is readily installed in a cooling tower for ease of alteration of the normal positioning of the units to accommodate variations in the heat transfer requirements in the cooling tower. The above units may be readily manufactured as by extrusion to form continuous units having rectangular cells followed by cutting the units at the principal planar angle. Alternatively, such units could be formed by assembling slotted slats into an interlocking configuration.

It is a general object of the invention to provide a fill assembly packing for a crossflow cooling tower which overcomes the aforementioned disadvantages of known packing.

It is another object of the invention to provide a fill assembly packing formed of a number of integral readily manufacturable prefabricated units which may be conveniently placed into and removed from a cooling tower for economy and flexibility of construction and for ease of repair or replacement.

It is a further object of the invention to provide a packing of the above type in which the spacing of horizontal splash plates may be readily pre-adjusted to achieve maximum heat transfer efficiency.

Additional objects and features of the invention will appear from the following description in which the preferred embodiment is set forth in detail in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation in cross section of a crossflow cooling tower for housing the packing of the invention;

FIG. 2 is an enlarged cross sectional view of the packing broken out from the area 2—2 of FIG. 1;

FIG. 3 is an enlarged end view of packing taken along the line 3—3 of FIG. 2;

FIG. 4 is an enlarged end view of a cellular portion of the packing of FIG. 3 showing ribbed sidewalls;

FIG. 5 is a side cross sectional view of FIG. 4 taken along the line 5—5 of FIG. 4; and

FIGS. 6 and 7 are enlarged cross sectional views of packing showing another embodiment of FIG. 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The crossflow cooling tower illustrated schematically in FIG. 1, is broadly designated by number 10 and includes a pair of conventionally inclined fill assemblies 11 and 12, a cooled water basin 13 disposed below assemblies 11 and 12 in a position to receive water gravitating therefrom, and a pair of open top distribution pans or trays 14 and 16 positioned directly above respective fill assemblies 11 and 12 in location to permit water to gravitate from corresponding trays 14 and 16 through suitable apertures directly onto the upper portion of fill assemblies 11 and 12. A housing illustrated by the number 17 encloses assemblies 11 and 12 along with basin 13 with trays 14 and 16, which trays are supported by a housing 17 on opposite sides of the central plenum exhaust chamber 18 between opposed inner faces of fill assemblies 11 and 12. Suitable pump structure, not shown, is operably coupled to basin 13 and trays 14 and 16 for removing cooled water from basin 13, delivering the water to equipment requiring the same for cooling and for returning the thus-warmed water to trays 14 and 16.

Referring to FIG. 1, a vertical stack 19 is secured to the horizontal top face of housing 17 and extends upwardly from central chamber 18 to form an upper outlet for air exiting therefrom. Fan means 20 positioned within stack 19, adapted to be operably coupled to a suitable source of power for actuation, causes currents of air to be drawn through assemblies 11 and 12 generally along path A and forced upwardly through chamber 18 and stack 19 for discharge through the upper portion of the latter generally along path B. Alternatively, the cooling tower may operate by natural induction by the elimination of fan means 20 in which case air would be induced to flow through the fill assemblies by means of the natural convection of the warm exhaust air stream rising through chamber 18.

Fill assemblies 11 and 12 are each provided with a pair of inclined drift eliminator walls 22 opposed to air inlet louver walls 21 forming a transverse cross section in the shape of a parallelogram. Walls 21 and 22 may be of any conventional type, such as a series of baffles inclined toward the central portion of the fill assemblies 11 and 12 to permit the free flow of air therethrough but to prevent significant quantities of water droplets to escape therefrom. The purpose of the parallelogram configuration is to compensate for the action of air currents which flow past the water gravitating through fill assembly 11 and 12 and cause the water to be forced inwardly toward chamber 18 at a slope similar to that of walls 21 and 22.

A pair of inlet openings 23 and 24 are provided on opposite sides of housing 17. Each opening is defined by a downwardly extending lip 26 projecting from top wall 27 of housing 17, supporting base 28 secured to the upper outer portion of basin 13 and by wall 21.

Walls 21 and 22 are secured to their upper ends in any suitable manner to the lower surface of the corresponding tray 14 or 16 thereabove. Wall 21 at its lower end is secured to base 28 by suitable means such as seat 29. Wall 22 may be secured at its lower end to base structure 30 which bridges the distance between opposed sides of casing 17 directly above basin 13. In an alternative embodiment, not shown, wall 22 may be secured at its lower end to a lower portion of basin 13 so that liquid in basin 13 functions as an air seal between walls 22.

In general operation, surrounding air is drawn into the openings 23 and 24 from the surroundings along path A either by natural air currents or by forced induction of fan means 20. Air currents then flow through fill assemblies 11 and 12 and out stack 19 along path B. Gravitating droplets of water from trays 14 and 16 in the fill assemblies are contacted by the transversely flowing air and fall into basin 13. Thus, the water is cooled either by heat exchange between warm water and cooler air or by the cooling effect of water evaporating under the influence of a fast-moving interesecting stream of unsaturated air or both.

Referring to FIGS. 2–7, packing, generally denoted as the numeral 31, is disposed throughout substantially the entire fill assemblies 11 and 12. Packing 31 comprises a series of superposed inclined integral cellular units 32, each unit having upper and lower parallel principal faces 33 and 34 lying in the principal plane of the units. Each unit is formed of a series of horizontally open stacked cells 36 which provide a horizontal air passageway 37. Each cell 36 is framed at its top and bottom by generally horizontal splash plates 38 and at its sides by upstanding generally vertical walls 39. Walls 39 serve to support plates 38 and as an air-liquid contact surface. Air traveling through passageway 37 is presented with a rectangular cross sectional pathway which is best shown in FIG. 3. A side cross sectional view of each cell is in the configuration of a parallelogram with sloping sides.

Each unit 32 may be formed by molding or extrusion of a plastic or ceramic material. In a preferred technique, the units are extruded through an extrusion head which forms a rectangular gridwork in continuous sections and this gridwork would be severed in parallel sections at the desired angle to the horizontal for principal faces 33 and 34.

In another fabrication technique, units could be formed by assembling slotted slats, as of wood, into an interlocking configuration to form a staircase-like structure with the plates as the "treats." The sides and plates would be slotted part-way in such manner that the plates are generally horizontal when the sides are at the planar angle. For purposes to be explained herein, with a small planar angle it is preferred to form the open edges of the plates in a generally vertical direction, as in conventional, rectangular wooden slats.

Referring again to FIGS. 2–5, each unit 32 is stacked with principal faces 33 and 34 in abutting relationship to corresponding faces 34 and 33 of adjacent units with the minor exception that the outermost units of the stacked assembly have only one face in abutting relationship. Referring to FIG. 2, a sloped tandem column 41 of cells lying in the same principal plane is formed by stacking a number of units so that the bottom plate 38 of one unit rests upon the top plate 38 of the next lower unit forming a double plate thickness 40 at each resting point. If the sidewalls are of sufficient strength, the double thickness could be avoided by the elimination of one of the outermost plates of each tandem unit. Each column 41 is supported at its lower end by a per-

forate two-leveled platform **42** spanning the distance between walls **21** and **22** and mounted in a suitable manner at its respective ends to supporting base **28** and base structure **30.** Platform **42** may be formed of a meshed rigid structure with adjacent links at two different levels. The two different heights of blocks **43** are provided to vertically offset the splash plates **38** of adjacent units for the purpose of allowing an optimum distribution of gravitating water.

For purposes of illustration, the description of the embodiment of FIGS. **2–5** is generally limited to adjacent upper and lower columns of units numbered **41***a* and **41***b* with each corresponding portion thereof respectively lettered *a* and *b*. The positions of each plate **38** with respect to each of its proximal plates is adjusted to provide maximum distribution of gravitating water for cooling contact with transversely flowing air. Such positioning is controlled by adjusting the principal planar angle of each unit **32** along with the distance of vertical offset between proximal plates **38** in adjacent units.

As generally discussed above, the open edges of a first plate in a first unit overhang an intermediate portion of lower second and third plates. Referring specifically to FIG. **2,** one open end **49***a* of upper plate **38***a* in a unit column **41***a* overhangs the next lowermost plate **38***b* of adjacent column **41***b* (the second plate). The other open end **51***a* overhangs the next lowermost plate **38***a* in column **41***b* (the third plate). In the configuration of FIG. **2,** the third plate **38***a* is a portion of the first column **41***a* of units. As will be explained in more detail hereinafter, plate relationship may be varied by altering the planar angle with the horizontal or by addition of interunit spacers or both. By doing so, the third plate (i.e., the one over which one of the open edges of the first plate overhangs) may be part of the second unit (i.e., the next lowermost unit adjacent to the first unit) or even part of a unit below the second one. In either of the latter configurations, water flows over both open edges of the first plate to the second and third plates, neither of which is contained in the first unit. The second and third plates then function like the first plate to continue the liquid distribution.

Referring to FIG. **2,** the planar angle is preferably set so that water falling in path **47** onto plate **38***a* splits both into a forward path which flows over forward edge **49***a* and splashes onto an intermediate portion of the next lowermost plate in column **41***b* and also into a rearward path falling over rearward edge **51***a* to splash onto an intermediate portion of the next lowermost plate **38***a* of column **41***a*. To accomplish such intermediate splashing with, for example, a half cell vertical offset is suitable with about a principal planar angle of 30° to 60°, producing the more central overhangs for most even spread out distribution. For configurations wherein the third plate forms part of a second, third or fourth unit, rather than the first unit as in FIG. **2,** as will be explained herein, the angle may be decreased to as low as 5° or less.

Referring to FIG. **2,** with the air flowing in direction **52,** the positioning of edge **51***a* over the next lowermost plate in column **41***a* is preferably slightly to the rear of center of the latter plate to allow for the action of the sweeping air to push the gravitating liquid in a path slightly off from the vertical. In like manner, the action of the sweeping air on the gravitating water is preferably taken into account when positioning edge **49***a* relative to the center of proximal lower plate **38***b* by a proper choice of the principal planar angle and the stagger vertical distance therebetween.

Referring to FIG. **3,** in one arrangement, proximal cells of adjacent units are offset by about half a cell both vertically and horizontally. The horizontal offset is provided to increase the turbulence of the air traveling through the grid-like units. The horizontal offset exposes the walls **39***b* and the vertical offset exposes plates **38***b* to the transversely flowing air even though column **41***b* is behind column **41***a*. Thus, a cross-like structure is seen in the "window" of each cell in column **41***a* which increases the number of surfaces for partitioning the air and increasing turbulence to provide a high degree of air-liquid contact for increased efficiency of heat transfer.

Referring to FIGS. **4** and **5,** upstanding walls **39** may be provided with horizontal projecting ribs **53** serving to prevent a substantial amount of gravitating water from flowing down the walls in a concentrated fast-moving stream which would tend to decrease the intimacy of air-liquid contact, thus lowering the efficiency of heat transfer. By employing ribs **53,** a portion of the water traveling down walls **39** flows over projecting edge of both the upper and lower ribs, thus gravitating in droplets onto the splash plates **38.** The ribs further serve to spread water flowing from upper face **33** and next uppermost splash plate edge **51** in a horizontal direction to decrease any tendency of the gravitating water to flow in a fast-moving stream down faces **39** and thus more effectively wet the surfaces of faces **39.**

As shown in FIGS. **1–5,** liquid is distributed from trays **14** and **16** onto the top splash plate of each column **41.** Gravitating liquid strikes splash plate **38***a* and spreads out into two paths thereon. In the forward path, water travels over forward edge **49***a* and gravitates onto an intermediate portion of the next lowermost plate **38***b* of adjacent column **41***b*. In the rearward path, water travels over rearward edge **51***a* and gravitates onto the next lowermost plate **38***a* in column **41***a*. In the overall packing, water striking a central portion of a first plate splits into streams and gravitates onto a central portion of two next lower plates each of which in turn splits the stream into two additional paths. Thus, all but the outermost plates are fed by gravitating water flowing from at least two sources.

By the above described arrangement, a thin uniform layer of water forms on each plate of the array since each plate, except for the relatively few outermost ones, is fed in the same manner. Air flows through passageways **37** in direction **52** and is partitioned due to the vertical and horizontal offsetting of each cell in relation to proximal cells of adjacent columns thus creating a certain amount of turbulence to assist in air-liquid contact. The transversely flowing air intimately contacts the water gravitating in droplets and the water which forms in a thin film on each plate. The droplets formed as water strike the splash plates and the thinness of the film of water on the above splash plates and walls allows for a high degree of surface contact between the air and liquid to promote a highly efficient heat transfer between air and liquid.

Referring to FIG. **6,** another embodiment of the cellular packing of the invention is shown employing a small planar angle with the horizontal, by forming the plate edges to be generally upright in operative place-

ment and by the optional use of spacers **60** between adjacent columns of units, and one open edge of a first plate **61** in a first unit **62** projects over an intermediate portion of a second plate **63** in a second unit **64.** Spacers **60** are preferably positioned below sidewalls to avoid interference with falling liquid. In this configuration, the other open edge of plate **61** would overhang third plate **66** in unit **64.** It is noted that the overall array of plates of the packing in FIGS. **2** and **6** is quite similar. The distinction resides primarily in the difference in planar angles which accounts for the repositioning of the third plate from the first unit as shown in FIG. **2,** to the second unit, as shown in FIG. **6.**

Referring to FIG. **7,** another embodiment of packing similar to that of FIG. **6** is shown except that the planar angle is substantially less than that shown in FIG. **6.** In this way, the open edge of first plate **61** overhangs an intermediate portion of second plate **66** in unit **67** below second unit **64** and third plate **68** in unit **69** below unit **67.** A variety of other configurations may be produced by further altering the planar angle.

The packing of the embodiments of FIGS. **6** and **7** may be fabricated in a manner similar to the aforementioned techniques. In addition, the same packing may be supported as shown in FIG. **2.**

When the packing of the FIGS. **6** and **7** embodiments are placed in tower **10,** the packing functions to assist the intimacy of contact between crossflowing air and gravitating liquid in the aforementioned mode of FIG. **2** packing since the overall array of splash plates is quite similar.

As discussed above, it becomes necessary to form the edges of the splash plates of the embodiments shown in FIGS. **6** and **7** in a generally upright direction when using relatively small planar angles. Otherwise, the edges would elongate to such an extent as to substantially interfere with the downflowing liquid. Consequently, for use with small planar angles, the aforementioned fabrication technique of extrusion to form rectangular cells followed by slicing at the planar angle to form units must be followed by an alteration step in which the elongated plate portions are cut off to form generally upright edges which do not impede liquid flow. This is rather easily accomplished for cellular materials which are not exceedingly brittle, such as a vast number of polymers and foamed polymers. Another method of construction for the small planar angle is the aforementioned interlocking staircase-type. By using conventional slats as the "treads" in this method no alteration is necessary for use with units having smaller planar angles.

Although the above packing has been described in terms of cells having a generally rectangular configuration, this may be varied within the scope of the invention. For example, the cells may be hexagonal so that each sidewall would have two intersecting sloped portions. Furthermore, either the sidewalls or the plates may be of curved, ridged or rippled shape. Although the sidewalls may be substantially sloped, it is preferred to maintain a generally horizontal plane for the splash plates. Although the slope of the packing cellular units is herein described as being toward the central chamber, the packing could also be sloped in the opposite direction within the scope of this invention.

In addition, although water may be employed as the cooled liquid, it should be understood that other liquids may be cooled using the packed crossflow cooling tower of the invention. For example, the packing of the invention may be utilized in a crossflow tower similar to the one described herein for purposes other than cooling, such as scrubbing, when it is desired to provide intimate contact and mixing of a gas and a liquid.

It is apparent from the foregoing that an improved packing for a cooling or scrubbing tower has been provided which is readily manufacturable in a prefabricated form and which enables intimate air-liquid contact for highly efficient heat transfer.

I claim:

1. In an apparatus for the contact of gravitating liquid with transversely flowing air, a packing comprising a plurality of superposed cellular units, the principal planes of each of said units being generally parallel and inclined at a substantial angle to the vertical, each unit having a series of horizontally open stacked cells framed by air partitioning spaced support sidewalls and by spaced substantially horizontal liquid splash plates, each of said plates in one unit being vertically offset from proximal plates in adjacent units, each of said units being formed of a matrix of cells having a rectangular vertical cross section, one open edge of a first one of said plates in a first unit overhanging an intermediate portion of a lower second plate and the other open edge of said first plate overhanging an intermediate portion of a lower third plate whereby liquid falling onto said first plate flows over said edges onto the upper surface of said second and third plates while air flowing transversely to said falling liquid through said cellular units contacts and cools said liquid.

* * * * *