

[54] COOLING TOWER APPARATUS

[75] Inventors: **Benjamin V. Blazer**, Paterson;
Mahmoud S. El-Tahry, Passaic, both
of N.J.

[73] Assignee: **Blazer Corporation**, East
Rutherford, N.J.

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Ser. No. 742,567, July 5, 1968, Pat. No. 3,494,109.

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261/72

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

[58] Field of Search 261/DIG. 11, 23 R,
261/29, 30, 72, 111, 112; 210/534

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Primary Examiner—Tim R. Miles

Assistant Examiner—Steven H. Markowitz

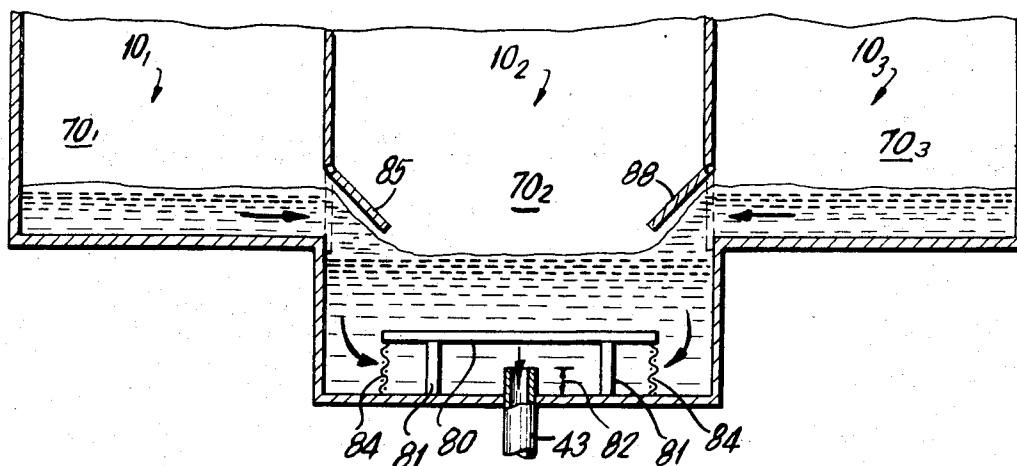
Attorney—Stephen B. Judlowe et al.

[57] ABSTRACT

An improved modular cooling tower includes an air fan centrally located at the bottom of the tower, and a baffle vane and pivoted shutter arrangement disposed above the fan. The fan generates an air flow which passes through the baffles and vanes to react with a heated liquid flowing downward through the tower via a plurality of evaporating surfaces. The shutter structure is adapted to pass the fan generated air flow for cooling purposes while preventing the escape of fluid or vapor laden air from the tower fan orifice, thus obviating a potentially hazardous condensation condition.

In accordance with other aspects of the present invention, improved sump, fan and drive apparatus is provided to accommodate plural module installations.

2 Claims, 7 Drawing Figures



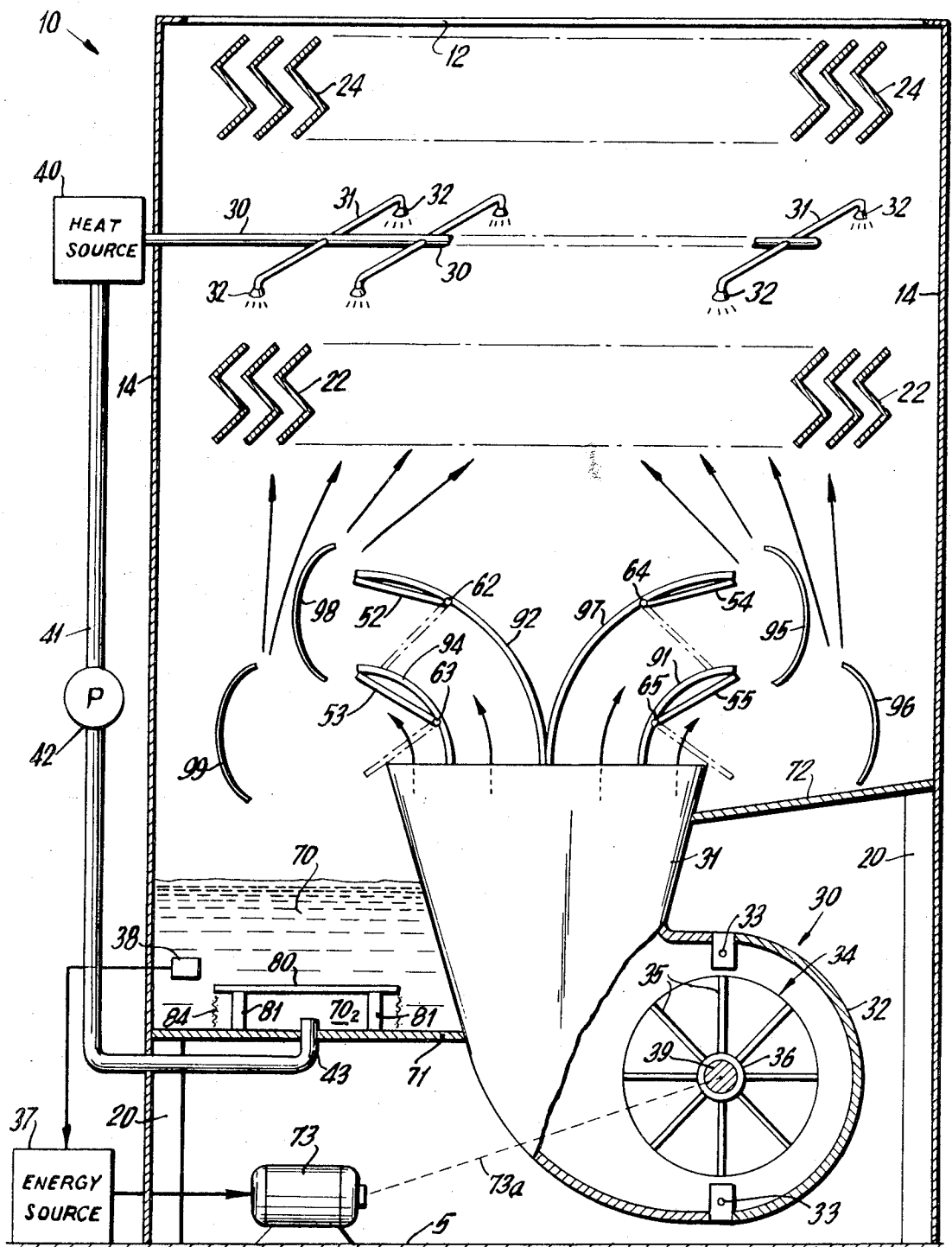


FIG. 1

INVENTORS
BENJAMIN V. BLAZER
MAHMOUD S. EL-TAHRY
BY
Sandoz, Hoppgood & Calimafide
ATTORNEYS

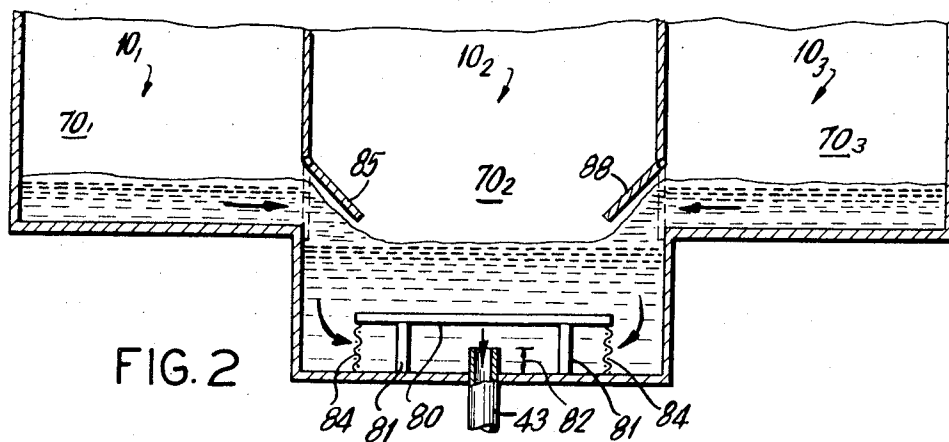


FIG. 2

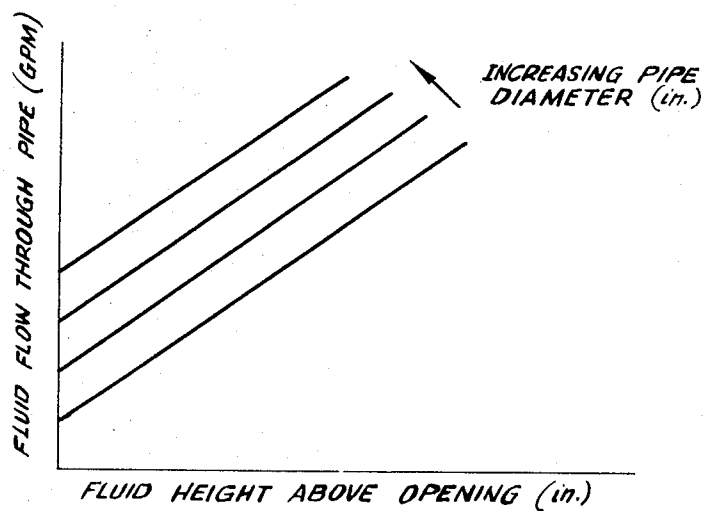


FIG. 3

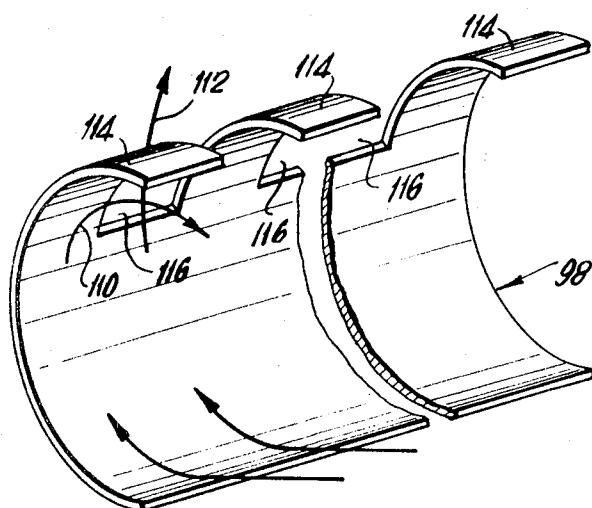
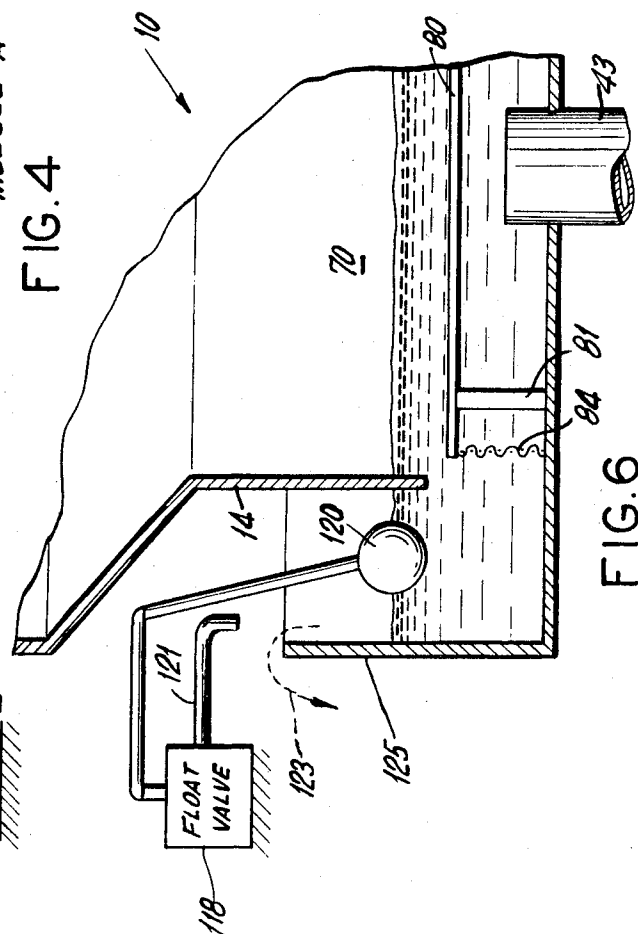


FIG. 5

INVENTORS
BENJAMIN V. BLAZER
MAHMOUD S. EL-TAHRY
BY

Sandoz, Hayward & Collins
ATTORNEYS



INVENTORS
BENJAMIN V. BLAZER
MAHMOUD S. EL-TAHRY
BY

Sandoe, Hoppood & Calimafde
ATTORNEYS

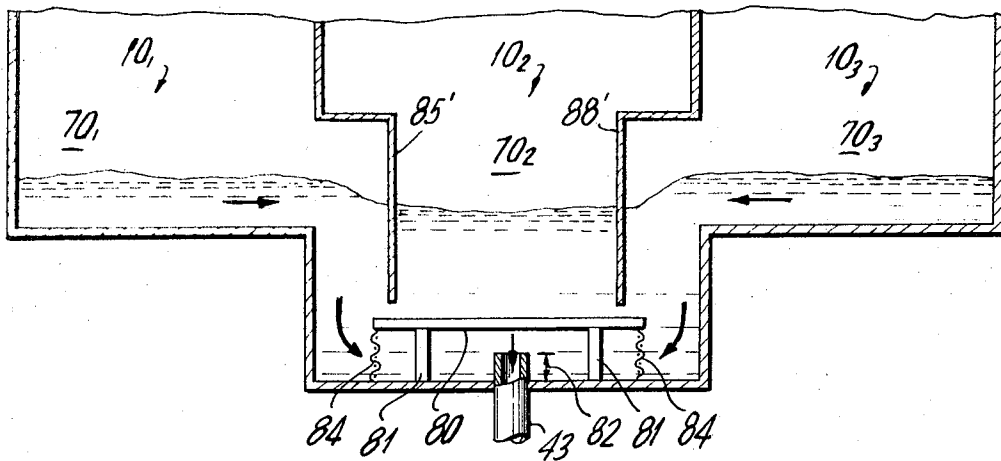


FIG. 7

INVENTORS
BENJAMIN V. BLAZER
MAHMOUD S. EL-TAHRY

BY

Sandoz, Hopgood & Calimafde
ATTORNEYS

COOLING TOWER APPARATUS

This application is a continuation-in-part of our like entitled application Ser. No. 9,794 filed Feb. 9, 1970, now U.S. Pat. No. 3,637,195 which in turn, is a continuation-in-part of Ser. No. 742,567 filed July 5, 1968, now U.S. Pat. No. 3,494,109.

This invention relates to heat transfer apparatus and, more specifically, to an improved cooling tower arrangement for cooling a heated liquid by an evaporator process.

Heat exchanging apparatus for cooling a flowing heated liquid with a counter-flowing air stream has been widely employed. Such arrangements typically employ nozzles for supplying a heated liquid into the tower, with the liquid flowing downward under the action of gravity. Blowing apparatus is employed to generate an upward air flow exiting through the top of the tower. The moving air stream reacts with, and cools the liquid by an evaporator process.

However, prior art cooling tower arrangements have been characterized by one or more of the deficiencies considered hereinbelow, and have thus not been completely satisfactory. First, the requisite air flowing fans have commonly been located at the top of the cooling tower to induce an upward air flow, with the air radially entering the tower through apertures located about the bottom periphery thereof. Accordingly, such an induced draft, or "draw through" cooling tower must be fabricated of strong structural materials to support the relatively weighty top-mounted fan and its attendant driving apparatus. This problem is often compounded throughout an entire building structure since the cooling towers are placed on top of the building in many installations. Then also, relatively large, oversized fans are required for such an arrangement since the air flow is induced by the relatively inefficient low pressure, upstream side of the fan, and not by the more efficient discharge fan side. Further, fan maintenance is complicated since all work must be performed on top of the tower.

Of special importance, air carrying considerable water vapor escapes from the tower through the lower tower apertures included in the induced draft and other tower configurations. The vapor so conveyed often-times condenses on the building top thus forming water pools and, in winter, ice formations. Such water and/or ice collection creates hazardous conditions for tower maintenance and other roof top activities; causes structural damage attributable to corrosive and weight effects; and also periodically generates a potentially harmful water flow running off the building top.

One alternative building tower configuration employs one or more blower fans mounted external to the tower about its lower periphery, thus largely obviating the structural problems accruing to tower top fan mounting. However, the horizontally protruding fans impart a large vertical profile to such cooling towers which thus take up a relatively large roof area for any given cooling capacity. Also the fans, located at best at a number of discrete locations, do not produce an air flow which is uniform throughout the tower. Thus segments of the flowing heated liquid are not acted upon by a significant counter air flow and are thus not cooled appreciably. Further, vapor can escape from such towers through the fan mounting apertures when the fans are inactive.

Moreover, a plurality of cooling towers are often required on top of a building structure where increased cooling capacity is required. Prior art tower arrangements place a heavy weight load on the building structure, each such tower holding a full quantum of cooled fluid in a sump awaiting recycling of a pump to a heat source. Accordingly, sufficient structural strength must be incorporated into the building to support this weight load.

In addition, where plural tower modules have been employed, or plural centrifugal fans within a single module, there has been great difficulty in removing the fans when service or inspection is required. The impeller in a centrifugal fan has heretofore been extracted axially from the fan scroll, first requiring that a common fan driving shaft be withdrawn. This is difficult per se, further inconvenient when several fans are coupled to one shaft, and particularly disadvantageous where there is tight module packing such that there is little or no room to conveniently maneuver the shaft.

Further, in cooling towers with a high thermal loading, the cooled fluid must be extracted and recycled at a relatively rapid rate. This has produced water cavitation above a drain outlet, thereby reducing pump and drain efficiency. Moreover, in many cases, the insufficient water head has resulted in air being drawn into the pump and fluid conduits, causing noisy and potentially harmful vibrations, pump oxidation, and severely reduced efficiencies.

It is thus an object of the present invention to provide an improved cooling tower arrangement.

More specifically, it is an object of the present invention to provide a cooling tower arrangement having a fan located at the bottom portion thereof to facilitate maintenance access to the fan, and to permit fabricating the tower of relatively light, inexpensive structural materials making maximum use of prefabrication techniques, rather than site work construction.

Still another object of the present invention is the provision of a cooling tower arrangement which prevents water vapor from escaping from the lower portion thereof, and which occupies a relatively small surface area.

Yet another object of the present invention is the provision of a modular cooling tower arrangement wherein plural modules may be readily and conveniently assembled.

A still further object of the present invention is the provision of an improved sump arrangement which greatly reduces the water load to be supported by a building structure, and where cavitation problems are eliminated.

It is another object of the present invention to provide a cooling tower fan and improved vane and baffle assembly which provides uniform air distribution about the tower cross section.

Yet another object of the present invention is the provision of an improved drive arrangement for plural cooling towers employing a flexible coupling.

The above and other objects of the present invention are realized in a specific, illustrative modular cooling tower arrangement which includes a nozzle array for spraying water for downward translation through a plurality of corrugated evaporating surface plates. One or more centrifugal fans are centrally located at the bottom of the tower and generate an upward air flow through the evaporating surfaces acting through a plu-

rality of baffle defining vanes disposed vertically above the fan. Pivoted shutter plates are secured to the turning vanes.

During the cooling process, the velocity pressure generated by the fans keeps the pivoted shutter plates open and the air flow uniformly passes through the turning baffles to the evaporating plates where it reacts with, and efficiently cools the downward moving heated liquid. The discharge velocity and static pressure produced by the energized fans is more than sufficient to prevent liquid and water vapor from escaping from the tower through the fan orifice.

A plurality of the cooling tower modules may be cascaded to effect increased cooling capacity. When cascaded, only one such tower employs a relatively deep (full size) sump, the remaining tower sumps being connected by a flapper check valve with the full sump. This arrangement decreases the weight load to be supported by a building structure and the fluid heating area required for winter operation, and increases the efficiency of the water extracting conduits and pump(s). Further in this regard, anti-cavitation apparatus is provided to ensure a full water head above a water exiting drain, thereby preventing air from entering the fluid circulating system.

In accordance with other aspects of the present invention, a split scroll is employed for each of the fans to permit easy impeller removal for inspection and/or maintenance. Further, selected turning vanes have an irregular upper edge such that air leaves the turning surfaces at varying tangent directions to uniformly distribute air throughout the tower for efficient interaction with the falling heated fluid. Further, an improved motor drive and flexible coupling is employed to join two modules together to accommodate possible misalignment of the fan impeller driving shafts for the adjacent modules; to permit such modules to be driven by relatively inexpensive and commercially available single shaft motors rather than double shaft motors heretofore employed; and wherein the flexible coupling need sustain and transmit the driving torque for only one module.

A complete understanding of the present invention and of the above and other features and advantages thereof may be gained from a consideration of the following detailed description of an illustrative embodiment thereof presented hereinbelow in conjunction with the accompanying drawing in which:

FIG. 1 is a schematic cross-sectional diagram illustrating a modular cooling tower arrangement which embodies the principles of the present invention;

FIG. 2 is a cross-sectional schematic diagram depicting a sump configuration for a cooling tower assembly formed of three individual cooling tower modules;

FIG. 3 is a graph depicting the relationship between fluid flow through a conduit, the height of fluid disposed about the conduit, and conduit diameter;

FIG. 4 schematically illustrates in cross-section a driving arrangement for two contiguous cooling tower modules;

FIG. 5 depicts a turning vane employed in the arrangement of FIG. 1;

FIG. 6 illustrates a make-up water system for the module of FIG. 1; and

FIG. 7 depicts in cross-section an alternative sump configuration for a cooling tower assembly formed of three individual cooling tower modules.

Referring now to FIG. 1, there is shown a composite cooling tower 10 of any desired cross-sectional shape having side walls 14, an open top 12, operative bottom surfaces 71 and 72, and standoff mounting apparatus 20. The tower 10 is located on a surface 5 which may illustratively comprise the top of a building.

Heated liquid, for example, water is supplied by a heat source 40 to a plurality of emitting nozzles 32 by way of trunk and branch conduits 30 and 31. The water flows downward through a plurality of corrugated evaporating surface plates 22 into a reservoir sump area 70. Water is recirculated from the sump 70 to the heat source 40 and eventually to the nozzles 32 by a conduit 43-41. The recirculation path will typically include a pump 42. The heat source 40 may comprise any apparatus for imparting heat to a liquid such as water cooled machinery (e.g., compressors or other motors), air conditioning equipment, industrial or chemical processes, or the like.

Disposed at the bottom of the tower is at least one, and typically a plurality of fans, e.g., a centrifugal fan 30. As discussed below in conjunction with FIG. 4, three such fans may be employed, only one being shown in the cross-sectional view of FIG. 1. The fan 30 includes an outer scroll comprising scroll portions 31 and 32, the scroll portion 31 including an expanding exit end portion thereof to convert a portion of the air velocity generated by the fan to static air pressure by means of the well known static regain mechanism. Mounted within the assembled scroll 31-32 is an impeller wheel 34 which includes driven vanes 35 and a hub 36. The wheel is supported, and driven for rotation by a shaft 39, the hub 36 being secured to the shaft 39 by any well known mechanism such as a bolt, key and slot, or the like.

The front and rear scroll portions 31 and 32 are secured together when the fan 30 is in service, as by screws 33. Should the impeller 34 or other internal fan assembly require extraction for service, inspection, or maintenance, the screws 33 are extracted and the rear scroll portion removed. The impeller and internal fan portion are then readily available for inspection. Should the impellers require service, end bearings 100 and 101 (FIG. 4) which support the shaft 39 are simply removed from tower structural members 13 (as by removing screws), and the entire shaft with its impeller wheels 34 secured thereto simply removed from the back of the tower.

A motor 72 is connected by any suitable coupling 73, e.g., a belt, chain or the like, to the shaft 39 (see, for example, the belt 106 and pulley wheel 105 of FIG. 4). When supplied with electrical energy from an energy source 37, the motor 72 and the coupling 73 rotate the impeller wheel 34 thereby forcing air upward through the scroll portion 31 and into the cooling tower for heat exchanging purposes. A temperature sensor 38 may optionally be provided within the sump 70 to disconnect energy from the motor when the water is cooled sufficiently such that no further cooling is appropriate.

A plurality of air baffle defining vanes 91, 92, and 94-99 are transversely connected across the interior of the cooling tower. Four plate assemblies 52, 53, 54 and 55 are pivotally attached to the surfaces 92, 94, 97 and 91, respectively, as by hinges 62, 63, 64 and 65. The plates 52-55 may be formed of water resistant metal, rubber or plastic.

When the fan 30 is energized, the air flow about and between the vane structures 92, 94, 97 and 91 retains the plates 52-55 in an open position (shown in solid line in FIG. 1), such that air can exit from the scroll portion 31 and flow through the vane defined baffles without impediment. More particularly, air exiting from the scroll portion 31 follows the path indicated by vectors in FIG. 1 and flows through the baffles where it is redirected by vanes 95, 96, 98 and 99 to be uniformly distributed across the cross-section of the tower. The air flow from the plates 95, 96, 98 and 88 moves upward to and through the evaporator surface plates 22 ("fill") for interaction with the downward moving heating liquid. The corrugated shape and close spacing of the plates 22 serve to break up the flowing liquid mass so that a large liquid surface area, moving relatively slowly, is present for a relatively extended time period to be acted upon by the air flow for efficient heat exchanging.

A plurality of corrugated eliminator plates 24 are mounted above the nozzles 32. Plates 24 permit the heated, vapor bearing rising air stream to escape from the tower while preventing water in a liquid state from escaping from the tower.

When the fan 30 is deenergized, the plates 52-55 rotate downward under action of their gravity moment weight to positions shown dashed in FIG. 1, effectively sealing the orifice of the scroll portion 31. This prevents vapor or water, which may still be flowing from the nozzles 32, from escaping from the tower through the fan 30 to the top of the building 5 where water accumulation or ice conditions may develop. Further, the plates 52-55 prevent water from reaching the interior of the fan 30 where freezing or oxidation can occur.

The air turning vane 98, illustrative of the vanes 95, 96, 98 and 99, is depicted in detail in FIG. 5. The upper part of the vane 98 includes portions 114 which are fully curved, and portions 116 which terminate intermediate the full curvature. As indicated by the vectors 110 and 112 in FIG. 5, air leaves the upper (downstream) edge of the plate 98 tangentially to the edge. Accordingly, air is distributed across the cross-section of the tower by reason of the differing upper edge tangents of the plates 95, 96, 98 and 99 and portions thereof. The air distribution is further aided by the pressure gradient effected should a disproportionate amount of air tend to flow to any given spot or area.

By way of functional operation for the above-described cooling tower apparatus shown in FIG. 1, heated liquid supplied by the source 40 and the nozzle 32 flows downward through the tower, and in particular flows between and against the evaporating surface plates 22.

When cooling is being effected, i.e., when the transducer 38 notes a liquid temperature in the reservoir 70 above the threshold level, the fan 30 is energized by the source 37, motor 72 and coupling 73 and generates an air flow through the opened plates 52-55 between the turning vanes. The plates 52-55 are retained in their raised positions by the velocity pressure of the air, and the plates do not impede the air flow to any appreciable extent.

The air flow proceeds upward in the tower 10 to and through the plate array 22, and is uniformly distributed throughout the cross section of the tower. The flowing air reacts with the water, both within and below the plates 22, by evaporating a small portion of the water

thus removing a quantum of heat energy, principally determined by the heat of vaporization for the evaporated water, from the liquid state fluid which remains in the tower. Accordingly, the liquid is cooled as it flows downward through the composite structure 10.

As the water continues to flow downward towards the bottom of the tower 10, it is prevented by the positive air pressure generated by the fan 30 from flowing into the fan scroll portion 31 onto the building top 5. To the contrary, the water either falls directly, or is deflected by the air pressure gradient or the surface 72 into the water collecting sump 70 for collection and recirculation. Similarly, the fan generated air pressure prevents any vapor laden air from escaping onto the building top 5.

The heated air, transporting the evaporated fluid, passes through the eliminator plates 24 and escapes through the open tower top 12. Accordingly, fluid must be continuously introduced into the system to replace that small percentage of fluid that is being lost (and which has effected the desired heat transfer).

The above-described mode of tower operation continues either indefinitely until shut off or until the transducer 38 senses that the water has been sufficiently cooled, whereupon the fan 30 is deactivated. As the air velocity pressure decreases responsive to the fan being deenergized, the plates 52-55 encounter a monotonically decreasing upward force, and thus move toward their dashed orientation to seal the scroll 31 orifice. Accordingly, with the fan 30 off, neither the continuously falling water nor the moisture laden air is permitted to escape through the scroll, and thus no condensation hazard is produced on the tower supporting surface 5.

The cooling tower resides in this passive state until the transducer 38 again notes a water temperature increase to a point at or exceeding the threshold level (or until a "down" tower is again put into service). When this occurs the fan is energized by the controlled energy source 37 and the above-described operation is repeated.

Thus, a cooling tower embodying the principles of the present invention has been shown by the above to cool a heated liquid in an efficient and uniform manner, while not allowing a liquid accumulation on the tower supporting surface. The tower includes a bottom mounted fan which generates an air flow moving from the efficient discharge side thereof, and the weight of the fan is not supported by the tower walls. Accordingly, the tower may advantageously be fabricated from relatively light, inexpensive building material and, moreover, be largely pre-fabricated to avoid the expense and inconvenience attendant with job site construction. Further, the bottom located fan is readily accessible for maintenance purposes.

The above discussion has considered the single cooling tower module of FIG. 1. As noted above, a plurality of such modules may be interconnected where increased cooling capacity is required. We have discovered, when assembling more than one module into a composite cooling structure, that it is desirable to eliminate most of the sump areas of all but one centrally located tower module. The sump assembly for three cooling tower modules 10₁, 10₂ and 10₃ is shown in FIG. 2. The sumps 70₁ and 70₃ associated with the tower modules 10₁ and 10₃ are truncated, and only the sump 72 associated with the module 10₂ includes full depth. The

water exit conduit 43 is located at the bottom of the full sump 70₂.

The heated fluid falling downward in the tower module 10₂ falls directly into the sump 70₂, while that flowing downward in the towers 10₁ and 10₃ flows into the sump 70₂ via sumps 70₁ and 70₃ and hinged flapper valve plates 85 and 88. Since most of the water is accommodated in the sump 70₂, there is a greater head of water in this sump above the orifice of conduit 43 than there would be if water were individually collected in the several tower sumps. Accordingly, this pronounced head of water above the conduit 43 allows a relatively greater amount of water to flow through a relatively small diameter pipe, thus permitting a pipe cost savings since the price of piping increases markedly with diameter. There is a concomitant savings in weight for the tower assembly as well. A graphical relationship between fluid flow through a conduit vis-a-vis the fluid head and pipe diameter illustrating this savings is shown in FIG. 3.

Further, for winter operation, only the bottom area of the tower 10₂ need be heated since only the sump 70₂ collects cooled fluid awaiting recirculation. The flapper plates 85 and 88 prevent moist air from flowing from the tower 10₂ into the tower 10₁ or 10₃ when these latter towers are shut down, as for winter operation or other reduced load application.

An alternative sump configuration for plural cooling tower modules is shown in FIG. 7, wherein like reference numerals identify like structural elements vis-a-vis the sump arrangement of FIG. 2. In FIG. 6, a water seal formed by plates 85' and 88' isolates the moist air in each cooling tower module 10₁-10₃, i.e., prevents air in any tower from escaping into any other tower module, while permitting cooled fluid in each compartment to reach the exit conduit 43. Thus, again assuming one or more towers is shut down, e.g., the right tower 10₃, the water seal about the plate 88' prevents air (under pressure) in the center tower 10₂ from flowing into the tower 10₃. The head of water to the right of the plate simply rises to accommodate the air pressure differential on the two sides of the plate 88'.

For tower assemblies of large capacity, there is a rapid fluid circulation with attendant large fluid velocity at the orifice of the output conduit (i.e., the pipe 43 in the instant case). In prior art arrangements, this rapid fluid extraction has generated a fluid cavitation above the conduit thereby lowering pump and circulation efficiencies, as well as the aforementioned attendant serious disadvantages obtaining if air is drawn into the pump and fluid system. To obviate these difficulties, we employ a plate 80 disposed above the input to the conduit 43, the plate being supported as by stand-offs 81. The water flow per unit of time through the system is determined by the velocity of water entering the pipe 43 multiplied by the cross-sectional area of the pipe. This quantity of water will enter the volume beneath the plate 80 through an area defined by the periphery of the plate 80, multiplied by the distance between the plate 80 and the bottom of the sump 70₂. Since this latter area is much greater than the cross-section of the pipe 43, water moves relatively slowly beneath the plate 80 and hence the entire volume between the plate 80 is always filled with water. This is aided by the head of water above the plate 80. Accordingly, a full head of water is assured above the pipe 43, and cavitation problems are eliminated. Thus, the

pump and circulation apparatus perform efficiently and no air can be drawn into the system.

A filter 84 may advantageously be disposed about the periphery of the plate 80 to block dirt and other undesired impediments. Also, the pipe 43 may project a distance 82 above the bottom of the sump, such that dirt and other foreign matter will collect as sediment at the bottom of the sump within the height 82 to be collected and removed at an appropriate time while not flowing into the pipe 43 and clogging the fluid apparatus.

The driving arrangement for driving two contiguous tower modules A and B is shown in FIG. 4 and has largely been described above. Each module includes a shaft 39 mounted between two end bearings 100 and 101. The impellers 34 for one or more fans 30 are secured to each shaft 39, three such impellers being shown in the drawing. A driven pulley 105 is secured to one of the shafts 39 and driven by the motor 72 acting through the belt coupling 106. A flexible coupling 103 of any well known type is employed to join the two shafts, the flexible coupling accommodating any shaft misalignment in the system. The entire assembly may be driven by a single shaft rather than by a complex and expensive double shaft motor, and the flexible coupling 103 need transmit only the torque required for the module distant from the pulley 105, in this case the tower module B.

Finally, a make-up water system is shown in FIG. 6. Where plural modules are employed, only one such water make-up system will be utilized and connected with the tower module which includes the full sump. The tower wall 14 is indented over a limited transverse distance (e.g., 2 feet), and a float valve 118, controlled by a float 120 is employed. When the water level decreases below a minimally acceptable height, the float 120 activates the valve 118 and make-up water flows into the sump 70 through a nozzle 121. The threshold level is adjusted above the top of plate 80, and set to a value for optimum system operation.

The tower side wall area is open, and the height of the wall 125 is made something more than the height above the roof top 25 of the system overflow discharge valve. If the system water level rises unduly, and the excess water is not dissipated through the discharge valve for any reason, the wall 125 serves as an energizing overflow mechanism and water follows a dashed path 123 discharging from the tower over the wall 125.

It is to be understood that the above-described arrangement is only illustrative of the principles of the present invention. Numerous modifications and adaptations thereof will be readily apparent to those skilled in the art without departing from the spirit and scope of the present invention.

We claim:

1. A plurality of fluid-gas phase interacting means each including means for developing a downward fluid flow within said interacting means, means for generating an upward gaseous flow within said interacting means, means defining a fluid sump about the bottom of each of said interacting means, said sump in one of said interacting means being relatively deep and said sumps in the other interacting means being relatively shallow, and fluid passing means connecting said relatively deep and relatively shallow sumps.

2. A combination as in claim 1 wherein said fluid passing means include means for permitting only a one-way flow therethrough.

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