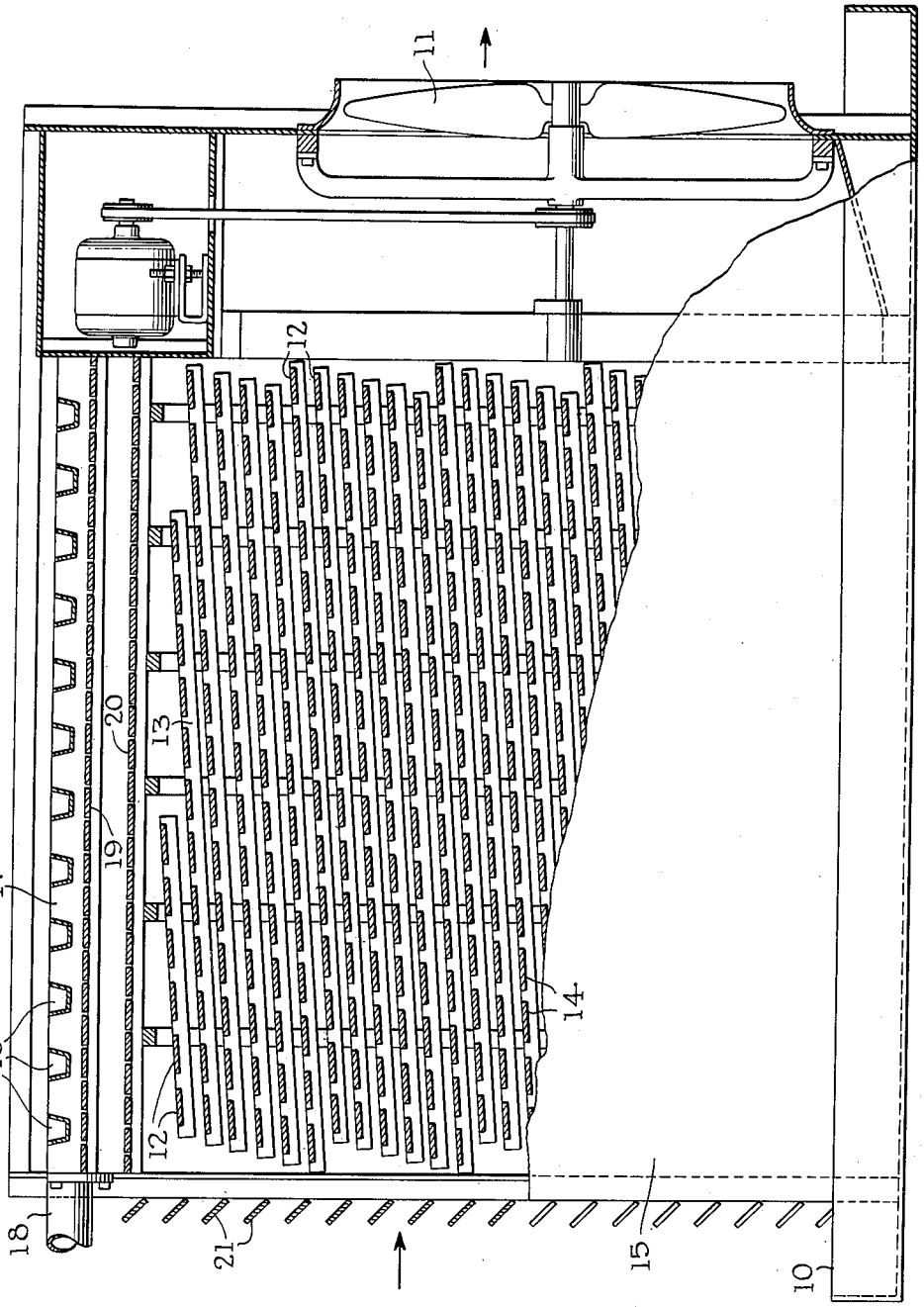
Jan. 31, 1956 F. OPHULS ET AL 2,733,055

COOLING TOWERS

Filed July 28, 1950 2 Sheets-Sheet 1

Fig. 1



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Filed July 28, 1950 2 Sheets-Sheet 2

Fig. 3.

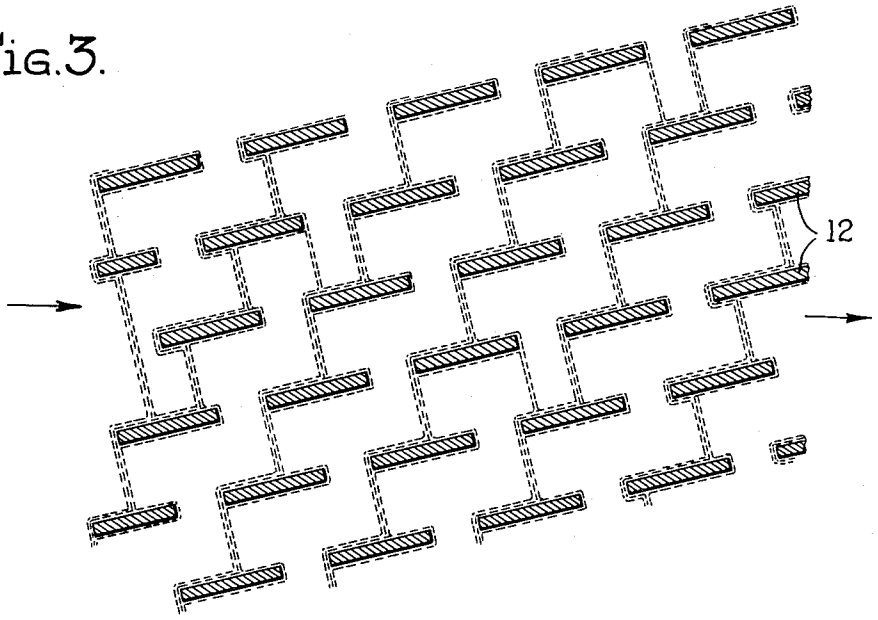
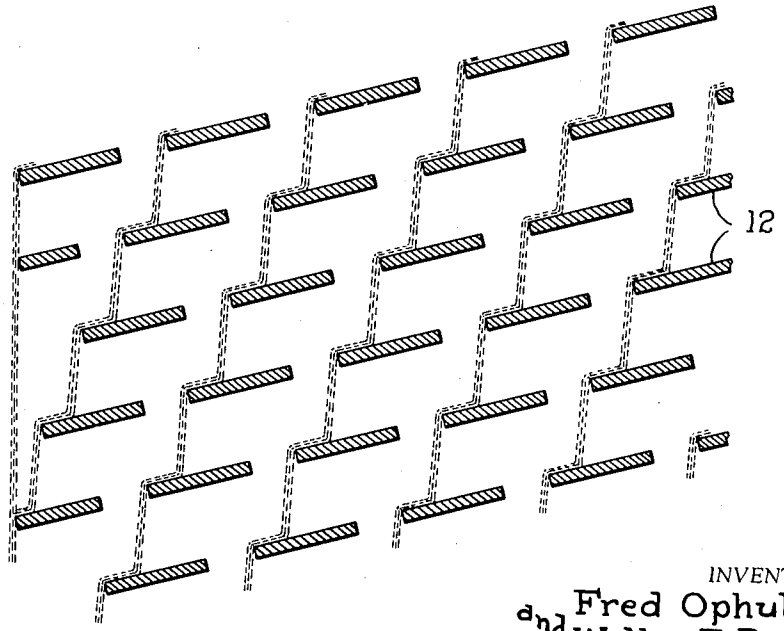


Fig. 2.



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United States Patent Office 2,733,055 Patented Jan. 31, 1956

2,733,055

COOLING TOWERS

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Application July 28, 1950, Serial No. 176,435

2 Claims. (Cl. 261—24)

This invention relates to cooling towers of the forced draft type, and more particularly to the filling for such towers.

The basic problem in apparatus of this type has always been to provide continuous, efficient cooling of large volumes of water, in as small a space as possible. The size of the units has become increasingly important with the rise in value of commercial property, and most towers are now mounted on the roofs of buildings housing the apparatus for which cooling water is required. Common examples of commercial installations requiring large quantities of cooling water are refrigerated warehouses, and ice-making plants. Since the cost of operating such plants bears a direct relation to the temperature of the cooling water, it will be apparent that the efficiency of the cooling towers becomes a major consideration.

Accordingly, it is the object of this invention to provide a cooling tower which is compact in size and which will efficiently cool large quantities of water.

A further object is to provide a novel type of filling for a forced draft cooling tower which will insure effective utilization of a maximum of the cooling space.

Further objects and advantages will be apparent from the following description read in conjunction with the accompanying drawings in which:

Figure 1 is a side elevation, partly in section, which shows, somewhat diagrammatically, a tower embodying my invention.

Figure 2 is a diagrammatic showing of the water fall over a section of the filling of the tower shown in Figure 1, without forced draft in the direction indicated by the arrow.

Figure 3 is a showing similar to that of Figure 2 except there is forced draft in the direction of the arrow.

The tower is surrounded at its base by a sump 10 from which the cooling water is pumped, or is conducted by gravity to its point of use. The tower itself is a rectangular box-like structure open at two ends, but closed at the sides. A forced draft of air, in the direction indicated, is provided by the motor driven fan 11, operating as an exhaust fan.

The tower filling consists of a plurality of slats 12 which are supported by the stringers 13. Each stringer has slots 14 milled out of its upper surface at regularly spaced intervals throughout its length. The slats 12 are placed in these slots 14, so that they may easily be removed. The stringers 13 may be supported in any manner, as for example, by bolting them to the sides 15 of the tower. Several stringers are required for each deck to prevent sagging of the slats under the weight of the water, and, as can be seen from the drawing, the decks substantially fill the interior of the tower. The slats in each successive deck are staggered, substantially as shown, so that water falling from the top to the bottom of the tower is interrupted in its fall by each deck. Each deck is inclined toward the air intake end of the tower for reasons which will be hereinafter described.

The water to be cooled is evenly distributed over the top of the tower filling, as for example from a plurality of transversely arranged pans 16. These pans are each attached at their inner ends to a central longitudinally positioned feeder pan 17. The latter is supplied for example by a connecting pipe 18. Water in continuous circulation overflows the edges of pans 16 and strikes the horizontal decks 19 and 20. The slats in these decks are closely spaced to prevent feedback of air from the exhaust fan to the top of the tower filling. Also the slats are staggered to provide an even distribution of water over the top decks of the tower filling. It will be apparent that this is only a preferred embodiment, and there are many equivalents for distribution of the water over the tower filling.

The inclined louvers 21 which extend across the open air-intake end of the tower, serve as splash guards for the water as well as to deflect the incoming air to the surface of the inclined decks.

The function and operation of this tower filling is best understood by first considering the operation of a tower identical to the one shown but with horizontal decks. With water circulating through the tower filling, and with no forced draft, it will be apparent that the water distribution over each deck will be substantially even, i. e. all slats in each deck will be continuously wetted as the water falls from top to bottom of the tower filling. As soon as the fan is operated, however, and air is pulled through the tower from left to right, there is a drift of the water in the same direction. This results in rendering the slats in the lower left hand (air inlet) part of the tower useless as far as any cooling effect is concerned because they are no longer wetted by the falling water. A tower with horizontal decks cannot therefore operate at maximum efficiency because a large part of the tower filling is not being utilized to provide liquid-air contact. In addition, the water which is carried along the decks with the air stream is discharged into the fan and there is a continual loss of water. The water loss can be cut down by the use of more eliminators at the fan end of the filling but this retards the air flow to such an extent that greatly increased input to the forced draft means is required. Under these conditions there is still another factor which contributes to the inefficiency of the tower. Since a good part of the water is being carried along with the air stream, both along the surface of the decks and through the air, the water is moving with the air flow instead of counter-current thereto, and the rate of heat transfer is reduced accordingly.

By means of our improved tower filling all of these disadvantages of the prior art towers are obviated. The broad idea of counter-flow between the air and the cooling water is of course old and there are several known schemes for accomplishing this purpose to be found in the prior art. For example, the patents to Bentz 1,218,045 of 1917 and Rasmussen 1,905,422 of 1933 each show individually inclined cooling surfaces or slats to provide for a counter-flow of the air and water. An apparent disadvantage to fillings of this type is that for the same horsepower input to the forced draft means, a smaller volume of air can be pulled through the tower than in one with horizontal decks.

A tower using our improved filling, however, permits substantially the same volume of air to be pulled through the tower for the same horsepower input to the forced draft means as in the case of a tower with horizontal decks, and yet achieves a maximum of counter-flow between the air and water which results in greatly increased overall efficiency.

Referring now to Figures 2 and 3 of the attached drawings, Figure 2 represents diagrammatically a section of the improved filling of my tower taken adjacent the air intake end and shows in general the pattern of waterfall

without forced draft. Due to the inclined decks there is a natural drift of the water toward the air intake end and as shown in the drawing only a part of the slats over which the water falls will be wetted. In addition, the slats in the lower right hand portion of the tower will not be wetted at all. The reason for this is obvious when one considers the path of fall of an individual stream of water starting at the top of the tower filling. As it flows downward through the filling the only forces acting on it are gravity which accelerates its downward flow, and the coefficient of friction between the water and each slat which retards the force of gravity, but only by a very small amount. Due to the incline of the decks, the stream which starts out at the top of the filling will gradually work toward the air inlet end, and a large percentage of the water distributed at the top of the filling will leave the tower at the air inlet end.

With forced draft as shown in Figure 3, however, it is possible so to coordinate the velocity of air flow with the pitch of the decks that the fall of water through the filling is substantially vertical as shown. We now have the force of the moving air acting on the water stream in such a way as to substantially impede the natural flow from left to right and from top to bottom. More water is held in the tower, because the moving air forms a dam on each slat which increases the thickness of the water film on each slat. Some water is thus caused to fall over the rear or trailing edge of some of the slats, but the large part of the fall is over the leading edges as shown. It should also be noted in Fig. 3 that not only is the entire upper surface of each slat wetted, but also the undersurfaces as well as the leading and trailing edge surfaces. The area of liquid-air contact (and therefore, heat exchange area) is therefore greatly increased. This result is thought to be due to a combination of factors, including surface tension effects and adhesion forces between the water and the slats which cause the water to cling to the underside of the slats.

It should also be noted in Fig. 3 that the water streams do not leave each slat at the same point. Here again, it is quite probable that surface tension effects enter into the picture. Observation of the operation of these towers shows that the individual water streams are in constant horizontal motion, i. e. the point at which they leave the underside of any given slat is constantly changing.

In a tower constructed in accordance with our invention and operated in accordance with our invention as shown in Fig. 3, three important results are achieved; namely, a counter-flow of air and water is established, all surfaces of all the slats are wetted to effect a maximum heat exchange, and a larger volume of air is drawn through the tower for a given power input to the fan.

We have discovered that there is an optimum relationship between the several variables in towers of this type to yield the best results. From a purely physical standpoint, maximum efficiency is achieved when the angle of impingement of the water streams on each deck is substantially perpendicular to the deck surface.

The basic variables include the angle of incline of the decks, the air velocity through the tower, the rate of water flow, and the drop in air pressure across the tower, as a change in any of these will change the angle of impingement of the water streams on the decks. There are at least two approaches to the problem of coordinating the variables in an equation which correctly relates these quantities. One such equation which is illustrative is as follows:

$$\tan x=\left(5.2P-\frac{DV^2}{64.4}\right)\left(\frac{d}{5d_wN}\right)$$

where :

x=angle of inclination of the decks to the horizontal.
p=pressure of the air at the exit from the tower filling in inches of water.

D=specific weight of the air in pounds per cubic foot at the ambient temperature and humidity.
V=velocity of the air between the decks in feet per second.
d=distance normal to the decks from the bottom of one deck to the top of the one below it in inches.
d_w=average diameter of the water stream in inches.
N=number of slats per deck.

This formula is based on theory. Substitution of known data taken from a tower built in accordance with the teaching of this application in which the variables were experimentally fixed for best operation, however, has proved that the formula is correct. It is therefore sufficient to enable one skilled in the art to practice the invention without resorting to experimental procedures to obtain proper operation. The designer should fix the following quantities:

(*a*) Pressure of the air leaving the filling (P)
(*b*) Specific density of the entering air (D)
(*c*) Velocity of the air between the decks (V)
(*d*) The distance between the decks (*d*)
(*e*) The diameter of the water streams (d_w)
(*f*) The number of slats in each deck (N)

Substituting them in the above formula will then yield the correct angle of inclination of the decks to the horizontal.

The foregoing formula is satisfactory from a designer's standpoint. The operation of a given tower may also be at least closely approximated by another formula which is based entirely on the aerodynamic theories of fluid flow.

$$\tan x=\frac{DV^2R-DV^2}{263d_w}$$

where $R=C_D+1$ and C_D is the drag coefficient.

While this formula seems to represent correctly the relationships between air and water flow where both quantities can be isolated, the previous formula is perhaps more accurate for prevailing conditions as these are found in a tower.

The following table lists the various dimensions and quantities of one specific example of a tower of this type which provides satisfactory operation in accordance with the present invention:

(1) Incline of decks to the horizontal	7.55°.
(2) Area of deck projected on a horizontal plane	63 sq. ft.
(3) Rate of feed of water	315 G. P. M.
(4) Spacing of decks	2½".
(5) Number of decks	32.
(6) Size of slats	3¼" x ⅜".
(7) Spacing of slats	1½".
(8) Number of slats per deck	23.
(9) Cubic displacement of forced draft means	33,000 C. F. M.
(10) Net cross-sectional area of air flow	38 sq. ft.
(11) Velocity of air between decks	13.7 ft. per. sec.
(12) Pressure of air at filling exit	0.385" H_2O.
(13) Average diameter of water streams	¼".

Of course, it will be obvious that the above is one specific example, which, for a given size of tower, relates the critical design factors to yield the desired result. The basic variables for a given tower size are apparently the pitch of the decks, the air velocity and the rate of flow of the water. These latter, of course, will have a practical limit for a given size tower, but the air velocity and pitch of the decks may be varied interdependently to produce the desired result.

Cooling towers constructed according to our invention are approximately one half the size of conventional towers having the same cooling capacity. In addition to handling the same or larger volumes of water, the towers of this invention are less expensive to operate, and their performance gives an approach of water tempera-

ture off the tower to within five degrees of the ambient wet bulb temperature or better, depending somewhat upon the temperature and relative humidity of the ambient air.

We claim:

1. In a cooling tower, a plurality of parallel decks substantially filling the tower each deck including a plurality of spaced parallel flat slats with the faces of the slats located in planes parallel to the deck, and the slats of adjacent decks being staggered with the forward and rearward edges of each slat respectively located substantially above two slats of the next lower deck which are adjacent to each other, the said decks being spaced apart distances less than the width of the slats of which they are composed, blower means for effecting air flow through the tower in a direction generally parallel to the planes of the decks, the said decks being inclined with respect to the horizontal with their lower edges at the air inlet end of the tower, and means for distributing the water to be cooled substantially uniformly over the uppermost deck, the said tower being substantially rectangular in a plane perpendicular to the longitudinal axis of the slats, with two of the sides of the rectangle being horizontal and the other two sides vertical, the air pressure of the blower means and the inclination of said decks being so related that approximately as much water gravitates to the lower quarter of the tower at the air inlet end thereof as is carried backward to the lower quarter of the tower at the outlet end thereof by the air draft.

2. The combination of claim 1 in which the air pressure of the blower has such magnitude that some of the water falling on the top of the slats is blown over the uppermost edge of the slats and from there runs down the underside of the slats and falls off near the lowermost part of the slats.

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