filling over which the water cascades from top to bottom. In many cases, a combination of the spray-filled and wood-filled design is used.

The *forced draft* type of *tower* (Fig. 7), has the advantages of being suitable for corrosive waters and having the fan mounted near the ground level on a rigid foundation where it is easily accessible.

The heated air leaves the top of a forced draft tower at a low velocity and may be subject to *recirculation* to the fan inlet, with consequent reduction in performance. This reduction could be as much as 20 per cent under certain conditions. During cold weather, recirculation may cause ice formation on adjacent equipment and buildings as well as in the tower

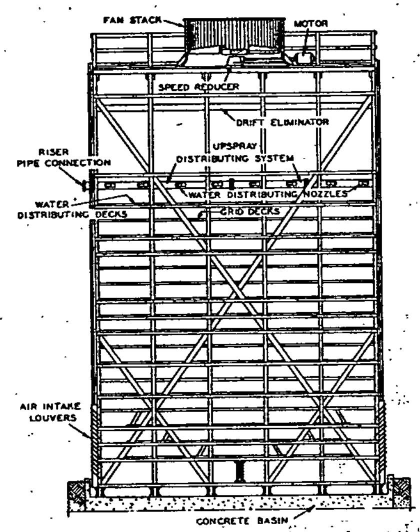

Fig. 8. Counterflow Induced Draft Cooling Tower

fan ring with possible resultant fan breakage. Fan sizes are limited to 12 ft or less, and therefore more fans, motors, starters, and wiring are needed than for induced draft towers. Induced draft towers, since fans and motors are not visible, are therefore somewhat more adaptable to architectural treatment.

In the *spray-filled mechanical draft tower*, the area presented to the air is the combined surface area of the small drops present in the tower at any one time. The net free cross-sectional area of the air spaces in a spray-filled tower is greater than that of the wood-filled tower for the same plan area. Before discharging to the atmosphere, the water-laden exhaust air passes through a drift eliminator to remove entrained moisture. This type of tower is particularly applicable for installations in restricted areas where city ordinances require fire-proof construction.

In the wood-filled tower, lumber of various cross sections is laid horizontally across the space on as close centers, horizontally and vertically,

as required, without introducing too great a resistance to air flow. The water is distributed over the top layer by means of spray nozzles, troughs, splash heads, or through evenly spaced nozzles located in the floor of an overhead open-type water distribution basin, and drops from piece to piece of the wood filling as it progresses downward. As the air moves upward or across the wood filling, the latter presents a large wetted surface, repeatedly breaks up the falling drops of water, and continuously provides new drop surfaces whose integrated areas are several times that of the wood-fill area.

The efficiency of a mechanical draft tower is improved by increasing the amount of filling, height, area, or air quantity. Increasing the height increases the length of time the air is in contact with the water, without affecting seriously the fan power required, but increases the pumping power. Increasing the area while maintaining constant fan power increases the air quantity somewhat and because of lowered velocity increases the time this air is in contact with the water. The surface area of water in contact with the air is increased in both cases. Increasing the air quantity decreases the time the air is in contact with the water, but since a greater quantity of air is passing through, the average differential between the water temperature and wet-bulb temperature of the air is increased, and this speeds up the heat transfer rate. Increased air quantities are obtained only at the expense of increased fan power, which increases approximately as the cube of the air handled by fans of the disc type.

The performance of mechanical draft towers is independent of wind velocity, hence it is possible to design them for more exacting performance. They require less space and less piping than atmospheric deck towers, and the pumping head varies from 11 to 26 feet, depending upon the design. Overall plant economy due to colder water temperature usually more than offsets the additional operating expense and initial cost as compared with those of atmospheric towers.

The *counterflow* (conventional) type of *induced draft tower* has the fan located at the top, Fig. 8, to provide vertical air movement across the filling. Air is discharged upward at a high velocity to prevent recirculation. Another type, for small requirements, has the induced draft fan in one end (see Fig. 9) to provide horizontal flow.

Another induced draft tower, developed for the purpose of obtaining compactness, larger capacity, increased flexibility and improved performance, is the *cross flow* type. This type of tower employs multiple fans centered along the top, each fan drawing air through two cells paired to the suction chamber which is partitioned midway beneath the fans and fitted with *drift eliminators* that turn the air upward toward the fan outlet. This tower obtains a horizontal air movement as water falls in a cascade of small drops over the filling and across the air stream with less resistance to air flow. The air travel is longer than with the conventional design.

Air velocities through mechanical draft towers vary from 250 to 400 fpm over the gross area of the structure. The air requirements are approximately 300 to 400 cfm of air per ton of mechanical refrigeration and about 100 to 150 cfm of air per gallon of water passing through the tower. Cooling tower calculations are based upon the fact that mechanical refrigeration requires approximately 30 gallon-deg of cooling water per minute per ton of refrigeration. In atmospheric cooling towers, if 5 gpm were circulated, the water-cooling range would be 6 F; with mechanical draft towers, 3 or 4 gpm are usually circulated for a desired water-cooling range of 10 or $7\frac{1}{2}$ F. Some designs of mechanical draft towers are limited to 6