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 deg; 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 or 7 gpm per sq ft because of blanketing effect, while the capacity of the most efficient types ranges up to 9 or 10 gpm.

When an inside cooling tower is required, some adaptation of a spray filled or wood filled induced draft tower is often used, and occasionally an

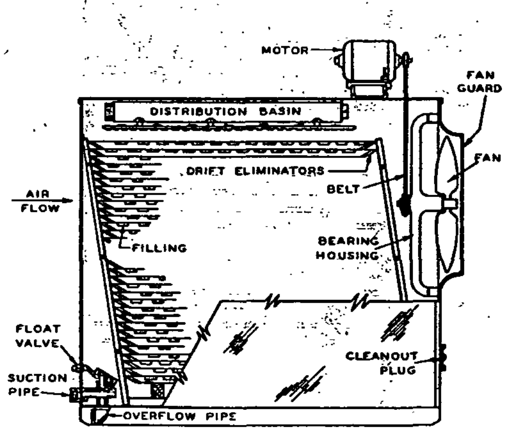

Fig. 9. Small Horizontal Induced Draft Cooling Tower for 3 to 50-ton Refrigerating Units

air washer is converted to this service. In this type of application precautions must be taken to prevent the discharged air from short circuiting to the intake.

MECHANICS OF ATMOSPHERIC WATER-COOLING

The heat exchange in atmospheric water-cooling equipment is accomplished partially by a transfer of sensible heat which raises the wet-bulb temperature of the moving air; but most of the cooling is due to an exchange of latent heat resulting from the evaporation of a small part of the water. If all of the water were cooled by evaporation, the rate of evaporation would be approximately one percent for each 10 deg of cooling. In practice, the loss of circulating water by evaporation will approximate 1 percent for 12 to 14 deg of actual cooling due to the additional amount of cooling by sensible heat transfer, and the rate of evaporation will vary from about 0.64 percent of the water circulated in the winter to 0.88 percent in the summer for a water-cooling range of 10 deg.

The lowest temperature to which water may be cooled in atmospheric

cooling equipment is the temperature of adiabatic saturation, which is at the wet-bulb temperature of the air. Performance is measured in terms of *approach* (5 to 10 F deg, with 7 F deg average) of the cooled water to the wet-bulb temperature of the ambient air when cooling the water through some desired range. The *water-cooling range* in some installations will vary from 10 to 12 F deg when a spray pond is used, and from 5 to 17 F deg (with 10 F deg average) for a mechanical draft cooling tower.

Heat absorption by the moving air in an atmospheric water-cooling tower continues as long as the wet-bulb temperature of the air is lower than the temperature of the water. The rate of heat transfer depends upon: (1) the area of water in contact with the air; (2) the relative velocity of the air and water during contact; (3) the difference between the wet-bulb temperature of the air and the initial temperature of the water; and (4) the time of contact of the air with the water. The rate of heat dissipation is also influenced by many other lesser factors[3] which further complicate the cooling tower design. Ultimate selection of water-cooling equipment for any specified service depends on overall economic considerations established from correlated performance data. As the enthalpy of the moving air increases, its wet-bulb temperature rises (see Chapter 3). Since it is impracticable to allow the air to be in contact with the water for a long enough time to permit the wet-bulb temperature of the moving air and the temperature of the water to reach equilibrium, atmospheric water-cooling equipment aims to circulate only enough air to cool the water to the desired temperature with least expenditure of power.

DESIGN CONDITIONS FOR WATER-COOLING

The maximum wet-bulb (design) temperature at which the total quantity of circulating water must be cooled through a specified range by water-cooling equipment is never selected as the highest wet-bulb temperature ever known to have occurred for some locality, nor the average wet-bulb temperature over any period of time. The *maximum* basis would require cooling equipment several times larger than normal capacity, and the *average* basis would result, for a large part of the time, in higher condenser temperatures than those for which the plant was designed.

Accepted design practice for water-cooling towers, evaporative condensers, and spray ponds, is to use the maximum hourly outdoor dry-bulb temperature which will be exceeded no more than $2\frac{1}{2}$ percent of the time for the months of June to September; also, to use the maximum hourly wet-bulb temperature which will be exceeded no more than 5 percent of the total hours for the same period. Tabulation of these data has not been completed. The limited portion of such data as are available is given in Table 3, Chapter 12 for airport weather stations; for other localities design dry-bulb and wet-bulb temperatures in use locally are tabulated as a guide to design temperatures. More complete summer weather data, statistics, charts, maps, and technical analysis have been prepared by Albright.[4]

Equipment for steam turbine condensers and internal combustion engines, is usually based upon somewhat lower design temperatures if peak loads occur at night or during winter months when outdoor temperatures are lower.

Knowing the hot water temperature and the wet-bulb temperature for which the equipment must be designed, the cold water temperature must be chosen to place the requirement within the effectiveness range of the