low pressure. In many cases these sprays are set at an angle with the air flow. Air washers of this type not only perform necessary heat transfer functions, but also are effective removers of dust and dirt from the air stream.

Essential requirements in the air washer operation are: uniform distribution of the air across the chamber section; moderate air velocity of from 250 to 600 fpm in the washer chamber; an adequate amount of spray water broken up into fine droplets throughout the air stream, at pressures of from 15 to 30 psig; sufficient length of travel through the water

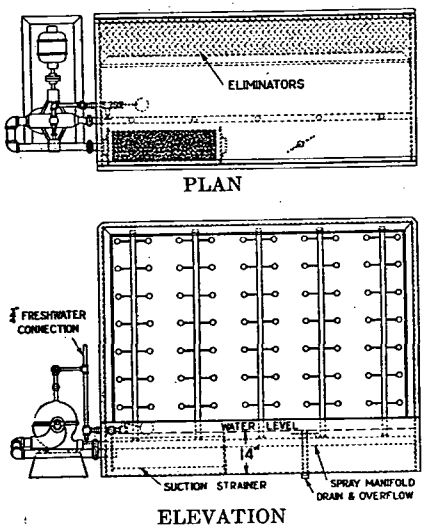

FIG. 1. TYPICAL SINGLE-BANK AIR WASHER

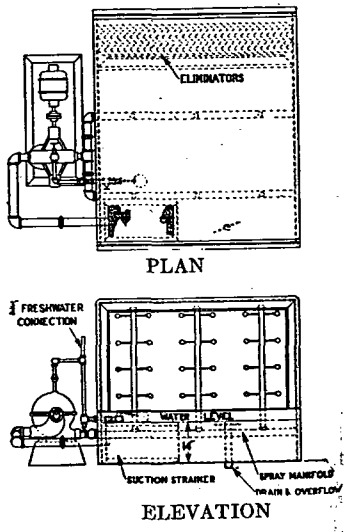

FIG. 2. TYPICAL TWO-BANK AIR WASHER

spray and wetted surfaces; and the elimination of entrained moisture from the outlet air.

Expected performances, physical size, length, number of sprays, etc., vary greatly, depending upon the functions of the installation. In general, the width and height of an air washer are dictated by the space available. Washers of nearly equal height and width are desirable from an air flow and economic standpoint, although not necessary. The length of washers varies considerably. A space of approximately $2\frac{1}{2}$ ft between spray banks is used, and the first and last banks of sprays are located about 1 ft to $1\frac{1}{2}$ ft from the entering or leaving end of the washer. In addition, air washers are very often furnished with cooling coils or heating coils within the washer chamber, and the use of these coils affects the overall length of the washer.

Where increase of overall heat transfer between the air and water is required, multistage washers are used. These washers are equivalent to a number of washers in series, and the water is often pumped from one stage to the other where conditions permit.

The resistance to air flow through an air washer varies with the type of eliminator and wetted surfaces, number of banks of spray and their

direction, air velocity, size and type of other resistances such as cooling and heating coils, and other factors such as air density. Resistances vary from as low as $\frac{1}{4}$ in. to higher than 1 in. water column, and it is therefore necessary that the manufacturer be consulted in regard to the resistance of any particular washer design involved.

HUMIDIFICATION WITH AIR WASHERS

Air humidification can be accomplished in three ways with an air washer. These are: (1) use of recirculated spray water without prior treatment of the air; (2) preheating the air and washing it with recirculated spray water; and (3) using heated spray water. In any air washing installation the air should not enter the washer with a dry-bulb temperature less than 35 F in order to eliminate danger of freezing the spray water.

Method 1. Except for the small amount of energy added from outside by the recirculating pump in the form of shaft work, and for the small amount of heat leak from outside into the apparatus, including the pump and its connecting piping, the process would be strictly adiabatic. Evaporation from the liquid spray would therefore be expected to bring the air immediately in contact with it to saturation adiabatically; and, since the liquid is recirculated, its temperature would be expected to adjust to the thermodynamic wet-bulb temperature of the entering air.

It does not follow from the foregoing reasoning that the whole air stream is brought to complete saturation, but merely that its state point should move along a line of constant thermodynamic wet-bulb temperature as explained in Chapter 3. The extent to which the final temperature approaches the thermodynamic wet-bulb temperature of the entering air, or the extent to which complete saturation is approached, is conveniently expressed by a ratio known as *humidifying effectiveness* or *saturating effectiveness*, and is defined as

$$e_h = \frac{t_1 - t_2}{t_1 - t'} \qquad (1)$$

where

e_h = humidifying effectiveness, percent.
t_1 = dry-bulb temperature of the entering air, Fahrenheit degrees.
t_2 = dry-bulb temperature of the leaving air, Fahrenheit degrees.
t' = thermodynamic wet-bulb temperature of the entering air, Fahrenheit degrees.

The following may be taken as representative humidifying or saturating effectiveness of an air washer for the conditions stated:

1 bank—downstream	60–70 percent
1 bank—upstream	65–75 percent
2 banks—downstream	85–90 percent
2 banks—1 upstream and 1 downstream	90–95 percent
2 banks—upstream	90–95 percent

The humidifying or saturating effectiveness of a washer is dependent upon the essential items of design mentioned under Air Washers. Other conditions being the same, low velocity of air flow is more conducive to higher humidification effectiveness.

Method 2. The preheating of the air increases both the dry- and wet-bulb temperatures, lowers the relative humidity, but does not alter the humidity ratio (pound water vapor per pound dry air). At a higher wet-