to the air and a part of the sensible heat of the initial mixture is transformed to latent heat as evaporation of some of the spray water takes place. Theoretically the spray water and the dry- and wet-bulb temperatures of the air should come to the wet-bulb temperature of the air entering the washer and the air should leave the washer adiabatically saturated at the entering wet-bulb temperature. Due to limitations of air washer construction and operation air is not generally completely adiabatically saturated. This introduces an item into the calculations which is known as humidifying or saturating efficiency. This efficiency is the ratio of the actual reduction of dry-bulb temperature to the reduction of dry-bulb temperature theoretically possible. Expressed as a percentage humidifying efficiency is:

$$e_h = \frac{(t_1 - t_2)\,100}{t_1 - t'} \qquad (1)$$

where

e_h = humidifying efficiency, per cent.
t_1 = initial dry-bulb temperature, degrees Fahrenheit.
t_2 = final dry-bulb temperature, degrees Fahrenheit.
t' = initial wet-bulb temperature of the entering air, degrees Fahrenheit.

The humidifying or saturating efficiency of a washer is dependent upon the number of spray banks and nozzles, the effectiveness of the nozzles in breaking an adequate quantity of water into a fine spray, the velocity of air flow through the water sprays, and the time of the contact of the air with the spray water. Other conditions being the same, low velocities of air flow are more conducive to higher humidifying efficiencies than high velocities of air flow. The following may be taken as representative humidifying or saturating efficiencies of air washers for the conditions stated:

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

The air leaving the washer may require the use of a reheater coil to produce the required dry-bulb temperature and relative humidity.

When air of a given specific humidity has a low initial dry-bulb temperature it may be preheated before it enters a washer using recirculated spray water. The preheating of the air increases both the dry- and wet-bulb temperatures and lowers the relative humidity, but not the specific humidity of the air. With an increased wet-bulb temperature, the air is capable of accumulating more moisture by the process of adiabatic saturation and the final specific humidity and the final dry-bulb temperature of the air as it leaves the washer will be higher. An addition of sensible heat by the preheater takes place prior to the air entry into the washer. In the case of method 2 the process of humidification within the washer is similar to method 1. The final desired conditions are secured by adjusting the wet-bulb temperature of the entering air and the use of a reheater when such is necessary.

Method 3 involves heating the spray water to a temperature equal

to the dew-point temperature of the air at the final desired conditions. The water heater may be located either in the washer sump or external to it as in Fig. 3. The air tends to become saturated as it comes in contact with the heated spray water and if the humidifying efficiency of the washer is 100 per cent, the air will leave the washer saturated at the spray-water temperature. Reheating of the air will give the necessary final dry-bulb temperature and relative humidity of the air if the spray water has been maintained at the proper temperature. In this process both heat and moisture are added to the air as it passes through the washer and the dry-bulb temperature of the leaving air is greater than its entering dry-bulb temperature.

Example 1. Air is to be maintained at 70 F with a relative humidity of 40 per cent when the outside air is at 0 F and 70 per cent relative humidity and a barometric pressure of 29.92 in. of Hg. Find the required temperature of the spray water, weight of water vapor to be added, and the heat added in the process.

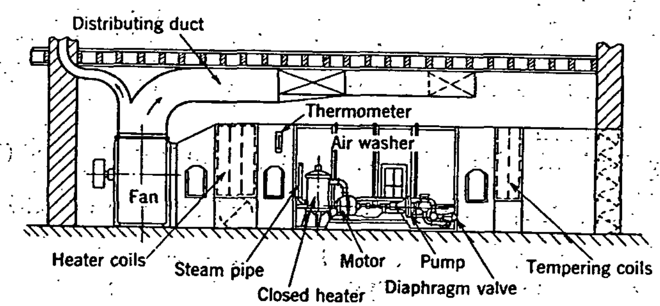

FIG. 3. AIR WASHER WITH SPRAY WATER HEATING ARRANGEMENT

Solution. From Example 2, Chapter 1, the final dew-point temperature is 44.5 F, W_1 = 0.000548, W_2 = 0.00618, and $W_2 - W_1$ = 0.005632 lb per pound of dry air. Therefore, the spray water temperature should be maintained at 44.5 F and the moisture addition per pound of dry air is 0.005632 lb. Assuming that the air after being preheated enters the washer at 40 F and that it leaves the washer saturated at 44.5 F the heat added per pound of dry air is:

Preheater:	[0.24 (40 − 0)] + [0.45 × 0.000548 (40 − 0)] =	9.61
Washer:	[0.24 (44.5 − 40)] + [0.45 × 0.000548 (44.5 − 40)] + (0.005632 × 1079.2) =	7.16
Reheater:	[0.24 (70 − 44.5)] + [0.45 × 0.00618 (70 − 44.5)] =	6.19
		22.96

If the make-up spray water enters the heater at 40 F its initial heat of the liquid per pound of dry air is 0.005632 × 4.5 = 0.03 Btu making the total heat per pound of dry air, excluding pipe losses, chargeable to the heaters equal to 22.96 − 0.03 = 22.93 Btu. The chargeable heat for humidification alone is (0.005632 × 1079.2) + [0.45 × 0.005632 (70 − 44.5)] − (0.005632 × 4.5) = 6.11 Btu per pound of dry air.

APPARATUS FOR DIRECT HUMIDIFICATION

Humidifiers may be divided into the following general types, according to the method of operation: (1) *Direct*, which spray into the room; (2) *Indirect*, which introduce moistened air; and (3) *Combined* direct and indirect.