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

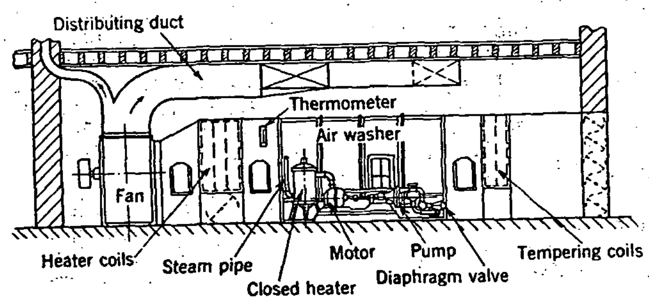

FIG. 3. AIR WASHER WITH SPRAY WATER HEATING ARRANGEMENT

of air flow are more conducive to higher humidifying efficiencies. 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 reheating 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 reheating when necessary.

Method 3 involves heating the spray water to a temperature higher than the leaving air temperature. In passing through the heated spray, both the temperature and humidity of the air is increased. By properly controlling the spray water temperature, the air may be made to leave the washer in a completely saturated condition. Reheating the air will give the necessary final dry-bulb temperature and relative humidity. The water heater may be located in the washer sump, or external to it as in Fig. 3.

APPARATUS FOR DIRECT HUMIDIFICATION

Humidifiers may be divided into the following general types, according to the method of operation: (1) indirect, such as the air washer, which introduces moistened air; and (2) direct, which sprays moisture into the room.

As in the cases of humidification by use of an air washer, the heat necessary for the vaporization of the moisture added to the air by direct humidification is secured either from heat stored in the spray water or by a transformation of sensible to latent heat in the air humidified. In the latter case the total heat of the air remains constant but the dry-bulb temperature of the air humidified is reduced.

Direct humidification is usually preferable where high relative humidities must be maintained, but where there is little cooling or ventilation required. In comfort air conditioning, where both humidification and ventilation are required, the indirect humidifier is preferable. In industrial applications, where the cooling or ventilation load is large and where very high relative humidities must be maintained, a combined system employing both direct and indirect humidifiers is sometimes used.

Spray Generation

Spray generation is obtained by (1) atomization, (2) impact, (3) hydraulic separation, and (4) mechanical separation.

Atomization involves the use of a compressed air jet to reduce the water particles to a fine spray. With the *impact* method, a jet of water under pressure impinges directly on the end of a small round wire. Where *hydraulic separation* is employed, a jet of water enters a cylindrical chamber and escapes through an axial port with a rapid rotation which causes it immediately to separate in a fine cone-shaped spray. In the *mechanical separation* process, water is thrown by centrifugal force from the surface of a rapidly revolving disc and separates into particles sufficiently small to be utilized in certain types of mechanical humidifiers.

Spray Distribution

Spray distribution is obtained by (1) air jet, (2) induction, and (3) fan propulsion.

The air jet which generates the spray in atomizers also carries the spray through a space sufficient for its distribution and evaporation, and this method of distribution is termed *air jet*. Where distribution is obtained by *induction*, the aspirating effect of an impact or centrifugal spray jet is