wet surfaces; (3) by passing it both through a spray and over wet surfaces. After the air is washed it is freed from entrained water.

When air is cleansed by washing its humidity or moisture content is usually changed. In passing through the water spray or over the wet surfaces, both the dry and wet bulb temperature of the air approaches that of the water, at which temperature the air tends to become saturated. The moisture content of the air may, therefore, be controlled by controlling the water temperature. By using water at a temperature below the dew point temperature of the entering air the washer becomes a dehumidifier; or by heating the water to a temperature above the dew point of the entering air the humidity or moisture contents of the air may be increased. By raising the dry bulb temperature of the air after leaving the washer, its relative humidity may also be controlled. The humidifying efficiency of any air washer may be given as:

$$E = 1 - \frac{\text{Final wet bulb depression}}{\text{Initial wet bulb depression}}$$

for example: With an initial wet bulb depression of 20 deg. and the final wet bulb depression of 5 deg., the humidifying efficiency is

$$E = 1 - \frac{5 \text{ deg.}}{20 \text{ deg.}} = 0.75$$

The usual humidifying efficiency of a good air washer is 70 per cent. The humidifying efficiency of air washers of the commonly termed humidifier type should range from 95 to 98 per cent.

## TEMPERATURE AND HUMIDITY CONTROL

Air washers require a method of control of temperature to prevent freezing by too low temperature, and to prevent over-humidification by too high temperatures of the air entering and leaving the washer. There are available one method of hand control and five methods of automatic or semi-automatic control. The method of hand control is by tempering heaters, divided into two or more sections in series; the outer section being turned on by hand whenever the outside temperature approaches freezing; the successive sections being turned on as the temperature drops below freezing. Where two sections are available it is usual to turn on the second section when the outside temperature goes below zero, and to turn on the third section, where necessary, at temperatures below zero. The first, or outside section must always be turned on full in cold weather to prevent freezing of the heaters. The steam supply to the second, or inside section, may be hand-regulated at all temperatures warmer than about 10 deg. above zero.

The five systems of automatic regulation are:

1. Substitution of automatic regulation for hand regulation, the automatic regulation being operated in a similar manner; the sections being controlled both by variations in the outside temperature conditions and by an auxiliary control for one inside section from a thermostat located on the discharge side of the air washer. (It is not possible ordinarily to control the temperature of the air entering the washer except where there





is an unusually long tunnel or duct for the thorough mixture of the air leaving the tempering heaters before it comes in contact with the thermostat.)

2. By heating the spray water so as to maintain a temperature or dew point (as the air is then saturated) of the air leaving the washer at between 35 and 40 deg. This method does not necessarily require a tempering heater. It is preferable, however, to use one section for the purpose of tempering the air should the washer be shut down, this to prevent freezing of the water when the apparatus is not in operation. More than one tempering section should never be used except where temperatures may go considerably below zero; then the tempering sections may be turned on, one at about 20 deg. fahr., and the second at about 0 deg. fahr. The tempering section may be operated manually or by a thermostat connected with the outside air. The steam supply for water heating should be sufficient to heat and saturate the air at from 10 to 35 deg. fahr., when water heating is used in conjunction with a tempering section. This is to allow a sufficient margin for safety of operation. The steam requirements for this are given later.

3. By regulating the heat supplied either through tempering sections or through the spray water so that the water in the tank shall be kept well above the freezing point. Inasmuch as the wet bulb temperature of the air and the water in the tank are but few degrees apart when the water in the tank is not heated directly, this method is a fairly effective and simple one. One permissible variation of this method is to use a thermostat in the air leaving the washer, controlling the dry bulb temperatures at this point through regulation of the steam supply to the inside tempering section. The wet bulb temperature of the air is controlled by means of water leaving the eliminator plates and is held at the desired point by means of adding heat to the spray water. This will control exactly the temperature and relative humidity of the leaving air. Two or more tempering sections are required for this method.

4. The fourth method is desirable where recirculation is used and consists in maintaining the temperature leaving the washer at about 40 deg. by means of a thermostat located at this point and controlling the admixture of fresh and return air through automatically operated dampers. This prevents over-humidification, eliminates danger of freezing, and effects the highest economy in cost, as no steam is required for either tempering or humidifying except after the air has passed the washer.

5. The fifth method of automatic control is to reheat the air leaving the air washer to a definite thermostatically controlled temperature, and to control the relative humidity of the air by means of a hygrostat which operates either on the tempering sections to heat the air or which controls a water heater for the spray water.

## STEAM REQUIREMENTS FOR HEATING AND HUMIDIFYING AIR

Where the spray water is not heated it is necessary that the wet bulb temperature of the incoming air be above the freezing point; otherwise the eliminator plates will coat with ice and stop up, even if the dry bulb temperature of the leaving air is above the freezing point. It is necessary to heat zero air to 48 deg. in order that the wet bulb temperature may be 35 deg. The temperature of the leaving air may then be expected to be approximately 39 deg. dry bulb and 35 deg. wet bulb, with a dew point of 31 deg. The additional heat required due to humidification is that indicated by the temperature drop of 9 deg., or 162 B.t.u. per 100 cu. ft. of air, or 1 b.hp. for every 3400 cu. ft. of air per minute.

These are the minimum requirements for humidification, above those required for heating the air. The following Table 1 gives the heat required, from various outside entering wet bulb temperatures, to various dew point temperatures corresponding to various relative humidities at 70 deg.

These values are the total heat required for both heating and humidifying the air. The amount of heat required for humidifying only may be found by subtracting from the values given the heat required to