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 F. 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 F, and the second at about 0 deg F. 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 F, when water heating is used in conjunction with a tempering section. This is to allow a sufficient margin for safety of operation.

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 tánk 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 a thermostat in the 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 F by means of a thermostat located at this point 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

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 F in order that the wet-bulb temperature may be 35 F. The temperature of the leaving air may then be expected to be approximately 39 F dry-bulb and 35 F wet-bulb, with a dew-point of 31 F. If the humidifying capacity of the washer is 75 per cent the additional heat required to furnish humidification is that indicated by the temperature drop of 9 deg, or 162 Btu per 100 cu ft of air, or one boiler horsepower for every 3400 cu ft of air per minute. These are the minimum requirements for humidification, above those required for heating the air.

REFRIGERATING MACHINES

The refrigerating machine with which the heat is removed from the air consists of three essential parts, the evaporator, the compressor and the condenser. There are, of course, many valves, accessories and devices each peculiar to the several different types of machines and necessary to their proper operation.

In the evaporator, or cooler, a pressure is maintained which causes the

refrigerant to evaporate or boil at a sufficiently low temperature to absorb heat from the water, air or other medium in contact with the cooling surface. Various devices such as separators, accumulators and eliminators are required to remove any entrainment of liquid from the gas leaving the cooler. Liquid refrigerant must be fed to the cooler at the same rate at which it is evaporated so as to maintain an approximately constant level. Various manual and automatic valves are available for this purpose.

Many different types of coolers are available. Probably the earliest design was the open Baudelot which consisted of a number of superimposed pipes over which the water to be cooled flowed from a carefully leveled flooding trough carried just above the uppermost pipe. Drip strips were required to prevent an unnecessary loss by splashing from the pipes. For extremely small tonnages such a cooling surface might be submerged, but with a submerged coil the rate of heat transfer will vary over a wide range, depending upon the agitation of the water.

Where proper protection against freeze-ups can be provided enclosed coolers of either the shell and coil or the shell and tube type may be used to simplify water handling problems. In many cases the loss of considerable static head can be avoided by the use of a closed cooler.

Good practice calls for a drop in water temperature ranging from the minimum of about 6 deg to a maximum of 10 deg, the lesser change in water temperature requiring a correspondingly greater volume to be pumped and carried through pipes. A mean difference between water temperature and refrigerant temperature of 7.5 to 15 deg is satisfactory. The temperature at which heat must be received by the refrigerant is therefore determined by the mean water temperature and the mean effective temperature difference.

Inasmuch as the latent heat per pound of refrigerant is approximately constant within the narrow range of temperature which is utilized in water cooling and the volume of gas per pound of refrigerant increases very rapidly as the temperature and pressure is reduced, the temperature of the refrigerant determines the volume of gas which must be handled by the compressor.

The function performed by the compressor is that of withdrawing the gaseous refrigerant from the cooler and delivering it to the condenser at such a pressure that its heat can be absorbed by water at ordinary temperatures and the gas recondensed into a liquid ready to be returned to the cooler. The construction of condensers follows along the same general lines as that of coolers. The atmospheric type in which the latent heat of a considerable amount of evaporation is added to the sensible heat absorption by the water is almost identical with the Baudelot. Shell and tube condensers are almost identical with the coolers. The double pipe condenser in which the cooling water is passed through the inner of two concentric pipes with the refrigerant in the annular space is quite commonly used. It is important in designing and locating condensers to make adequate provision not only for cleaning but also for the removal and replacement of the tubes or complete sections.

The condenser water must receive and carry away all of the heat absorbed in the cooler, plus the heat equivalent of the power used in driving the compressor, with slight corrections for radiation direct from the com-