the quantity of air introduced, or with valves or dampers which govern the heat output from local heaters such as radiators. Usually the control is a combination of both volume control and of air temperature control.

In installations for auditoriums and theaters the requirements are different from those in factories, since there must be a considerable volume of air circulated in order to provide ventilation and cooling. The moisture content of this air must be relatively constant, but its temperature must be variable. A satisfactory solution of this problem has proved difficult, but special systems of control are now in general use which permit the temperature and humidity of theaters to be controlled independently and at the same time, to be immediately responsive to changes in occupancy. Some of these arrangements are successful in operation without the use of any external heat whatever.

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 compressor and from gas transmission lines between the compressor and the condenser.

Two to three gallons of water per minute per ton of refrigeration will rise approximately 15 to 10 deg in passing through the condenser. Good practice calls for a condensing temperature not more than from 3 to 8 deg above the final temperature of the condenser water. The power required to drive the compressor is approximately proportional to the difference between the condensing temperature and the evaporating temperature so that it is obvious that by increasing the investment in cooling and condensing surface the operating cost may be reduced.

There are two types of compressors in use in large plants, the *positive-displacement* type and the *centrifugal*. Of the former there are two general types, the *reciprocating* and the *rotary*.

SYSTEMS OF AIR DISTRIBUTION

In systems of air conditioning, the method of air distribution, as well as the practical details of design are of utmost importance.

In an installation where exact relative humidity control is required, uniform temperature conditions are very important, because a variation in relative humidity will be caused by any variation in temperature. Moreover, the air is usually admitted, especially in summer, at temperatures lower than that of the room in order to effect the necessary cooling. Therefore, the air must be distributed uniformly, not with respect to floor space but with respect to the amount of heat to be absorbed in the various portions of the room. Thus it is necessary for the air conditioning engineer to have fairly exact information as to the distribu-