

either a temperature or pressure controller provides a safety feature against excessive pressures on the high side of the compressor.

Many compressors may be *unloaded* by instruments sensing room or duct conditions, or by refrigerant pressures, thus reducing the frequency of starting and stopping. If two or more compressors are used for a single cooling system, *step controllers* are used to start them in sequence at intervals of a few seconds to avoid the large momentary electric input that simultaneous starting would demand.

When condensers are water cooled, thermostatic control to vary the quantity of water is needed for economical operation. Mechanical air condensers may be started and stopped with temperature demands.

Chilled water may be stored in tanks at temperatures slightly lower than required for air cooling coils. The control of temperature for the water distribution system is as described for Ice Cooling.

Ice Cooling

When ice is used for the cooling or dehumidification of air, it is usually placed in bunkers and water is sprayed over it. This water, after being cooled, may be used in air washers or surface cooling coils and is usually returned to the bunker for additional cooling after being used.

Control of the water temperature leaving the cold water tank may be maintained by a temperature controller, which measures the temperature of the water in the tank and modulates a control valve in a by-pass which permits a portion of the return water to return directly to the tank instead of passing through the sprays.

Vacuum Refrigeration

A vacuum refrigerating system consists of an evaporator, compressor, condenser and auxiliaries. The refrigerant used is water, and water vapor (steam) is the power medium.

Water which has been passed through an air washer or cooling coil is sprayed directly into the evaporator or water cooler where it is cooled by its own evaporation. A condenser is attached directly to the compressor discharge and its function is to recondense the water vapor drawn from the evaporator, plus the steam which supplies the energy for compression.

The temperature of the cold water leaving the flash chamber should be measured by a temperature controller which will in turn operate a two-position or positive-control valve installed in the steam line to the jet so as to permit steam to flow only when cooling is required. If city water is used in the condenser, the amount of water should be modulated according to the demand as measured at the condenser outlet by means of a temperature controller and control valve.

Cooling by Well Water

When well water is available in sufficient quantities at low temperatures during the cooling season, it may be pumped directly to air washers or cooling coils. Control is usually effected through control valves on the water supply to the cooling unit actuated by temperature or humidity controllers, or both, located either at the outlet of the conditioner or in the conditioned space.

Chapter 35

INSTRUMENTS AND TEST METHODS

Temperature Measurement, Pressure Measurement, Measurement of Air Movement, Air Change Measurements, Measurement of Relative Humidity, Dust Determination, Heat Transfer Through Building Materials, Measurement of Heat Exchange for Comfort Conditions, Combustion Analysis, Smoke Density Measurements, Carbon Monoxide Measurements

IN previous chapters, data from many tests and from much research on various divisions of heating, ventilating and air conditioning have been given. References have also been cited to a number of test codes adopted by the Society for the testing and rating of various types of equipment. This chapter presents a description of many test instruments, and discusses their use.

TEMPERATURE MEASUREMENT

Changes in the intensity of heat may be determined by several methods such as measuring the change in volume of a liquid, the change in internal pressure of a confined gas, the current set-up between dissimilar metals joined in a circuit, or the change in resistance of an electrical circuit.

Thermometers

The most common method used is the change in volume of a liquid such as mercury or alcohol enclosed in glass. Mercurial thermometers may be used for measuring temperatures from -40°F to approximately 1000°F . The lower limit is set by the freezing point of mercury. Since the boiling point of mercury is only about 675°F , the space above the mercury in thermometers designed for higher temperatures must be filled with an inert gas under pressure. Alcohol thermometers may be used for temperatures from -94°F to $+248^{\circ}\text{F}$.

The more accurate thermometers are individually calibrated and have divisions etched on the stem. The two most common reference points are the freezing and boiling points of water. On the Fahrenheit scale, which is most commonly used in engineering work, there are 180 divisions between these points. On the Centigrade scale which is used by chemists and physicists, there are 100 divisions in this range. The temperature in degrees Fahrenheit equals $\frac{9}{5}$ of the temperature in degrees Centigrade, plus 32.

For permanent installations, glass thermometers are often protected by metal jackets and equipped with metal scales. Due to the heat