Tests have shown that the propeller type anemometer can be used successfully on most of the common types of supply grilles [30, 31]. The core area is divided into equal squares, and the anemometer is held against the face of the grille for the same length of time in each. To get the air volume in cubic feet per minute, the average corrected velocity in feet per minute thus obtained is multiplied by the average of the gross and net free area of the grille (core) in square feet.

On exhaust openings, the anemometer traverse is made as described previously. The air volume may be determined by multiplying the corrected velocity in feet per minute by the gross core area of the grille in square feet and by a coefficient for average conditions of 0.85 [32].

When a propeller type anemometer is held in a stream of varying velocities, it tends to indicate higher than the true average, that is, the speed of the propeller is nearer to the top velocity in its area than it is to the minimum velocity. This is the main reason for the large difference in ratings of unit ventilators by the anemometer method and by air volume measurements in a duct approach to the inlet [33].

Any of the other anemometers described can be used within their range at the face of supply grilles when properly applied. In principle it is a case of finding the velocity at many points and using the average thus found with the correct discharge area at that cross-section. The deflecting vane anemometer equipped with a jet on the end of a rubber tube has been found especially convenient and accurate on supply grilles [34]. On modern air conditioning grilles the core area is used without a correction coefficient when the jet is held one inch away from the face of the grille. At this distance the constriction due to the thin bars has disappeared since the small air jets have reunited, and the air stream has not yet spread beyond the core dimensions. With deflecting grilles the exploring jet should be turned to the angle giving a maximum reading. With suitable traversing tips and calibration, this instrument may also be used on exhaust grilles if proper grille factors are applied [35].

Smoke is a qualitative tool which is very useful in studying air movements. Satisfactory smoke can be obtained from titanium tetra-chloride (which, however, is very irritating to nasal membranes) or by mixing potassium chlorate and powdered sugar (a non-irritating smoke) and firing the mixture with a match. This latter process evolves considerable heat and it should be confined in a pan away from flammable materials. The titanium tetra-chloride smoke lends itself to spot determinations, particularly for leakage through casings and ducts, as it can be easily handled in a small pistol-like ejector. The fumes of aqua ammonia and of sulfuric acid, if permitted to mix, form a white precipitate which is useful for some purposes. Two bottles, one containing ammonia water and the other acid, are connected to a common nozzle by means of rubber tubing. Air is forced over the surfaces of the liquids in the bottles by means of a syringe and the two streams, upon mixing at the nozzle, form a white cloud.

## AIR CHANGE MEASUREMENTS

Atmospheric air contains a certain amount of carbon dioxide. Its concentration is increased within enclosures by the carbon dioxide given off by occupants. The total air change through open windows, infiltration, and mechanical ventilation, may be measured by the carbon dioxide concentration but absorption of $CO_2$ by walls and other materials may introduce errors [36] and consequently some investigators prefer hydrogen



to $CO_2$ for such tests. Since occupants also give off moisture, the increase in humidity may also be used as an index of ventilation. Usually more direct methods of measuring air supply and air distribution are in favor.

## MEASUREMENT OF RELATIVE HUMIDITY

Wet- and dry-bulb mercurial thermometers are commonly used in the form of a sling psychrometer to determine relative humidity. The wet-bulb wick and water for wetting it must be clean, and the temperature of the water should preferably be slightly above the wet-bulb temperature. An air stream velocity of 900 fpm is recommended, although higher velocities will result in greater accuracy [37]. This velocity is obtained with the sling psychrometer by whirling it rapidly, followed by reading the wet-bulb thermometer quickly before its indication changes. Owing to the human element involved in this method, more accurate results are obtained with types of psychrometers in which air is drawn over the thermometers by a fan, or by a bulb operated aspirator. In ducts, the air flow itself gives the proper evaporating conditions. Several observations should be made until the minimum temperature is reached. Relative humidity may be obtained from tables or psychrometric charts [38]. Although it is common practice to use the charts which are based on a barometric pressure of 29.92 in. Hg, a correction for barometric pressure is necessary for extreme accuracy. This correction is made by multiplying the relative humidity as determined from the chart by the ratio of the observed barometric pressure and the standard barometric pressure.

For temperatures below 32 F, the water on the wick is allowed to freeze, during which time the temperature will drop below the true wet-bulb. A thin film of ice is more desirable than a thick one, and it is satisfactory to remove the wick and freeze a thin film directly on the bulb. Care must be taken to read the temperatures accurately due to the slight wet-bulb depressions. Tables for ice conditions must be used [39].

Dew-point apparatus for humidity measurements consists of a polished plated container cooled by the evaporation of a volatile liquid within. The temperature at which the first slight water vapor forms on the polished surface is the dew-point. If the temperature is below 32 F, the deposit will appear as frost. Another method of determining humidity is by chemical means in which the water vapor is removed by a drying agent and weighed on a chemical balance. A thermal conductivity method is available for temperatures above 212 F or for extremely low humidities [40].

## DUST DETERMINATION

The measurement of dust is complicated by the many kinds involved. Some of the collecting methods are impingement on viscous surfaces, impingement at high velocity under water, collection on porous crucibles or filter paper through which air passes, and electric precipitation. Determination may be by direct weighing of samples or by microscopic counting. A commonly used method employs the Smith-Greenburg impinger which collects samples in water or alcohol and in which particles are counted under a microscope in various cells such as the Hatch or Dunn cells. Another method employs the Lewis [41] sampling tube with the analytical determination of the increase in weight of a porous crucible. All reports should state the method of sampling and counting. The A.S.H.V.E. Code for Testing and Rating Air Cleaning Devices Used in General Ventilation Work specifies the porous crucible method [42].