and one up-stream, is sometimes used for low velocities, but it should be carefully calibrated for accurate results. A special form of this tube design consists of two straight 1/8 in. tubes soldered together, closed at the end, and with a 0.04 in. hole in each tube opposite the line of contact. This tube is useful in exploring velocities on exhaust inlets, such as on hoods placed around grinding wheels.

The rounded approach orifice or nozzle of the general type described in the A.S.H.V.E. Unit Heater[12] and Unit Ventilator[13] Codes is an accurate air measuring device. When it is well made, the coefficient closely approaches unity. The discharge from such a nozzle is uniform[14] and provides a good location for calibration of air velocity instruments[15].

The Venturi meter is like the nozzle except for the addition of a downstream transition section that reduces the pressure drop through the measuring apparatus.

The thin-plate square-edged orifice has a decided advantage over the nozzle and Venturi meter in cost. Its coefficient is approximately 0.60. The exact value depends on the location of the connections, the pressure drop, the diameter ratio of orifice to pipe, and the sharpness of the edge[16].

Another method of air measurement uses the thermal electric principle where by means of a measured amount of current, heat is put into the air stream. The temperature rise is measured, and with the specific heat of the air mixture known, the weight of air flowing may be calculated. Heat should be applied uniformly to the mass of air passing, and the small temperature difference must be determined accurately.

Air Currents in Free Spaces

One of the instruments useful in determining the velocity of air currents in free spaces is the Kata-thermometer. It is essentially an alcohol thermometer with a large bulb. The stem has two marks, one corresponding to 95 F, and the other 100 F. The instrument is heated in water above 100 F, then dried and the time in seconds required for it to cool from 100 to 95 when placed in the air current gives a measure of the non-directional velocity. It is important to wipe the Kata-thermometer dry before taking the reading. Each Kata has its own factor etched on the stem, and this factor must be used with its cooling formula or chart for obtaining the velocity. The Kata-thermometer is useful in exploring ventilated spaces to determine whether the proper air movement and distribution are being maintained. It is also used in determining the cooling power of the atmosphere, since it loses heat by radiation and convection when dry, and by radiation, convection, and evaporation when the bulb is equipped with a wetted cloth covering[17].

Another instrument for measuring low velocity air currents is the heated thermometer anemometer[18]. This consists of an ordinary mercurial glass thermometer with a resistance winding on the bulb. Current is supplied from an external source in a measured amount. The temperature rise shown on this heated thermometer over that shown by an ordinary thermometer at the same location, and the current supplied, make it possible to calculate the non-directional velocity of the air stream. Since a smaller bulb is used than that on the Kata-thermometer, it is less affected by radiant heat sources.

The heated thermocouple anemometer employs a thermocouple instead of a thermometer[19].

Another instrument is the hot wire anemometer which has been made in several patterns. In general, a measured current is supplied to raise the temperature of a fine bare wire above the temperature of the surrounding air. With the use of a very fine wire, minute fluctuations in velocity may be measured, and the area exposed to radiant exchange with heated or cooled surfaces is at a minimum. This instrument is easily adapted to remote reading or recording. A group of them may be connected together to give the average velocity in a space, or the velocity at individual points within a test space, by suitable switching arrangements[20,21].

Deflecting Vane Anemometer

The deflecting vane anemometer consists of a pivoted vane enclosed in a case, against which air exerts a pressure as it passes through the instrument from an up-stream to a down-stream opening. The movement of the vane is resisted by a hair spring and a damping magnet. The instrument gives instantaneous readings of directional velocities on an indicating scale. When used in fluctuating velocities, it is necessary to average visually the swings of the needle to obtain average velocities. This instrument is very useful for studying mixing of air in a room[22] and in locating and measuring peak velocities that may be objectionable. Various attachments are available, such as the double tube arrangement for obtaining velocities in ducts, and a device for measuring static pressures. Each instrument and the attachments for it must receive individual calibration.

Propeller or Revolving Vane Anemometer

The propeller or revolving vane anemometer consists of a light revolving wheel connected through a gear train to a set of recording dials that read the linear feet of air passing in a measured length of time. It is made in various sizes, 3 in., 4 in., and 6 in. being most common. Each instrument requires individual calibration. At low velocities the friction drag of the mechanism is considerable. In order to compensate for this, a gear train that overspeeds is commonly used. For this reason the correction is often additive at the lower range and subtractive at the upper range with the least correction in the middle range of velocities. Most of these are not sensitive enough for use below 200 fpm.

Measurement of Velocities at Inlets and Outlets of Ducts

In the field it is often advisable to make volume measurements at the

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[12] Standard Code for Testing and Rating Steam Unit Heaters (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930, p. 165), adapted January, 1930 by A.S.H.V.E.

[13] A.S.H.V.E. Standard Code for Testing and Rating Steam Unit Ventilators (A.S.H.V.E. TRANSACTIONS, Vol. 38, 1932, p. 25), adopted June, 1932.

[14] Discharge Coefficients of Square Edged Orifices for Measuring the Flow of Air, by H. S. Bean, E. Buckingham and P. S. Murphy (*Bureau of Standards Journal of Research*, Vol. 2, 1929, p. 561).

[15] A.S.H.V.E. RESEARCH REPORT No. 1140—The Use of Air Velocity Meters, by G. L. Tuve, D. K. Wright, Jr. and L. J. Seigel (A.S.H.V.E. TRANSACTIONS, Vol. 45, 1939, p. 645).

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[22] A.S.H.V.E. RESEARCH REPORT No. 1204—Entrainment and Jet-Pump Action of Air Streams, by G. L. Tuve, G. B. Priester and D. K. Wright, Jr. (A.S.H.V.E. TRANSACTIONS, Vol. 48, 1942, p. 241).