

section at the Pitot station by use of a long transition piece. In any case, a large number of readings in two traverses should be taken, with 20 being quite desirable. These should be taken at the centers of equal areas for correct determination of volumes. For round pipe, these would be located from the center by multiplying the radius by the following factors: 0.316, 0.548, 0.707, 0.837 and 0.961. A fundamentally correct method of measurement is obtained with a Pitot tube and therefore it can be used without calibration. For small pipes it is sometimes necessary to construct a Pitot tube smaller than the standard size. Such a small Pitot tube should be geometrically similar to the standard tube. Pulsating or disturbed flow will give erroneous results and every effort should be made to remove disturbances in the Pitot tube section.

Many forms of Pitot tubes other than the one described have been used and calibrated⁶. A double-ended tube, one end pointing down-stream, 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 $\frac{1}{8}$ 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 Heater⁷ and Upit Ventilator⁸ Codes is an accurate air measuring device. When it is well made, the coefficient closely approaches unity. The velocity at the mouth is increased over that in the duct, and the resulting increased velocity pressures may be measured accurately. The discharge from such a nozzle is uniform⁹ and provides a good location for calibration of air velocity instruments¹⁰.

The Venturi meter is like the nozzle except for the addition of a down-stream transition section that reduces the friction drop through the measuring apparatus. Since a good one is expensive, the Venturi meter is seldom used with gases, although it is often used to measure liquids.

The thin-plate square-edged orifice has a decided advantage over the rounded approach orifice 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 edge¹¹.

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.

⁶Technical Notes No. 546, (National Advisory Committee for Aeronautics, November, 1935).

⁷Standard Code for Testing and Rating Steam Unit Heaters (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930, p. 165).

⁸Standard Code for Testing and Rating Steam Unit Ventilators (A.S.H.V.E. TRANSACTIONS, Vol. 38, 1932, p. 25).

⁹Discharge 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 Research*, Vol. 2, 1929, p. 581).

¹⁰A.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).

¹¹Flow Measurement by Nozzles and Orifice Plates (A.S.M.E. Power Test Codes, Chapter 4 of Part 5, 1940).

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 above 100 F, and the time in seconds required for it to cool from 100 to 93 when placed in the air current gives a measure of the non-directional velocity. The usual way of heating the bulb is in a water bath, and it is important to wipe the Kata-thermometer dry before taking the reading. A thermodynamically controlled water bath is very convenient to use along with two instruments so one may be heating while the other is in use. For high atmospheric temperatures the high temperature Kata with a range of 130 to 135 F may be used. Usually several readings are taken in a given location and the average used. Each Kata has its own factor etched on the stem, and this factor must be used with the 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 is being maintained. The Kata-thermometer also finds use 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 covering¹².

Another instrument for measuring low velocity air currents is the heated thermometer anemometer¹³. 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.

Another instrument is the hot wire anemometer which is available 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 made 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^{14,15}.

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.

¹²Temperature, Humidity and Air Motion Effects in Ventilation, by O. W. Armspach and Margaret Ingels (A.S.H.V.E. TRANSACTIONS, Vol. 28, 1922, p. 103).

¹³The Heated Thermometer Anemometer, by C. P. Yaglou (*Journal Industrial Hygiene and Toxicology*, Vol. 20, October 1938, No. 8).

¹⁴Development of Testing Apparatus for Thermostats, by D. D. Wile (A.S.H.V.E. TRANSACTIONS, Vol. 42, 1936, p. 349).

¹⁵Linear Hot Wire Anemometer, Its Application to Technical Physics, by L. V. King (*Journal Franklin Institute*, 1916).