static pressure rise: the algebraic difference between the static pressure at the fan outlet and the static pressure at the fan inlet.

static suction lift: the same as the *static discharge head*, except that it has a negative value and it is measured at the inlet to the pumping device.

4. INSTRUMENTATION

4.1 Scope. This section covers the required or recommended instrumentation needed to obtain the measurements required for air or fluid system balancing as well as other instruments that are useful or necessary in special situations.

For each instrument, this section provides a description, recommended uses, limitations, accuracy requirements, and calibration requirements.

4.2 General. Great care should be taken to follow the manufacturers' instructions and the instructions herein regarding safety in the use of these instruments for field measurements.

This standard does not preclude the use of new instruments as they are developed and proven to be as accurate as, or more accurate than, the instruments described herein.

For detailed instructions on the use, limitations, and accuracy of the instruments under field conditions, see Sections 7 through 11 on system effects, measurements, and testing and balancing.

4.3 Air-Balancing Instruments

4.3.1 Inclined Manometer

4.3.1.1 Description. The inclined manometer is made of a single tube, inclined (usually with a 10:1 slope) to enlarge the reading. Alcohol or special oils are normally used in place of water. Such oils have a lower specific gravity than water and, thus, serve to further enlarge the reading. Manometers using such fluids have scales calibrated in inches of water (Pascals) corresponding to the pressure indicated on the oil of a known specific gravity.

4.3.1.2 Recommended Uses. Use with Pitot static tubes or static pressure probes.

4.3.1.3 Limitations

a. Not to be used to measure air velocities less than 600 fpm (3.0 m/s). A micromanometer, hook gauge, or another sensitive instrument shall be used for acceptable accuracy in this range.
b. In using the manometer, it must be carefully leveled and held in a rigid position so that when "0" pressure is registered, the end of the meniscus arc of the fluid exactly bisects the center of the zero line.

4.3.1.4 Calibration Required. Every 12 months, the instrument shall be verified with a recently calibrated instrument, and if the reading on the instrument to be verified is not within 2% of the reading on the reference instrument (recently calibrated instrument), then the instrument must be calibrated before it can be used.

4.3.2 Combination Vertical-Inclined Manometer

4.3.2.1 Description. The combination vertical-inclined manometer is constructed of an inclined fluid column with a scale of 0 to 1.0 in of water (0 to 250 Pa) or 0 to 2.0 in. of water (0 to 500 Pa) connected to a vertical fluid column with scales of 5 in. of water (1250 Pa) or 10 in. of water (2500 Pa).

4.3.2.2 Recommended Uses. Use with Pitot static tubes or static pressure probes.

4.3.2.3 Limitations

a. Not to be used to measure air velocities less than 600 fpm (3.0 m/s). A micromanometer, hook gauge, or another sensitive instrument shall be used for acceptable accuracy in this range.
b. In using the manometer, it must be carefully leveled and held in a rigid position so that when "0" pressure is registered, the end of the meniscus arc of the fluid exactly bisects the center of the zero line.

4.3.2.4 Calibration Required. Every 12 months, the instrument shall be verified with a recently calibrated instrument, and if the reading on the instrument to be verified is not within 2% of the reading on the reference instrument (recently calibrated instrument), then the instrument must be calibrated before it can be used.

4.3.3 Pitot Static Tube

4.3.3.1 Description. A Pitot static tube, used in conjunction with a manometer, provides a basic method of determining the air velocity within a duct. The typical Pitot static tube is of a double concentric tube construction, consisting of a 1/8 in. (3.2 mm) O.D. inner tube that is concentrically located inside a 5/16 in. (7.9 mm) O.D. outer tube. The outer static tube has eight equally spaced 0.04 in. (1.02 mm) diameter holes around the circumference of the outer tube, located 2.5 in. (63.5 mm) back from the nose or open end of the Pitot tube tip. At the base end, or tube-connection end, the inner tube is open ended, as is the head. The outer tube has a side outlet tube connector perpendicular to the outer tube, directly parallel with and in the same direction as the head end of the Pitot static tube.

4.3.3.2 Recommended Uses

a. Use to measure airstream "total pressure" by connecting the inner tube outlet connector to one side of a manometer or draft gauge.
b. Use to measure airstream "static pressure" by connecting the outer tube side outlet connector to one side of a manometer or draft gauge.
c. Use to measure airstream "velocity pressure" by connecting both the inner and outer tube connectors to opposite sides of a manometer or draft gauge.
d. This instrument, when used with a manometer or micromanometer, is a reliable and rugged instrument. Its use is preferred over any other method for the field measurement of air velocity, system total air, outdoor air, return air quantities, fan static pressure, fan total pressure, and fan outlet velocity pressures, where such measured quantities may be required.
e. The following instruments may be used with the Pitot static tube:

1. Micromanometer—very low pressure differential, less than 1.0 in. of water (250 Pa)
2. Inclined manometer—moderate pressure differential, 0 to 10 in. of water (0 to 2500 Pa)
3. U-tube manometer—medium pressure differential, greater than 10 in. of water (2500 Pa)
4. Diaphragm-type pressure gauge
5. Electronic differential pressure meters

4.3.3.3 Limitations

a. The accuracy depends upon uniformity of flow and completeness of traverse.
b. A reasonably large space is required adjacent to the duct penetrations for maneuvering the instrument.
c. Care must be taken to avoid pinching instrument tubing.
d. Because of the distance between the impact and static holes, the Pitot static tube cannot be used to measure flow through orifice-type openings.
e. The Pitot static tube is susceptible to plugging in airstreams with heavy dust or moisture loadings.
f. Acceptance of the standard Pitot static tube is due to its accuracy in the correct determination of the static pressure. The total pressure is not affected by yaw or angularity up to approximately 8° on either side of parallel flow. The static pressure, however, is extremely sensitive to direction of flow.

4.3.3.4 Accuracy of Field Measurement. Rigorous error analysis shows that flow rate determinations by the Pitot static tube and manometer combination method can range from 5% to 10% error. Experience shows that qualified technicians can obtain measurements that range within 5% and 10% accuracy of actual flow under good field conditions. It has also been determined that suitable traverse conditions do not always exist, and measurements can then exceed a ±10% error rate.

4.3.3.5 Calibration Required. Every 12 months, the instrument shall be verified with a recently calibrated instrument, and if the reading on the instrument to be verified is not within 2% of the reading on the reference instrument (recently calibrated instrument), then the instrument must be calibrated before it can be used.

4.3.4 Chronometric Tachometer

4.3.4.1 Description. The chronometric tachometer is a hand-held instrument that combines an accurate timer and a revolution counter into one instrument. After the instrument tip is placed on the rotating shaft, the stopwatch button is depressed, which simultaneously activates the counter and the stop watch. After the timer has run for an accurately timed interval of 3 or 6 s, the instrument stops accumulating revolutions, even though it is still in contact with the rotating shaft. The scale is calibrated so that, with the 3 or 6 s stopwatch mechanism used in the instrument, the readings are read directly in rpm. Instrument accuracy shall be within ±0.5% of the scale range.

There are hand tachometers capable of producing instantaneous rpm measurement readings, such as the dial-face (Eddy-current) type or solid-state instruments with digital readout. Instrument accuracy shall be within ±1% of full-dial scale or range.

4.3.4.2 Recommended Uses. Use to determine the speed of any shaft having a countersunk end.

4.3.4.3 Limitations. The shaft end must be accessible and countersunk.

4.3.4.4 Accuracy of Field Measurements. Within one-half of a scale division mark.

4.3.4.5 Calibration Required. Check against readings made with a recently calibrated chronometric tachometer on each project. If the reading is not within ±2% of the recently calibrated tachometer, have the instrument tested for calibration.

4.3.5 Clamp-On Voltammeter

4.3.5.1 Description. The clamp-on type voltammeter has trigger-operated, clamp-on transformer jaws that permit current readings without interrupting electrical service. Most voltammeters have several scale ranges in amperes and volts. Two voltage test leads are furnished, which may quickly be connected to the bottom of the voltammeter opposite the end used for measuring current. Some of the voltammeter models are furnished with a built-in ohmmeter. Instrument accuracy is within ±3% of full scale.

4.3.5.2 Recommended Uses. Use to measure operating voltages and currents of electric motors and of electric-resistance heating coils.

4.3.5.3 Limitations

a. The proper range must be selected. When in doubt, begin with the highest range for both voltage and current scales. It is desirable for readings to occur about midscale. The accuracy of reading low currents can be improved by looping the conductor wire around the jaw once and dividing the current reading by two (2).
b. Depending upon the conditions at the point of measurement and the size of the voltammeter, access for measurement may be restrictive. Caution is required, particularly when taking measurements under confined conditions.
c. To avoid distortion of current readings by other fields, move the meter along the wire to verify that the reading remains constant.

4.3.5.4 Accuracy of Field Measurements. ±3% of full scale.

4.3.5.5 Calibration Required. Check against readings made with a recently calibrated clamp-on volt-ammeter on each project. If the reading is not within ± 2% of the recently calibrated instrument, have the instrument tested for calibration.

4.3.6 Deflecting Vane Anemometer

4.3.6.1 Description. The deflecting vane anemometer consists of a pivoted vane enclosed in a case. Air exerts a pressure upon the vane as it passes through the instrument from an upstream to a downstream opening. The movement of the vane is resisted by a hairspring. The instrument gives instantaneous readings of directional velocities on an indicating scale. The instrument is supplied with various types of remote and direct-connected measuring tips, or jets.

4.3.6.2 Recommended Uses

a. This instrument may be used for measurement of air quantities through both supply and return air terminals using the proper air-terminal factor, A_k (effective area), for airflow calculation.
b. This instrument may also be used for indicating low velocities (100 to 300 fpm, 0.5 to 1.5 m/s) where the instrument case itself with the appropriate probe attached is placed in the airstream, as within a hood or booth.

4.3.6.3 Limitations

a. The instrument shall not be used in extremely hot, cold, or contaminated air.
b. The instrument is affected by static electricity.
c. The instrument duct probe is sensitive to the presence and proximity of duct walls and tends to read high on the suction side and low on the discharge side of a fan.
d. The accuracy of the instrument is affected by position.

4.3.6.4 Accuracy of Field Measurements. Accuracy is within ±10% when the instrument is within calibration and used in accordance with the manufacturer's recommendations. Terminal A_k factors are a function of duct and damper conditions which affect the velocity immediately before the terminal. Use of this instrument with conditions not identical to the terminal manufacturer's test conditions produces measurement error. The instrument must be calibrated in the field for correction factor by Pitot-tube traverse within the limitations of the system.

4.3.6.5 Calibration Required. Check against readings made with a recently calibrated deflecting vane anemometer on each project. If the reading is not within ±2% of the recently calibrated instrument, have the instrument tested for calibration.

4.3.7 Revolving Vane or Propeller Anemometer

4.3.7.1 Mechanical Type

4.3.7.1.1 Description. The mechanical propeller or revolving vane anemometer consists of a light, wind-driven wheel connected through a gear train to a set of recording dials that read the linear feet (meters) of air passing through the wheel in a measured length of time. The instrument is made in various sizes, but 3, 4, and 5 in. (75, 100, and 125 mm) are the most common. Each instrument requires individual calibration. The required instrument accuracy of calibration is 1%–3% of scale (using a corrective chart).

4.3.7.1.2 Recommended Uses

a. Use to measure supply, return, and exhaust air quantities at registers and grilles.
b. Use to measure air quantities at the faces of return air dampers or openings, total air across the filter or coil face areas, etc.

4.3.7.1.3 Limitations

a. Each reading from this instrument must be corrected by its calibration chart.
b. The air terminal manufacturer's specified A_k factor for the terminal must be used in computing air quantities.
c. Total inlet area of the instrument must be in the measured airstream.
d. It is not suitable for measurement in ducts.
e. It is fragile and cannot be used in dusty or corrosive air.
f. Since the instrument has a turbine wheel of very low inertia, caution is advised as to reliability of readings in nonuniform, turbulent, or stratified airstreams. This is likely to occur downstream of dampers, face and bypass coils, or any device that causes turbulence in the airstream being measured.
g. The instrument is not direct reading and, therefore, must be timed manually.
h. At low velocities, the friction drag of the mechanism is considerable. In order to compensate for this, a gear is commonly used. For this reason, the correction is additive at the lower range and subtractive at the upper range, with the least correction in the middle of the range. Most of these instruments are not sensitive enough for use below 200 fpm (1.0 m/s), although ball-bearing models claim ranges down to 30 fpm (0.15 m/s). The useful range is from 200 to 2000 fpm (1.0 to 10.0 m/s).

4.3.7.1.4 Accuracy of Field Measurements

a. Smooth flow ±5% of reading above 200 fpm (1.0 m/s); not recommended for velocities below 200 fpm (1.0 m/s)
b. Nonuniform flow ±30%
c. The instrument must be calibrated in the field for a correction factor by Pitot-tube traverse within the limitations of the system.

4.3.7.1.5 Calibration Required. The instrument shall be calibrated by the manufacturer or other agency every six (6) months, depending on usage. Check against readings made with a recently calibrated instrument on each project. If the reading is not within ±2% of the recently calibrated instrument, have the instrument tested for calibration.

4.3.7.2 Direct Reading Digital Type

4.3.7.2.1 Description. This instrument is the same as the mechanical type in most respects, except that it uses a powered electronic circuit to convert a pulse generated by the rotating vane into a small electric current to give a meter reading calibrated directly in air velocity units. Generally, these instruments have microprocessor software to compensate for any nonlinearity.

4.3.7.2.2 Recommended Uses

a. Use to measure supply, return, and exhaust air quantities at registers and grilles.
b. Use to measure air quantities at the faces of return air dampers or openings or of total air across the filter or coil face areas, etc.

4.3.7.2.3 Limitations

a. The air terminal manufacturer's specified A_k factor (effective area) for the terminal must be used in computing air quantities.

b. The total inlet area of the instrument must be placed in the measured airstream.
c. It is not suitable for measurement in ducts.
d. It is fragile and cannot be used in dusty or corrosive air.
e. Since the instrument has a turbine wheel of very low inertia, caution is advised as to reliability of readings in nonuniform, turbulent, or stratified airstreams. This is likely to occur downstream of dampers, face and bypass coils, or any device that causes turbulence in the airstream being measured.
f. At low velocities, the friction drag of the mechanism is considerable. In order to compensate for this, a gear is commonly used. For this reason, the correction is additive at the lower range and subtractive at the upper range, with the least correction in the middle of the range. Most of these instruments are not sensitive enough for use below 200 fpm (1.0 m/s), although ball-bearing models claim ranges down to 30 fpm (0.15 m/s). The useful range is from 100 to 5000 fpm (0.51 to 25.4 m/s).

4.3.7.2.4 Accuracy of Field Measurements

a. For smooth flow: ±5% of reading above 200 fpm (1.0 m/s); Not recommended for velocities below 50 fpm (1.0 m/s).
b. For nonuniform flow: ±30%
c. For volume measurements, a correction factor must be established in the field by Pitot-tube traverse (the average velocity of the traverse must be > 1200 fpm for accuracy).

4.3.7.2.5 Calibration Required. By the manufacturer or other agency every six (6) months, depending on usage. Check against readings made with a recently calibrated instrument on each project. If the reading is not within ±2% of the recently calibrated instrument, have the instrument tested for calibration.

4.3.8 Thermal Anemometer

4.3.8.1 Description. The operation of this instrument depends on the principle that the resistance of a heated wire will change with its temperature. Incorporated with the instrument is a probe that is provided with a special type of wire element energized by batteries contained in the instrument case. As air flows over the element in the probe, the temperature of the element is changed from that which exists in still air. The resistance change is indicated as a velocity on the indicating scale of the instrument. Similar instruments are available using a heated thermocouple or heated thermistor instead of a hot wire. They have similar characteristics regarding uses, limitations, and accuracy to the thermal anemometer.

Some instruments are also provided with temperature scales that can be utilized simply by setting the proper selector button. Some instruments can measure static pressure with provided accessories.

4.3.8.2 Recommended Uses

a. Use to measure very low air velocities, such as room air currents and airflow in hoods (10 to 600 fpm; 0.05 to 3.0 m/s).
b. Use for measurements at grilles and diffusers.
c. Use for velocity measurements within ducts.

4.3.8.3 Limitations

a. The probe that is used with this instrument is very directional for velocity readings and must be located at the exact point on the diffuser or grille as specified by the terminal-unit manufacturer.
b. Probes are subject to fouling by dust and corrosive air.
c. The instrument probe must be used in the direction of calibration.
d. In general, these instruments should not be used in flammable or explosive atmospheres. However, there are special thermal anemometer probes available for use in these environments.

4.3.8.4 Accuracy of Field Measurements. Accuracy is ±10% above 100 fpm (0.5 m/s). The instrument must be calibrated in the field for the correction factor by Pitot-tube traverse within the limitations of the system.

4.3.8.5 Calibration Required. By the manufacturer or other agency every six (6) months. In addition, check the instrument against readings made with a recently calibrated instrument on each project. If the reading is not within ± 2% of the recently calibrated instrument, have the instrument tested for calibration.

4.3.9 Mercury Thermometers

4.3.9.1 Description. Mercury-filled glass-tube thermometers have a useful temperature range of –38°F to 950°F (–36°C to 510°C). They are available in a variety of temperature ranges, scale graduations, and lengths. The required instrument test accuracy minimum must be within a scale division mark.

4.3.9.2 Recommended Uses

a. The complete-stem-immersion calibrated thermometer must be used with the stem completely immersed in the fluid in which the temperature is to be measured.
b. Thermometers calibrated for partial stem immersion are more commonly used. They are used in conjunction with thermometer test wells specifically designed to receive them. No emergent stem correction is required for the partial-stem-immersion type.

4.3.9.3 Limitations

a. Radiation effects—When the temperature of the surrounding surfaces are substantially different from the measured fluid, there is a considerable radiation effect upon the thermometer reading if the thermometer is left unshielded or otherwise unprotected. Proper shielding or aspiration of the thermometer bulb and stem can minimize these radiation effects.
b. Time is required for the thermometer to reach the temperature of the fluid being measured.
c. Mercury may separate in the tube.

4.3.9.4 Accuracy of Field Measurements. Within one-half of a scale division mark.

4.3.10 Dial Thermometers

4.3.10.1 Description. Dial thermometers are of two general types: the stem type and the flexible-capillary type.