NEBB STANDARDS SECTION-6, PART 2 PROCEDURES

SECTION 6 BASIC TAB MEASUREMENTS

6.1 INTRODUCTION

The purpose of this Section is to describe the procedures used in making basic TAB measurements. These recommended procedures are to be followed for all TAB measurements so that the reported data is accurate and repeatable. Basic TAB measurements will be performed on air, water and possibly other fluids of various densities to determine properties, conditions, and flow rates of the fluids.

The ability to take accurate and repeatable measurements may depend on the skill of the technicians and measurement locations. The NEBB Certified TAB Firm is responsible to determine the appropriate location for all air and hydronic test measurements at terminals, equipment, ducts, and piping.

For air systems, it is necessary for the NEBB Certified TAB Firm to drill test holes for the purpose of taking measurements in ducts or equipment. These test holes shall be appropriately sized and sealed with the appropriate industry standard plugs when the measurements have been completed.

For hydronic systems, it is necessary to have test ports or pipe taps provided at equipment and in the piping system for pressure and temperature measurements. It is the NEBB Certified TAB Firm’s responsibility to advise the installing contractors where test ports are to be located. It is the responsibility of the installing contractors to furnish and install these test ports.

6.2 AIR PRESSURE PROCEDURES

The following procedures describe the methods to be utilized when making pressure measurements. While the procedures outlined here are prescriptive, instrumentation use should always be in accordance with the manufacturer’s recommendation. All instrumentation used for pressure measurements shall conform to the requirements of Table 4-1 for function, range, accuracy, and resolution.

6.2.1 INSTRUMENTS

The following instruments are typically utilized to perform pressure measurements:

- Electronic-Digital Manometer
- Inclined-Vertical Manometer
- U-Tube Manometer
- Magnehelic Gauge
- Pitot or Static sensing tips

Air pressure measurements for HVAC TAB procedures are accomplished with a manometer, connecting tubing and an appropriate sensing tip. This manometer may be as basic as an inclined oil manometer or as sophisticated as a multi-function instrument with manometric capabilities. In all cases the measurement of air pressure in an HVAC system is the basic measurement from which the most important system performance data is derived.

Static Pressure (SP) in an HVAC System is the potential energy a system possesses at the point of measurement to produce and maintain airflow against duct resistance, and can be either a positive or a negative value relative to the atmosphere.

Velocity Pressure (VP) is the kinetic energy of the airflow in a duct system, and is exerted only in the direction of the airflow. Velocity pressure cannot be measured directly; it is the difference between the *total pressure* and the *static pressure* at the point of measurement.

Total Pressure (TP) is the maximum pressure on a plane normal to the direction of flow. An impact tube, which is an open tube faced directly into the fluid stream, is used to measure *total pressure*. It is the sum of the *static pressure* and the *velocity pressure* at the point of measurement in the system. **(TP = SP + VP).**

6.2.2 GENERAL MEASUREMENT TECHNIQUES

It is important to note that field measurement of static pressures is not a reliable tool for analyzing fan performance. Accurate assessments of fan performance in the installed condition require rpm, airflow, power data, and an evaluation of System Effect. See the current edition of the following publications when attempting to evaluate system performance from field measurements: *AMCA 201 Fans and Systems, AMCA 203 Field Performance Measurements of Fan Systems,* and *AMCA 210 Laboratory Method of Testing for Aerodynamic Performance Rating.* The impact of System Effect should be taken into account during the design phase, but can occur because of installation problems.

Static pressure measurements are properly performed with a calibrated manometer and a Pitot tube or a static probe. Simply inserting a tube end into an air stream without a static tip or Pitot tube probe will result in significant measurement errors.

Velocity pressure measurements require the use of a Pitot tube and a calibrated manometer.

Examples of proper tubing connections to achieve the required measurements may be found in the current edition of the NEBB *Testing Adjusting Balancing Manual for Technicians.*

6.2.3 SPECIFIC MEASUREMENT TECHNIQUES

TAB specifications frequently ask the TAB firm to provide measurements of total static pressure and / or external static pressure across a fan or air handling system. When measuring static pressures on a fan it is important to understand that external static pressure refers to the sum of the absolute value of the pressures measured in the

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ductwork immediately external to the unit. Total static pressure refers to the sum of the absolute value of the pressures at the inlet and discharge of the fan.

6.3 AIR VELOCITY PROCEDURES

The following procedures describe the methods to be used when making air velocity measurements. While the procedures outlined here are prescriptive, instrumentation use should always be in accordance with the manufacturer's recommendation. All instrumentation used for air velocity measurements shall conform to the requirements of Table 4-1 for function, range, accuracy, and resolution.

6.3.1 INSTRUMENTS

The following instruments are typically utilized to perform air velocity measurements:

- Electronic-Digital Manometer
- Inclined-Vertical Manometer
- Magnehelic Gauge
- Pitot Tubes
- Airfoil Probes
- Rotating Vane anemometer
- Swinging Vane anemometer
- Bridled Vane anemometer
- Thermal Anemometer (Hot Wire)
- Velocity Grid

6.3.2 GENERAL MEASUREMENT TECHNIQUES

Air velocity measurements typically are performed in ducts; at the face of a grille, register or diffuser (GRD), at the inlet of a fume hood or bio-safety cabinet, at coils, at filter banks or at other designated points. Generally the measurements are performed to quantify the airflow performance of a particular piece of equipment or ducts under certain conditions.

It is important to note that field measurement of air velocity / total airflow is not a perfect tool for analyzing fan performance. Accurate assessments of fan performance in the installed condition require rpm, static pressure, power data, and an evaluation of System Effect. See the current edition of the following publications when attempting to evaluate system performance from field measurements: *AMCA 201 Fans and Systems*, *AMCA 203 Field Performance Measurements of Fan Systems*, and *AMCA 210 Laboratory Method of Testing for Aerodynamic Performance Rating.* The impact of System Effect should be taken into account during the design phase, but can occur because of installation problems.

Duct air velocity measurements typically are performed to determine air volume in a duct by Pitot tube traverses. The Pitot tube traverse, properly conducted, is the basis for all other airflow measurements performed by a NEBB Certified TAB Firm.

Other instruments used for air velocity measurements are rotating vane anemometers, swinging vane anemometers, bridled vane anemometers, thermal anemometers, velocity grids, etc. These devices are typically used for measurements where flow hoods are not appropriate, or where the air velocities are too low for accurate measurement by a Pitot tube traverse. In all cases the instrument manufacturer's application recommendations shall be followed. The measurements shall also comply with the recommendations of the manufacturer of the equipment to be measured. As an example most kitchen hood manufacturers have specific testing criteria to be followed when testing their products in the installed condition.

6.3.3 SPECIFIC MEASUREMENT TECHNIQUES

The Pitot tube traverse in a duct is performed as follows:

a) Measure the external dimensions of the duct to be traversed.

b) Determine if the duct is internally lined. This may require the drilling of an exploratory hole to allow the thickness of the liner, if present, to be measured.

c) Rectangular ducts may be traversed by either the *equal area method* or the *Log Tchebycheff method.* As of the date of this Standard, there is no credible evidence indicating that one method is more accurate than the other. NEBB makes no recommendation for either method, however the equal area method technique is easier to set up.

d) Mark the Pitot tube at the correct points, and connect the tubing to the Pitot tube and manometer. Verify the "zero" of the instrument as required prior to inserting the Pitot tube into the duct.

e) Insert the tube into the duct. The tip of the Pitot tube shall point into the air stream, and be parallel with the direction of airflow.

f) Perform and record a measurement of air velocity at each required point. If the selected instrument does not report velocity, each pressure measurement will require conversion to velocity before calculating the average velocity. Once the average duct velocity is determined, multiply the average velocity by the cross-sectional duct area (inside the insulation if applicable). The result is the total airflow volume in cfm or L/S.

g) Round duct is traversed by the equal area method. Only two holes are required to be drilled in the duct. The Pitot tube is marked in accordance with the table(s) in the NEBB *TAB Manual for Technicians*. The same technique to calculate airflow volume from average velocity, from (f) above, is used for calculating the round duct traverse volume.

h) The accuracy of a Pitot tube traverse is determined by the availability of a suitable location to perform the traverse. Suitability of the location is determined by the quality of the data measured. The traverse data is acceptably accurate if 75% of the readings are greater than 10% of the maximum value recorded during the traverse. *It is important to note that the acceptability of the traverse plane is determined solely by the quality of the data, and not necessarily by the location of the traverse plane.*

6.3.4 FACE VELOCITY MEASUREMENTS

The use of anemometers or velocity grids to measure air velocities at the face of a grille, register or diffuser, etc. is quite common, but generally not accurate when determining airflow without the incorporation of a correction factor. There are many variables in the measurement of airflow in the field that will affect the accuracy of any reading. The most appropriate method to compensate for the inherent uncertainty of these face velocity measurements is to develop a field correction factor when manufacturer's correction factors are not available. This is usually accomplished by performing a Pitot tube traverse of the duct leading to a typical terminal device and calculating the duct airflow. The air velocity reading at the face of the equipment being tested is then multiplied by a factor to generate an airflow value equal to the Pitot tube traverse. This factor can then be generally applied to similar situations to determine airflow at other points. *It is important to remember that the correction for any piece of equipment is specific to the instrument, and will vary with air velocity at the measurement point, deflection of vanes, etc.* If possible, it is best to construct a correction factor curve specific to each piece of equipment for several different velocities.

In general the above techniques do not require corrections for air density below 2,000 feet elevation or normal HVAC temperatures. Corrections can be calculated when necessary by use of the following equations:

<u>Equation 6-1</u>

ENGLISH (IP) UNITS **SI (METRIC) UNITS**

$$V = 1096.2\sqrt{\frac{V_p}{D}}$$

$$V = 1.414\sqrt{\frac{V_p}{D}}$$

Where: V = Air velocity – fpm (m/s)
V_P = Velocity pressure – in.w.g. (pascals)
D = Air density – lb/ft^3 (kg/m^3)

It is necessary to know the density of the air in order to use the above equations. Air density can be calculated as follows:

Equation 6-2

$$D = \frac{1.325 P_B}{(460 + T)} \qquad D = \frac{3.48 P_B}{(273 + T)}$$

Where:

P_B = Absolute static pressure - in. Hg (kPa)
(Barometric pressure + Static pressure)
T = Air temperature -°F (°C)

6.4 TEMPERATURE MEASUREMENT PROCEDURES

The following procedures describe the methods to be utilized when making temperature measurements. While the procedures outlined here are prescriptive, instrumentation use should always be in accordance with the manufacturer's recommendation. All instrumentation used for temperature measurements shall conform to the requirements of Table 4-1 for function, range, accuracy, and resolution.

6.4.1 INSTRUMENTS

The following instruments are typically utilized to perform temperature measurements:

- Liquid-in-glass thermometer
- Dial thermometer with a bi-metal helix coil
- Thermocouples
- Electric resistance thermometers including thermistors
- Psychrometers
- Electro Thermohygrometers

6.4.2 GENERAL MEASUREMENT TECHNIQUES

The purpose of most temperature measurements in TAB work is in connection with determination of heat flow, or in determining a heat balance. A heat balance calculation from measured data will never be perfect for a variety of reasons:

a) Radiant heat effects on temperature measuring instruments.
b) Effects of thermal storage of conduits and enclosures; i.e. ducts, pipes, etc.
c) Lack of a uniform temperature / velocity profile.
d) Use of standardized constants in equations representing average fluid values for density, specific heating value, etc.
e) Instrumentation accuracy, precision, and sensitivity.

For determining heat flow or heat balance, the TAB technician will be dealing with temperature differential. There are three issues of prime importance when taking temperature measurements:

1) Thorough mixing of the fluid entering and leaving the heat transfer equipment.
2) Steady state of the heat transfer conditions.
3) Using the same instrumentation.

Each of these issues needs to be understood prior to taking field measurements.

Adequate Mixing:
Adequate mixing is more readily available in hydronic systems than air systems. In air systems, a uniform temperature profile and its associated velocity profile sometimes can be impossible to achieve. For hydronic systems, thorough mixing normally can be attained due to the elbows immediately adjacent to the heat transfer equipment.

Steady State:
Most heat transfer processes in TAB work never achieve thermodynamic equilibrium or steady-state conditions. When steady state conditions do not exist, a sufficient number of temperature readings must be taken during a given time rate and the results integrated over that time.

Same Instrumentation:
The final issue deals with the use a single instrument. Differential temperature measurements shall be taken with the same instrument. The use of a single instrument negates errors in accuracy and precision.

6.4.3 SPECIFIC MEASUREMENT TECHNIQUES

Air Temperatures – Dry Bulb

Where a uniform profile exists, dry bulb temperature measurements may be as simple as a single point reading in the middle of the duct. Sometimes, multiple readings must be taken and then averaged. Where a non-uniform profile exists, an exact temperature traverse and a corresponding velocity traverse shall be made and the weighted average used as the resultant temperature. A weighted average means that the traverse would be weighted for the amount of air flowing, or velocity, in each of the equal area traverse grids. The measured temperature in each grid area would be multiplied by the corresponding airflow or velocity in that area grid. The sum of all of the temperature and airflow / velocity multiplications would then be divided by the total number of points in the traverse and the total airflow / velocity. A Pitot tube traverse is a weighted average simply because the area of each grid is identical to another. Example 6-1 follows....

Example 6-1

A temperature traverse of a 20" x 16" (500mm x 400mm) duct is to be made. A 16- point equal area traverse is performed. In Table 6.1, the measured temperatures (°F/°C) and corresponding velocities (fpm / m/s) are recorded. In Table 6.1 the temperature and the velocities are not constant. In Table 6.2 the same temperatures are shown but with the idealized condition that each area has the identical velocity / airflow.

Table 6.1 Variable Temperatures and Airflow Velocities

Position		A	B	C	D
1	Temperature	100°/38°	90°/32°	90°/32°	90°/32°
	Velocity	1000/5.0	900/4.5	900/4.5	850/4.3
2	Temperature	105°/41°	100°/38°	90°/32°	90°/32°
	Velocity	1100/5.5	100/0.5	850/4.3	850/4.3
3	Temperature	110°/43°	100°/38°	95°/35°	95°/35°
	Velocity	1200/6.0	1100/5.5	900/4.5	900/4.5
4	Temperature	110°/43°	100°/38°	90°/32°	90°/32°
	Velocity	1300/6.5	1200/6.0	100/0.5	900/4.5

Weighted Average Temperature - 97.74°F / 36.52°C

Table 6.2 Variable Temperatures and Identical Airflow Velocities

Position		A	B	C	D
1	Temperature	100°/38°	90°/32°	90°/32°	90°/32°
	Velocity	1000/5.0	1000/5.0	1000/5.0	1000/5.0
2	Temperature	105°/41°	100°/38°	90°/32°	90°/32°
	Velocity	1000/5.0	1000/5.0	1000/5.0	1000/5.0
3	Temperature	110°/43°	100°/38°	95°/35°	95°/35°
	Velocity	1000/5.0	1000/5.0	1000/5.0	1000/5.0

4	Temperature	110°/43°	100°/38°	90°/32°	90°/32°
	Velocity	1000/5.0	1000/5.0	1000/5.0	1000/5.0

Weighted Average Temperature – 96.56°F / 35.87°C

Air Temperatures – Wet Bulb

As with dry bulb measurements, where a uniform profile exists, wet bulb temperature measurements may be as simple as a single point reading in the middle of the duct. Sometimes, multiple readings must be taken and then averaged. Where a non-uniform profile exists, an exact temperature traverse and a corresponding velocity traverse shall be made and the weighted average used as the resultant temperature. Additionally, when the selected instrumentation is a wick type psychrometer, the wick, or sock, must remain continuously wetted with distilled water. The temperature of the water is to be the same temperature as the dry bulb air temperature. Wet bulb readings must be taken over time to assure that steady-state conditions exist.

Hydronic Temperatures

Hydronic temperatures shall be made by either of the following methods: insertion of a probe in pressure / temperature ports (P / T ports), immersion wells in the piping, or surface temperatures. Surface measurements shall only be used on steel or copper pipe and when measuring the differential temperature. The piping surface must be clean and free of rust or other oxidized surface. Immersion wells shall be of the proper length and shall be installed in the proper method to ensure accuracy. Most wells should be placed into the end of a tee fitting so that the fluid must pass directly over the well before leaving out the branch outlet of the tee. Wells installed on the branch side of a tee should be avoided.

6.5 FLOW MEASURING HOOD PROCEDURES

The following procedures describe the methods to be utilized when making air volume measurements with a flow-measuring hood. While the procedures outlined here are prescriptive, instrumentation use should always be in accordance with the manufacturer's recommendation. All instrumentation used for airflow measurements shall conform to the requirements of Table 4-1 for function, range, accuracy, and resolution.

6.5.1 INSTRUMENTS

Flow measuring hoods (various manufacturers)

6.5.2 GENERAL MEASUREMENT TECHNIQUES

The flow-measuring hood is a direct reading flow measurement device. It is designed with a fabric "sock" that covers the terminal air outlet device being measured. The conical or pyramid shaped hood collects all of the air entering or leaving an air terminal outlet and guides the airflow over the flow measuring instrumentation. Hoods generally are constructed so that the outlet tapers down to the metering section. A velocity measuring grid and calibrated differential pressure manometer or thermal anemometer in the hood will display the airflow in cfm (L/s) directly. However, it may be necessary to compare selected flow hood measurements with Pitot tube traverses of ducts connected to a grille, register, or diffuser (GRD) to develop correction factors specific to a system. This is up to the judgment of the NEBB Qualified TAB Supervisor.

6.5.3 SPECIFIC MEASUREMENT TECHNIQUES

The flow-measuring hood should be tailored for the particular job. The large end of the cone should be sized to fit over the complete diffuser and should have a gasket around the perimeter to prevent air leakage. Some digital instruments have memory, averaging, and printing capabilities. Flow measuring hoods should not be used where the velocities of the terminal devices are excessive or severely stratified.

It is important to note that inlet and outlet conditions of the measured grill, register, or diffuser (GRD) may affect the reading displayed by the flow-measuring hood. Repeated readings on the same GRD should be performed in the same manner and orientation.

The resistance to flow applied to the GRD when performing a flow measurement may have a significant effect on the actual value of the flow. The result is that, while a flow-measuring hood accurately measures the GRD air volume when applied to the GRD, the flow increases, sometimes substantially, when the flow-measuring hood is removed from the GRD. Analog flow measuring hoods are commonly supplied with correction curves to be used for this effect. Digital flow measuring hoods may feature devices to compute the correction with each reading, or use curves.

6.6 ROTATIONAL SPEED MEASUREMENT PROCEDURES

The following procedures describe the methods to be used when making rotational speed measurements. While the procedures outlined here are prescriptive, instrumentation use should always be in accordance with the manufacturer's recommendation. All instrumentation used for rotational speed measurements shall conform to the requirements of Table 4-1 for function, range, accuracy, and resolution.

6.6.1 INSTRUMENTS

The following instruments are typically utilized to perform rpm measurements:

- Chronometric Tachometers
- Digital Contact Tachometers
- Optical (Photo) Tachometers
- Stroboscopes

6.6.2 SAFETY CONSIDERATIONS

It is extremely important to understand that rotating machinery presents a significant safety hazard. Loose clothing, long hair and rings, or other body jewelry present a potential snagging hazard. Technicians performing these measurements shall exercise appropriate safety precautions when collecting the data.

6.6.3 GENERAL MEASUREMENT TECHNIQUES

The purpose of most rpm measurements in TAB work is to determine the rotational speed of a motor, fan or pump. The results are commonly expressed as revolutions per minute (rpm). This information is used to verify proper operational speed of the tested equipment.

6.6.4 SPECIFIC MEASUREMENT TECHNIQUES

Chronometric tachometers require contact with a rotating shaft. Special tips are attached to the end of the tachometer to provide a non-slip connection with the shaft. The meter is operated for a specific time, during which it indicates the revolutions of the shaft. After the measurement period is complete, the actual speed of the equipment is displayed as revolutions per minute.

Digital contact tachometers are used in a fashion similar to the chronometric tachometer. The difference is that the digital contact tachometer displays the rpm reading almost immediately upon contact with the rotating shaft. The display is LCD or LED, rather than a dial pointer that is found on the chronometric tachometer

Optical (Photo) tachometers usually require the equipment to be stopped so that a special piece of reflective tape, or paint, can be applied to the shaft. When the equipment is restarted the instrument is aimed at the reflective marker until the speed is calculated and displayed. This instrument typically uses a photocell to count the reflected light pulses from the reflective paint or tape as the shaft rotates.

The Stroboscope is an electronic tachometer that uses a flashing light of known and variable frequency. The frequency of the flashing light is electronically controlled and is adjustable. When the frequency of the flashing light is adjusted equal to the frequency of the rotating machine, the rotating components of the machine will appear to be stopped. It is important to have an estimate of equipment speed so that the stroboscope can be adjusted close to the expected rpm before the measurement is performed. The technician should be careful to determine the actual rpm, and not a harmonic multiple of the actual rpm.

6.7 HYDRONIC PRESSURE PROCEDURES

6.7.1 HYDRONIC PRESSURE MEASUREMENTS

The following procedures describe the methods to be utilized when performing hydronic pressure measurements. While the procedures outlined here are prescriptive, instrumentation use should always be in accordance with the manufacturer's recommendation. All instrumentation used for hydronic pressure measurements shall conform to the requirements of Table 4-1 for function, range, accuracy, and resolution.

6.7.2 INSTRUMENTS

The following instruments are typically used to perform hydronic pressure measurements:

- Electronic-Digital Hydronic Manometer
- Electronic-Digital Pressure Gauge
- Bourdon Tube Pressure Gauge
- Diaphragm-Bellows Type Meter

6.7.3 GENERAL MEASUREMENT TECHNIQUES:

Pressure measurements in hydronic systems involve four different pressures: static pressure, differential pressure, velocity pressure, and total pressure. Static pressure and differential pressure are the predominant measurements used in hydronic TAB work. There are rare occasions where velocity pressure is relevant.

Static Pressure (SP) in an HVAC System is the potential energy a system possesses at the point of measurement to produce and maintain hydronic flow against piping resistance, and can be either a positive or a negative value relative to the atmosphere.

Velocity Pressure (VP) is the kinetic energy of the hydronic flow in a piping system, and is exerted only in the direction of the flow. Velocity pressure cannot be measured directly; it is the difference between the *total pressure* and the *static pressure* at the point of measurement.

Total Pressure (TP) is the maximum pressure on a plane normal to the direction of flow. An impact tube, which is an open tube faced directly into the fluid stream, is used to measure *total pressure*. It is the sum of the *static pressure* and the *velocity pressure* at the point of measurement in the system. **(TP = SP + VP).**

Differential Pressure (ΔP) is the difference between two static pressures measured with respect to the same reference pressure. These are typically static pressure measurements taken across equipment, piping components, and flow measuring devices.

6.7.4 SPECIFIC MEASUREMENT TECHNIQUES

The following applies to all hydronic systems:

a) The system shall be free of air, and the instrument shall be purged of air before use.
b) Verify the range of the instrument to be used is appropriate for the system being tested and the type of measurements being taken.

c) Verify the system pressures and temperatures do not exceed instrument rating.
d) Verify the instrument is approved for use on the system to be tested. For example, is the instrument approved for use on systems that convey potable water or other fluids for human or animal consumption?
e) Correct readings as required if measurement points are at different elevations, if the instrument hoses are at different elevations, or the pressure gauges are at different elevations.
f) Pressure measurements shall be taken with the appropriate accessories, i.e. P / T probes of proper length and size, isolation valves, pulsation eliminators (snubbers), etc.

6.8 ELECTRICAL MEASUREMENT PROCEDURES

The following procedures describe the methods and safety precautions to be used when performing basic electrical measurements. While the procedures outlined here are prescriptive, instrumentation use should always be in accordance with the manufacturer's recommendation. All instrumentation used for electrical measurements shall conform to the requirements of Table 4-1 for function, range, accuracy, and resolution.

6.81 INSTRUMENTS

The primary electrical data needed for TAB work is to obtain electrical measurements of voltage and amperage. Various manufacturers provide meters to accomplish these functions. The most common instruments used for TAB work are volt-ammeters, which are capable of both functions.

6.8.2 SAFETY

EXTREME CARE MUST BE EXERCISED WHEN USING ELECTRICAL TEST INSTRUMENTS.

Carelessness or improper use of the test instrument can cause serious injury or death to the technician, and damage to the equipment. The precautions listed below are a partial list of recommended minimum safety practices:

a) Inspect meter before use.

b) Never assume a circuit is de-energized without testing it. Verify voltage meter operation on a known voltage source before using to determine if a circuit is de-energized.

c) Before working on or near de-energized equipment ensure proper lock out and tagging is in place.

d) Ensure meter leads come in contact only with terminals or other contacts intended.

e) Take initial voltage or amperage measurements with the meter set at its highest range. If necessary, adjust meter range lower until the reading is at mid range.

f) Do not pry or pull wires into place for amperage measurements while wire is energized. De-energize wire and test for verification.

g) Never pry or pull wires with tools or in a manner that can cause damage to the wire insulation.

h) Clamp meter jaws around the phase wire to be tested after the equipment is energized. (In rush current may cause meter damage.)

6.8.3 GENERAL MEASUREMENT TECHNIQUES:

Many types of electrical measurements may be required to accomplish TAB work. However, the primary purposes of TAB electrical measurement are for safety, and fan and pump motor performance. Equipment must be tested to ensure it is de-energized and safe to work on or near. NEBB procedures require fan motors and pumps to be left operating within the manufactures rated tolerances and at or below full load amperage ratings.

Voltage measurements are taken by connecting voltage test leads to the volt-ammeter and touching the electrical contacts with test lead probes.

Amperage measurements are taken by enclosing the energized phase wires inside the jaws of the clamp probe of the meter.

6.8.4 SPECIFIC MEASUREMENT TECHNIQUES:

Adhere to all safety precautions when taking the following readings:

a) Touch the volt-ammeter's test probes firmly against the terminals or other surfaces of the line under test. Read the meter making certain to read the correct scale if the meter has more than one scale.

b) When reading single-phase voltage, the leads should be touched to the two terminals. The resulting single reading is the voltage being applied to the motor.

c) When reading three-phase voltage, the leads should be touched to all three phase terminals, in the following manner:

1) T1 and T2
2) T1 and T3
3) T2 and T3

d) This will result in three readings that may be different, but should be within acceptable tolerances. Excessive voltage variance or "imbalance" may cause motors to overheat. Additionally, many solid-state motor controllers and inverters are sensitive to imbalanced voltages. Unacceptable voltage imbalance is present when the percent imbalance is more than 2% of the measured voltage. NEMA MG-1, 2003 states that motors shall operate at rated capacity with voltage imbalances up to 1%.

e) Voltage imbalance may be calculated using the following equation:

Equation 6-3

$$\% V_i = 100 \times V_d / V_a$$

Where:

V_i = Voltage imbalance
V_d = Maximum voltage deviation from average
V_a = Average voltage of three legs

f) To measure current flow, enclose the phase wire inside the ammeter jaw clamp. The wire should be positioned in the center of jaw clamp for the most accurate reading. Read the meter making certain to read the correct scale if the meter has more than one scale. For single-phase motors, one measurement is required on either leg feeding the motor. For three phase motors, each leg needs to be measured.

g) It is important to be aware of other loads that may be served by the phase wires being measured. It is common practice to connect auxiliary loads, such as control transformers or crankcase heaters to one leg of a three-phase system. Current imbalances exceeding 10% from the average value, calculated similarly to the voltage imbalance procedure, may indicate problems with the motor or power supply.

h) When measuring low currents, it may be necessary to loop the phase wire around the jaw clamp. This will amplify the reading for greater accuracy. However, the meter reading will be proportionally higher than the actual current per each additional loop. Two loops equals twice the actual amperage, three loops equals three times the actual amperage, etc.

i) Actual brake horsepower (kW) may be calculated using the following equations:

Equation 6-4

Single Phase Circuit:

$$\text{bhp} = \frac{I \times E \times pf \times eff}{746} \qquad \text{kW} = \frac{I \times E \times pf \times eff}{1000}$$

Equation 6-5

Three Phase Circuit:

$$\text{bhp} = \frac{\text{I x E x pf x eff x 1.73}}{746} \qquad \text{kW} = \frac{\text{I x E x pf x eff x 1.73}}{1000}$$

Where:

bhp = Brake horsepower
kW = Power (kilowatts)
I = Amps
E = Volts
pf = Power factor
eff = Efficiency
1.73 = Constant (3 phase motors)

j) In the preceding equations the power factor and efficiency values must be used to obtain the actual motor brake horsepower (kW). These values are typically difficult to obtain and a reasonable estimate may be used. The normal range for both power factor (pf) and efficiency (eff) is between 80 and 90 percent. Therefore, 80 percent may be used for one value and 90 percent for the other to obtain a reasonable estimate of brake horsepower (kW).

k) Alternative Brake Horsepower Calculations can be made using the following equations to obtain a reasonable approximation of brake horsepower (BHP):

Equation 6-6:

$$\text{Actual FL Amps} = \frac{\text{FL amps* x voltage*}}{\text{Actual voltage}}$$

*Nameplate ratings

Equation 6-7:

$$\text{BHP} = \text{HP (kW)* x} \frac{\text{(MO amps) - (NL amps x 0.5)}}{\text{(Actual FL amps) - (NL amps x 0.5)}}$$

* 1 HP = 0.746 kW

Where:

BHP = Brake horsepower
MO amps = Motor operating amps
NL amps = No load amps
FL amps = Full load amps
HP (kW) = Motor nameplate horsepower (kW)

6.8.5 Variable Frequency Drives

Modified electrical measurement procedures are required when a variable frequency drive (VFD) is used. There are two acceptable methods for determining voltage and amperage of a motor operated by a variable frequency drive

(VFD). The most accurate method is to use the voltage and amperage provided on the VFD display screen. Note: regardless of whether the motor is single or three phase, most VFD display screens only provide one voltage and amperage reading. Not all VFD's are equipped with display screens. When voltage and amperage readings cannot be taken from the VFD display screen, a true-RMS meter is required.

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