Environmental Testing Service, Inc.
150 Highway 216
Montevallo, AL 35115
Phone L1 (205) 476-8640
Email etstab@gmail.com
Website: etstab.com

Submittal for HVAC Test and Balance

Qualifications

Environmental Testing Service, Inc. is an independent test and balance agency certified by NEBB. Environmental Testing Service offers its customers over one hundred years of combined experience in the construction industry, and specialized in the testing, adjusting, and balancing of heating ventilation and air conditioning systems. We provide quality air and hydronic balancing of HVAC systems to our customers. This includes systems that are simplistic in nature to some of the most advanced HVAC systems in the world.

Scott Kleback is a 1996 graduate of Northview High School in Dothan, AL. He has worked in the test and balance industry since 1993. He graduated from Troy University in 2001 with a Bachelor of Science degree in mathematics. He has supervised and balanced air and hydronic systems on some of the most sophisticated systems throughout the world. Scott has completed the OSHA ten-hour construction safety course. He has completed all the requirements for NEBB Certified Professional status in Testing Adjusting and Balancing of Environmental Systems.

Steven Dale Benson is a 1985 graduate of Thompson High School in Alabaster, AL. He attended classes at the University of Alabama Birmingham. He started with Environmental Testing Service in 1985 and has supervised and balanced complex HVAC systems throughout the world. He is the current Vice President of Environmental Testing Service, Inc. He has also met all the NEEB requirements for NEBB certified technician status in Testing Adjusting and Balancing of Environmental Systems.

Phil Walker is a 2002 graduate of Pelham High School. Phil has completed the OSHA ten-hour construction safety course. He has met all the NEBB requirements for NEBB Certified Professional status in Testing Adjusting and Balancing of Environmental Systems.

Coleman Dale Benson has met all the NEBB requirements for NEBB certified technician status in Testing Adjusting and Balancing of Environmental Systems.

Patrick Mason Thomas has met all the NEBB requirements for NEBB certified technician status in Testing Adjusting and Balancing of Environmental Systems.

Selected Project List

Auburn Chemistry Building Auburn, AL   Owner: Auburn University Engineer: James S. Davis Jr.

St. Vincent's Chilton County Hospital Clanton, AL   Owner: St. Vincent's Health Systems Engineer: Whittaker and Rawson

Polyplex Decatur, AL   Owner: Polyplex Engineer: R. Mink

Dollar General Distribution Center Bessemer, AL   Owner: Dollar General Engineer: Leo E. Daly

Jefferson County DHR Birmingham, AL   Owner: Jefferson County   Engineer: Charles V. Johnson Jr.

Vance Federal Courthouse Birmingham, AL   Owner: United States Government Engineer: Thomas L. Hattemer

James C. Bailey Building Hanceville, AL   Owner: Wallace State Community College   Engineer: Dan Blackman

Raytheon AUR Building 7745 Huntsville, AL   Owner: United States Government Engineer: Thomas Ward Allen

Delta Delta Delta Sorority House Tuscaloosa, AL   Owner: The University of Alabama Engineer: Not Shown

Leon County Schools, All Schools Tallahassee, FL   Owner: Leon County School Board Renewable Contract every year since 1995.

Baptist Medical Center in Alabaster and Birmingham, AL   Analyze Central Chilled Water Systems, Rebalance Energy Conservation, Surgery Areas, Patient Rooms and Professional Office Buildings.

Brookwood Medical Center Homewood, AL   Owner: Baptist Health Systems Various Projects Including Women's Medical Center, Professional Office Buildings, Surgery Areas, Chilled Water Systems and Labor and Delivery.

Womack Army Hospital Fort Bragg, NC 350 Million Dollar Hospital Replacement   Owner: United States Army

Environmental Protection Agency Research Triangle Park, NC   Owner: EPA United States Government   Engineer: R.G. Vanderwell Engineering, Inc. in Boston Massachusetts

Shelby Baptist Hospital Nuclear Medicine Alabaster, AL   Owner: Baptist Health Systems

New Helena High School Helena, AL   Owner: Shelby County Board of Education

New Jemison High and McNair Jr. High School Huntsville, AL   Owner: Huntsville City School Board

Lyster Army Health Clinic Fort Rucker, AL

Healthsouth Rehab Isolation Room Dothan, AL

VA Hospital Birmingham, AL

Love’s Truck Stops Various Stores in The United States

Maxwell AFB and Gunter Annex Montgomery, AL   Various Buildings

UAB Women and Infant Center Birmingham, AL

Surmodics Pharmaceuticals Birmingham, AL Yearly Annual Checks

CMS Field Products Fume Hood Testing Pelham, AL

UAB Medical Center West Bessemer, AL

St Vincent’s Hospital 119 Birmingham, AL

DHS Faith Wing Anniston, AL

Fort Benning Battle Lab Fort Benning GA

Anniston Army Depot Miscellaneous Buildings Anniston, AL

UAB Student Health Service Birmingham, AL

Birmingham Shuttlesworth International Airport Phase II Birmingham AL

RSA Tower and RSA Executive Building Montgomery, AL   22 Story and 12 Story Office Buildings

New Embassy Compound Kyiv Ukraine   Owner: United States Government

New Embassy Compound Rabat Morocco   Owner: United States Government

New Embassy Compound Paramaribo Suriname   Owner: United States Government

Embassy Warehouse Ethiopia   Owner: United States Government

New Embassy Compound Swaziland Mbabane   Owner: United States Government

New Embassy Compound Vientiane Laos   Owner: United States Government

New Embassy Compound Benin Cotonou Africa   Owner: United States Government

New Embassy Compound Dakar Senegal   Owner: United States Government

New Embassy Compound Helsinki Finland   Owner: United States Government

New Embassy Compound Monrovia Liberia   Owner: United States Government

Firm Certification

ENVIRONMENTAL TESTING SERVICE, INC.

**HAS MET ALL REQUIREMENTS FOR NEBB CERTIFIED
STATUS IN THE FOLLOWING DISCIPLINE**

Testing, Adjusting and Balancing of Environmental Systems

2622

NEBB Certification Number

December 31, 2025

Expiration Date

NEBB President

NEBB President-Elect

NEBB

Certification

SCOTT KLEBACK

HAS MET ALL REQUIREMENTS FOR NEBB CERTIFIED PROFESSIONAL STATUS IN THE FOLLOWING DISCIPLINE

Testing, Adjusting and Balancing of Environmental Systems

This Certificate, as well as individual affiliation with a NEBB Certified Firm and associated NEBB Certification Stamp are REQUIRED to provide a NEBB Certified Report. Participation in the NEBB Quality Assurance Program requires the Certificant be affiliated with a NEBB Certified Firm

CP-23537

NEBB Certification Number

December 31, 2025

Expiration Date

NEBB President

NEBB President-Elect

NEBB®

Certification

CHARLES PHILLIP WALKER III

HAS MET ALL REQUIREMENTS FOR NEBB CERTIFIED PROFESSIONAL STATUS IN THE FOLLOWING DISCIPLINE

Testing, Adjusting and Balancing of Environmental Systems

This Certificate, as well as individual affiliation with a NEBB Certified Firm and associated NEBB Certification Stamp are REQUIRED to provide a NEBB Certified Report. Participation in the NEBB Quality Assurance Program requires the Certificant be affiliated with a NEBB Certified Firm

CP-24181

NEBB Certification Number

December 31, 2025

Expiration Date

NEBB President

NEBB President-Elect

Certification

STEVEN DALE BENSON

HAS MET ALL REQUIREMENTS FOR NEBB CERTIFIED TECHNICIAN STATUS IN THE FOLLOWING DISCIPLINE

Testing, Adjusting and Balancing of Environmental Systems

This Certificate, as well as individual affiliation with a NEBB Certified Firm and associated NEBB Certification Stamp are REQUIRED to provide a NEBB Certified Report. Participation in the NEBB Quality Assurance Program requires the Certificant be affiliated with a NEBB Certified Firm

CT-21785

NEBB Certification Number

December 31, 2025

Expiration Date

NEBB President

NEBB President-Elect

NEBB®

Certification

COLEMAN DALE BENSON

HAS MET ALL REQUIREMENTS FOR NEBB CERTIFIED TECHNICIAN STATUS IN THE FOLLOWING DISCIPLINE

Testing, Adjusting and Balancing of Environmental Systems

This Certificate, as well as individual affiliation with a NEBB Certified Firm and associated NEBB Certification Stamp are REQUIRED to provide a NEBB Certified Report. Participation in the NEBB Quality Assurance Program requires the Certificant be affiliated with a NEBB Certified Firm

CT-22053

NEBB Certification Number

December 31, 2025

Expiration Date

NEBB President

NEBB President-Elect

Certification

PATRICK MASON THOMAS

HAS MET ALL REQUIREMENTS FOR NEBB CERTIFIED TECHNICIAN STATUS IN THE FOLLOWING DISCIPLINE

Testing, Adjusting and Balancing of Environmental Systems

This Certificate, as well as individual affiliation with a NEBB Certified Firm and associated NEBB Certification Stamp are REQUIRED to provide a NEBB Certified Report. Participation in the NEBB Quality Assurance Program requires the Certificant be affiliated with a NEBB Certified Firm

CT-22706

NEBB Certification Number

December 31, 2025

Expiration Date

NEBB President

NEBB President-Elect

PROCEDURES

Section 6. TESTING, ADJUSTING & BALANCING MEASUREMENTS

6.1 INTRODUCTION

This section prescribes procedures for basic testing, adjusting, and balancing (TAB) measurements that are accurate and repeatable. TAB measurements will be performed on air, water, and fluids of various densities to determine properties, conditions, and flow rates of the fluids.

The ability to take accurate and repeatable measurements depends on technician skill and measurement locations. The NEBB CF 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 CF to drill test holes for the purpose of taking measurements in ducts or equipment. These test holes are appropriately sized, and they are sealed with the appropriate industry standard plugs when measurements are completed. The NEBB CF will verify requirements and use caution before drilling penetrations into fiberglass, PVC, or stainless-steel ducts, as these systems often contain hazardous materials. It is advisable that the CF assist the installing contractor as to where penetrations are to be located.

For hydronic systems, test ports or pipe taps are necessary for pressure and temperature measurements. It is advisable that the CF assist the installing contractors as to where test ports are to be located. It is the responsibility of the installing contractors to furnish and install the 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 is always in accordance with the manufacturer's recommendation. All instrumentation used for pressure measurements shall conform to the requirements of Section 4 of this *Standard*.

6.2.1 Instruments

The following instrument is typically utilized to perform pressure measurements:

- Micromanometer

Air pressure measurements for HVAC TAB procedures are accomplished with a micromanometer, connecting tubing and an appropriate sensing tip. This micromanometer may be a multi-function instrument with micromanometer 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.

6.2.2 General Measurement Techniques

Pressure measurements in air 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 air TAB work.

Field measurement of static pressures is not a definitive measurement; rather, it is simply an analysis tool for fan performance. Accurate assessments of fan performance in the installed condition require rotations per minute (rpm), airflow, power data, and sometimes an evaluation of System Effect. The impact of System Effect is to be considered during the project design phase by the design professional.

SP measurements are properly performed with a calibrated micromanometer 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 may result in significant measurement errors.

6.2.3 Specific Measurement Techniques

TAB specifications frequently ask the Certified Firm to provide measurements of total static pressure (TSP) and/or external static pressure (ESP) across a fan or air handling system. When measuring SP on a unit, the external static pressure refers to the difference between two measurement locations (unit supply pressure minus unit inlet pressure). If the inlet pressure is negative, algebraic rules for subtracting negative numbers will apply.

6.3 AIR VELOCITY

The following procedures describe the methods to be used when making air velocity measurements. While the procedures outlined here are prescriptive, instrumentation use will always be in accordance with the manufacturer's recommendation. All instrumentation used for air velocity measurements shall conform to the requirements of Section 4 of this *Standard*.

6.3.1 Instruments

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

- Electronic-Digital Micromanometer
- Rotating Vane anemometer
- Thermal Anemometer (Hot Wire)

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 coils, at filter banks or at other designated points. Correction factors must be obtained from the manufacturer's submittal information to correctly quantify airflow from the velocity measurement taken. These measurements are used to verify 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 only a tool in 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 considered during the design phase but can also occur because of installation problems.

Duct air velocity measurements typically are performed to determine air volume in a duct by Pitot tube or Airfoil traverses. The Pitot tube/Airfoil traverse, properly conducted, is the basis for all other airflow measurements performed by a CF.

Other instruments used for air velocity measurements are rotating vane anemometers, thermal anemometers, and velocity grids in conjunction with a micromanometer, 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 duct traverse. In all cases the instrument manufactures- er's application recommendations are to be followed. For 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 or Airfoil 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 to be measured. Subtract the thickness of the liner to calculate the free area of the duct.

c. Mark the Pitot tube or Airfoil at the correct points and connect the tubing to the probe and micromanometer. Verify the "zero" of the instruments as required prior to inserting the probe into the duct.

d. Insert the probe into the duct. The tip of the Pitot tube or Airfoil shall point into the air stream and be parallel with the direction of airflow.

e. 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. *Note:* Do not average velocity pressures. Once the average duct velocity is determined, multiply the average velocity by free area calculated in (b) above. The result is the total airflow volume.

f. Rectangular ducts are traversed by the Equal Area or Log Tchebycheff (Log-T) Method. Use the resultant average velocity to calculate the airflow volume in accordance with (e) above

- Equal Area Method. *Readings to be taken in the center of equal areas.*
  - <12″ (either axis) requires a minimum of two readings
  - 12″ or greater (Minimum of 3 readings each axis) requires a maximum of 6″ spacing between readings. *(Example: a 10X30 duct would have two readings in the 10″ axis and 5 readings in the 30″ axis for a total of 10 readings).* When the total number of data points exceeds 64, the spacing may be increased above 6″.
- Log Tchebycheff (Log-T) method - See the latest edition of the NEBB *TAB Manual for Technicians* for measuring point layout.

g. Round ducts are traversed by the Equal Area method for sizes 6″ and larger. Only two holes are required to be drilled in the duct at right angles to each other. Use the resultant average velocity to calculate the airflow volume in accordance with (e) above.

- Equal Area Method. *Readings to be taken in the center of rings of equal area*.
  - Six-point traverse (each axis) for duct diameters of 6″ to 9″
  - Eight-point traverse (each axis) for 10″ & 12" diameter
  - Ten-point traverse (each axis) for all diameters above 12″
- Round ducts 5″ or less may be measured using 90% of a single centerline velocity reading in lieu of the 6-point method

h. Flat oval ducts may be traversed as follows:

- Traverse the center portion of the flat oval as though it was a rectangular duct using the method described in 6.3.3f. Use the average velocity and the calculated area to determine air volume in the rectangular portion.
- Traverse the two end sections as though it was a round duct and traverse that area using the method described in 6.3.3g (horizontal plane only). Use the average velocity and the calculated area to determine air volume in the in the round portion.

Note: Do not combine all velocity readings. Calculate volumes separately, then total them.

Example: 12x48 flat oval: Center portion would be 12x36 with holes spaced 6″ apart and 3 readings per hole. The ends would be equivalent to a 12″ round with 8 readings on each end in the horizontal plane. Total the air volume of the rectangular and the round area to establish total air flow for the duct.

i. The accuracy of a 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. [*Reference:* Calculate 10% of the maximum reading taken. The traverse data is acceptable if 75% of the velocity pressure readings are greater than this value. 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.]

j. The location of a useful duct traverse is not necessarily dictated by the number of diameters of straight duct, but by the quality of the readings at any given location likely to produce a useful result as described in the previous paragraph. The location of a traverse point should be as far away from the fan inlet or outlet as possible to avoid undue turbulence and should not be taken in a section of duct that is transitioning in size. Judgment of the quality of a traverse should be based on the results of the traverse, not by the appearance of the duct section only.

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 effective 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 traverse of the duct leading to a typical terminal device and calculating the duct airflow. This process assumes that there is negligible leakage between the traverse location and the terminal device. 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 traverse. This factor can then be applied to identical situations to determine airflow at other points. (*Note:* 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.

Similarly, the use of anemometers or velocity grids to measure air velocities at coils and filters is quite common but may not be accurate when determining airflow without the incorporation of a correction factor. As stated above, there are many variables in the measurement of airflow in the field that will affect the accuracy of any reading. Follow the procedures as identified in the above paragraph.

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:

Equation 6-1

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

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

Equation 6-2

$$D = \frac{1.325P_8}{(460 + T)}$$

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 will always be in accordance with the manufacturer's recommendation. All instrumentation used for temperature measurements shall conform to the requirements of Section 4 of this *Standard*.

6.4.1 Instruments

The following instruments are typically utilized to perform temperature measurements:

- Digital Thermometer
- Electric resistance thermometers including Thermistor Digital Psychrometer
- Digital Thermo-hygrometer

6.4.2 Factors Affecting Air Temperature Measurements

It should be noted that even with a good test of equipment function and performance, the energy balance results can have errors resulting from:

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.

There are three issues of prime importance when taking temperature measurements. Each of these must be well understood prior to taking field measurements.

1. Adequate mixing: Adequate mixing is essential to obtaining useful measurements. 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.

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

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

6.4.3 Air Temperature Measurements

NEBB makes a distinction between two types of air temperature measurements in the field. Please refer to Appendix D for more information on these two types of measurements.

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 will always be in accordance with the manufacturers recommendation. All instrumentation used for direct reading hood measurements shall conform to the requirements of Section 4 of this *Standard*.

6.5.1 Instruments

The following instruments are typically utilized to perform airflow measurements:

- Flow measuring hoods, digital and analog

6.5.1.1 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 the air entering or leaving an air 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 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 GRD to develop correction factors specific to a system. This is up to the judgment of the CP.

**Even though an analog hood is not part of the NEBB TAB Required Instrumentation List, this type of instrument can be useful when troubleshooting unstable and variant flow conditions. The visual aspect of monitoring and demonstrating unstable flow conditions can be extremely helpful.*

6.5.1.2 Specific Measurement Techniques

The flow measuring hood should be modified for the 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 are not to 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 GRD may affect the reading displayed by the flow measuring hood. Repeated readings on the same GRD are to be performed in the same manner and orientation.

There are various sizes and configurations of capture hoods available, thus it is important that flow-measuring hoods only be used in manufacturer's recommended configurations.

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. It is the responsibility of the Certified Firm to account for this phenomenon in all cases. For exhaust/return applications, follow the manufacturer's recommended procedures.

When equipment manufacturer IOMs have specified startup and airflow measurements other than flow hood tabulation, the flow hood is used for proportioning only. Ensure the report summary identifies this, and all testing procedures utilized.

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 is always to be in accordance with the manufacturer's recommendation. All instrumentation used for rotational speed measurements shall conform to the requirements of Section 4 of this *Standard*.

6.6.1 Instruments

These instruments are typically used to perform rotations per minute (rpm) measurements:

- 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 must exercise appropriate safety precautions when collecting data.

Additionally, caution should always be used when opening operating units, as pressures exerted at access doors could cause injury.

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 rpm. This information is used to verify proper operational speed of the tested equipment.

6.6.4 Specific Measurement Techniques

Digital contact tachometer is applied to the rotating shaft and will display the rpm reading almost immediately upon contact with the rotating shaft. The display is either LCD or LED.

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, 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 will always be in accordance with the manufacturer's recommendation. All instrumentation used for hydronic pressure measurements conform to the requirements of the *NEBB TAB Required Instrumentation List* for function, range, accuracy, resolution, and calibration intervals.

6.7.2 Instruments

These instruments are typically used to perform hydronic pressure measurements:

- Electronic-Digital Hydronic Manometer
- Electronic-Digital Differential Pressure Gauge

**Please note that the NEBB TAB Required Instrumentation List allows the use of the same instrument for multiple functions/readings as long as it meets the appropriate range, accuracy, and resolution.*

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.

6.7.4 Specific Measurement Techniques

The following applies to all hydronic systems:

a. The system and instruments shall be free of air and at proper pressures prior to balancing.
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.

6.8 HYDRONIC FLOW PROCEDURES

6.8.1 Hydronic Flow Measurements

The following procedures describe the methods to be utilized when performing hydronic flow measurements. While the procedures outlined here are prescriptive, instrumentation use will always be in accordance with the manufacturer's recommendation. All instrumentation used for hydronic flow measurements conform to the requirements of the *NEBB TAB Required Instrumentation List* for function, range, accuracy, resolution, and calibration intervals.

6.8.2 Instruments

These instruments are typically used to perform hydronic flow measurements:

- Differential Pressure Meter
- Ultrasonic Flow Measuring Device

6.8.3 General Measurement Techniques

Pressure differential actual is compared to pressure differential design to calculate water flow rate.

Flow measurements in hydronic systems sometimes involve the use of externally installed (non-invasive) flow meter equipment. Ultrasonic devices use sound waves and transit time technique to calculate direct flow readings.

6.8.4 Specific Measurement Techniques

The following applies to all hydronic systems:

a. The system shall be free of air and the instrument purged of air before use.
b. In Ultrasonic use, verify the appropriate transducers for the pipe size and location. Ensure the instrument is appropriate for the system being tested and the type of measurements being taken. Ensure the proper gel on the transducers is always used. Ensure pipes are clean and free of insulation debris. Understand that erroneous readings may occur when measuring glycol solutions due to air entrainment in the solution.
c. Verify the instrument is appropriate for use on the system to be tested.

6.9 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 will be in accordance with the manufacturer's recommendation. All instrumentation used for electrical measurements conform to the requirements of the *NEBB TAB Required Instrumentation List* for function, range, accuracy, resolution, and calibration intervals.

Reading and reporting electrical data from data displays at Variable Frequency Drives (VFDs) serving equipment being tested is an acceptable procedure however, when utilized, the source will be noted on the report.

6.9.1 Instruments

The primary electrical data needed for TAB work is voltage and amperage. Various manufacturers provide meters to accomplish these functions. The most common instruments used for TAB work are:

- Volt-ammeter
- Multimeter
- True RMS meter

6.9.2 Safety

Extreme care must be exercised when using electrical test instruments.

In some cases, the electrician, site operations or maintenance staff must take the electrical readings for the NEBB CF. In addition to knowing the local and site-specific requirements for electrical safety, any personnel taking and recording electrical data should be aware of and wear the appropriate Personal Protective Equipment (PPE). All instrumentation used for electrical measurements shall conform to the requirements of Section 4 of this *Standard*.

Carelessness or improper use of the test instrument can cause serious damage to the equipment, as well as injury or death. 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 power is energized.
g. Clamp meter jaws around the phase wire to be tested after the equipment is energized. (In rush current may cause meter damage.)

6.9.3 General Measurement Techniques

Many types of electrical measurements can be required to accomplish TAB work. However, the primary purposes of TAB electrical measurement are for electrical system safety, fan and pump motor performance and protection of equipment. 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, as well as 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.

6.9.4 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 are to 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 are to be touched to all three phase terminals, in the following manner:
    - T1 and T2
    - T1 and T3
    - T2 and T3
d. The three readings in (c) might differ, but they are to 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% on any leg when compared to the average of the measured voltage.
e. Voltage imbalance is calculated using this 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 is to 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 any one phase to 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 equal twice the actual amperage, three loops equal three times the actual amperage, etc.

i. Actual brake horsepower (kW) is calculated using these equations:

Equation 6-4

Single Phase Circuit:

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

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

Equation 6-5

Three Phase Circuit:

$$\text{bhp} = \frac{I \times E \times \text{pf} \times \text{eff} \times 1.73}{746}$$

$$\text{kW} = \frac{I \times E \times \text{pf} \times \text{eff} \times 1.73}{1000}$$

Where:

bhp = Brake Horsepower
kW = Power (kilowatts)
I = Amps
E = Volts
pf = Power Factor
eff = Efficiency
1.73 = RMS Constant (3 phase motor)

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%. Therefore, 80% may be used for one value and 90% for the other to obtain a reasonable estimate of brake horsepower (kW).

k. Alternative Brake Horsepower calculations are made using these equations to obtain a reasonable approximation of brake horsepower (bhp):

Equation 6-6

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

*Motor Nameplate ratings

Equation 6-7

$$bhp = \frac{HP\ (kW)^{*} \times (MO\ amps) - (NL\ amps \times 0.5)}{(actual\ FL\ amps) - (NL\ amps \times 0.5)}$$

$$^{*}1\ HP = 0.746\ kW$$

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)

6.9.5 Variable Frequency Drives

Modified electrical measurement procedures are required when a variable frequency drive (VFD) is used. 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. If readings are obtained from the VFD Display, a note must accompany reading to state such.) If more than one motor is connected to the VFD, additional readings may need to be taken, or special care taken in calculating brake horsepower, based on the displayed amperage. Technician should be aware of how the VFD is wired and ensure that displayed amperage is accurate for each individual motor driven. However, not all VFDs are equipped with display screens. When voltage and amperage readings cannot be taken from the VFD display screen, a true RMS meter is required. Consult drive manufacturer for best reading methods and locations.

Section 7. PRELIMINARY TESTING, ADJUSTING & BALANCING

7.1 INTRODUCTION

This section describes preliminary procedures necessary for the testing, adjusting, and balancing (TAB) of environmental systems. The procedures presented in this manual are intended to address a variety of system types and techniques used for testing and measurement. Final responsibility lies with the engineer of record to determine the actual scope of TAB work for each project. *(See Section 3 about responsibilities)*

7.2 PLANNING

The entire TAB process should be thoroughly organized and planned. The process may include, but is not limited to, assigning to the NEBB TAB Certified Professional the following project responsibilities: establishing the schedule, work duration, phasing, crew size, crew skills, instrument/equipment requirements, instrument storage and rental, on-site office requirements, certification documents, NEBB Quality Assurance Program Certificate, control interface software/hardware requirements, on-site communications, TAB report form distribution, data collection, backup, safety requirements and meetings, first aid, coordination meetings, security clearance, access keys/codes, parking requirements, etc.

7.3 PRELIMINARY TAB PROCEDURES

Preparatory work for a TAB project includes procuring project contract documents, applicable change orders, approved submittals, and shop drawings as needed. Plans, specifications, and submittals should be reviewed to determine the scope of the project.

The preparation of a TAB agenda may be advisable or specified by the project documents. This is also often referred to as a "Pre-Field TAB Engineering Report." The agenda should list each step required to posture and balance a specific system or systems. The agenda should include any special job conditions, TAB procedures, instrumentation needed, and any anticipated problems. The information in the agenda is a clear definition of the NEBB TAB Certified Firm's intended scope. To be effective, the agenda should be submitted early in the project to allow for adequate review by the architect, engineer, commissioning authority and owner.

The Contract Documents should identify, and the TAB Agenda should clearly delineate which component setpoints are TAB calibrated, adjusted, or verified versus which are deemed sequence of operations control points by the EOR. Unless otherwise noted, it should not be assumed that TAB will verify or validate all points within a project's sequence of operation scheme.

After review, notify the appropriate project personnel of any clarifications or additional information required to achieve system balance.

The Appendix A. *Sample Pre-TAB Checklist* can be utilized by the contracting team providing it is modified to accurately reflect the equipment necessary on the project.

Section 8. AIR SYSTEM TESTING, ADJUSTING & BALANCING PROCEDURES

8.1 INTRODUCTION

This section describes procedures for testing, adjusting, and balancing (TAB) HVAC systems. Procedures in this section address most systems commonly installed. It is the responsibility of the NEBB CF or NEBB CP to determine appropriate procedures for systems not covered in this section.

Please note that unless otherwise specified by the contract documents, there is no TAB work required for stand-alone systems or components that have no field installed ductwork, or accessories that would change airflows from that shown in the manufacturers published date. Examples of components that fall into this category would include (but not be limited to):

- Electric Unit Heaters/Baseboard Heaters
- Ductless Mini-Spilt System
- VRF Cassette style units with no field installed duct
- Destratification fans
- Large ceiling fans
- Electric Cabinet Unit Heaters
- Infrared Space Heaters
- Air Curtains

8.2 PRELIMINARY SYSTEM PROCEDURES

8.2.1 Performance Parameters

Each type of HVAC system is designed to meet a set of performance parameters. This usually includes maximum heating capacity, maximum cooling capacity and ventilation effectiveness. Prior to the TAB process, the CF should normally set up a system to its ‘full load’ condition (or maximum capacity). The full load condition presents the greatest challenge to a system’s capacity meeting its design airflow requirements. Other operating conditions may be verified by controls response performance or as by direct TAB verifiable reporting when specifically required by the project documents.

8.2.2 Limitations

Not all systems are covered in this section, only those most installed. Confer with the engineer of record to establish the proper set up conditions for specific systems.

8.2.3 Basic Procedures

The following TAB procedures are basic to all types of air systems:

a. Verify that the construction team responsibilities for system installation and startup as discussed in Section 3 are complete.
b. Ensure any project phasing or partial system turnover will not invalidate reporting.
c. Record unit nameplate data as described in Section 5.
d. Confirm that all items affecting airflow of a duct system are ready for the TAB work, such as doors and windows closed, ceiling tiles (return air plenums) in place, transfer grilles in place, etc.
e. Confirm that automatic control devices are complete, properly installed and the control system has been commissioned by others prior to starting the TAB work.
f. Establish the conditions for design maximum system requirements.
g. Verify that all dampers are open or set, all related systems (supply, return, exhaust, etc.), are operating, motors are operating at or below full load amperage ratings, and rotation is correct.
h. Positive and negative pressurization zones are to be identified at this time.

8.3 ESTABLISHING FAN TOTAL AIRFLOW

8.3.1 Total Airflow Measurement

The most accurate and accepted field test of airflow is a Pitot tube or Airfoil traverse of the duct. Procedures for conducting a traverse are found in Section 6. In situations in which a traverse(s) is not available, the system airflow may be determined by alternate methods, such as anemometer or velocity grid traverses across coils and/or filters, or the summation of air outlet measurements. These alternative methods are subject to a greater degree of error than duct traverses and are to be used with caution.

Please note that with the introduction of ECM motors, several manufacturers now require in their IOM that no adjustments be made to the ECM settings. Therefore, the CF must use instruments like flow hoods as proportioning tools only. If you are going to use the values obtained from the equipment manufacturer, this must be stated in the report.

8.3.2 Comparison of Total Airflow

Additionally, if a traverse location is available, a comparison of the total outlet airflow measurement with the traverse readings of the fan total airflow *may* assist in quantifying possible duct leakage. It is important to note that differences between total air outlet volume and traverse totals may be indicative of duct leakage, measurement errors, or incorrect area factors. Accurate assessment of duct leakage requires a specific duct leakage test, which may or may not be in the scope of TAB project specification.

8.3.3 Use of Fan Curves

Fan curves can be used when other required data can be obtained, such as static pressure (SP), rotations per minute (rpm) and brake horsepower [bhp (W)]. However, technicians and report reviewers should be aware that System Effect and measurement errors might yield field readings that are incompatible with fan and design system curves.

8.3.4 Fan Speed Adjustment

If the fan volume is not within plus or minus 10% (unless other requirements are specified) of the design airflow requirement, adjust the drive of the fan to obtain the approximate required airflow. At the conclusion of all system balancing procedures, measure and record the fan suction static pressure, fan discharge static pressure, amperage and air volume measurements. Confirm that the fan motor is not operating more than its full load amperage rating. Care must be exercised when increasing fan speeds to avoid exceeding the maximum recommended rpm of the fan and the motor horsepower (W). (The motor power increases as the cube of the fan speed change.) When new systems do not perform as designed, new drives and motors may be required. Unless clearly specified in the contract documents, the responsibility for these items is outside the scope of the CF.

8.3.5 Common Reference Point

When performing SP readings on fan systems, it is necessary to take the readings based on a common static reference point.

8.3.6 Supply, Return, Exhaust Volumes

Using the methods outlined above, determine the volume of air being handled by the supply air fan, and return air fan if used. If a central exhaust fan system is used, also determine the airflow being handled by the exhaust fan. If several exhaust fans, such as power roof ventilators are related to a particular supply air system, it generally is not necessary to measure the airflow of each such exhaust fan until after the supply air system is balanced.

8.3.7 Outside Air Condition (DOAS or Economizer Mode)

Verify the system test data with the supply air and return air fans in the 100% outside air (OA) and exhaust air (EA) mode. Use caution as ambient conditions may adversely affect system operation.

8.4 BASIC AIR SYSTEM BALANCING PROCEDURES

Balancing air systems may be accomplished in various ways. Two methods for balancing supply, return and exhaust systems are presented. Regardless of the method, the objectives remain the same and the system will be considered balanced in accordance with this edition of NEBB *Procedural Standard for Testing, Adjusting and Balancing of Environmental System (Procedural Standard)* when the following conditions are satisfied:

a. All measured airflow quantities are within ±10% of the design airflow quantities unless there are reasons beyond the control of the CF. If the total available air is above or below design and cannot be decreased or increased, the air distribution system shall be proportionally balanced to within 10% of the available total. Deficiencies shall be noted in the TAB Report Summary.
b. There is at least one path with fully open dampers from the fan to an air inlet or outlet. Additionally, if a system contains branch dampers, there will be at least one wide-open path downstream of every adjusted branch damper.

8.4.1 Proportional Method (Ratio Method)

8.4.1.1 Supply Without Branch Ducts:

(*Note:* This is also appropriate for exhaust or return duct systems.)

a. Verify that all Grille, Register and Diffuser (GRD) dampers are wide open.
b. Ensure the air outlet deflections have been set as specified. This is an installer requirement.
c. Determine total system airflow by the most appropriate method. A duct traverse or multiple traverses shall be the preferred choice because they are the most accurate.
d. Calculate the percentage of actual airflow to design airflow.
e. Adjust the fan to approximately 110% of design airflow or as necessary.
f. Measure the airflow at all GRD’s.
g. Compute the ratio of measured airflow to design airflow for each GRD.
h. The damper serving the GRD at the lowest percentage of design flow is not adjusted in this procedure.
i. Using the take-off damper as the first choice and a face damper as the last resort (face dampers are NOT recommended for balancing), serving the GRD with the next (second) lowest percentage of design until both GRD’s are the same percentage of design. These GRD’s are now in balance.
j. Adjust the damper serving the GRD with the next (third) lowest percentage of design until all three GRD’s are at the same percentage of design, and in balance.
k. Continue this procedure until all remaining GRD’s have been adjusted to be in balance at approximately the same percentage of design airflow.
l. If necessary, adjust the fan speed to set all GRD’s at design airflow, ±10%.
m. Re-measure all GRD’s and record final values.
n. Mark all balance dampers in some manner that is permanent, so that adjustment may be restored if necessary.

8.4.1.2 Supply With Branch Ducts:

a. Follow above steps 8.4.1.1 (a) through (f) for the GRD’s on each branch.
b. Compute the ratio of measured branch flow to design branch flow.
c. The damper serving the branch at the lowest percentage of design flow is not adjusted in this procedure.
d. Adjust the damper serving the branch with the next (second) lowest percentage of design until both branches are the same percentage of design. These branches are now in balance
e. Adjust the damper serving the branch with the next (third) lowest percentage of design until all three branches are at the same percentage of design, and in balance.
f. Continue this procedure until all remaining branches have been adjusted to be in balance at approximately the same percentage of design airflow.
g. Adjust the fan to approximately 110% of design airflow (if not already done above).
h. Perform the proportioning techniques specified in above steps a) through m) for the diffusers on each branch.
i. Re-measure all GRD’s and record final airflow values.
j. Mark all dampers, with a permanent technique, so that adjustment may be restored if necessary.

8.4.2 Stepwise Method

8.4.2.1 Supply Without Branch Ducts:

(*Note:* This is also appropriate for exhaust or return duct systems.)

a. Verify that all GRD dampers are wide open.
b. Set air outlet deflections as specified.
c. Determine total system volume by the most appropriate method. A duct traverse shall be the preferred method. The sum of several traverses may be required.
d. Calculate the percentage of actual airflow to design airflow.
e. Adjust the fan to approximately 110% of design airflow or as necessary.
f. Measure the airflow at all GRD's.
g. Starting at the fan, as the GRD's closest to the fan will typically be the highest, adjust the GRD volume dampers to a value approximately 10% below design airflow requirements.
h. As the adjustment proceeds to the end of the system, the remaining GRD airflow values will increase.
i. Repeat the adjustment passes through the system until all GRD's are within ±10% of design airflow requirements and at least one GRD volume damper is wide open.
j. Adjust the fan to approximately 110% of design airflow or as necessary.
k. Re-measure all diffusers and record final airflow values.
l. Mark all dampers, with a permanent technique, so that adjustment may be restored if necessary.

8.4.2.2 Supply With Branch Ducts:

a. Follow above steps (a) through (e) for the GRD's on each branch.
b. Compute the ratio of measured branch flow to design branch flow.
c. Starting at the fan, as the branches closest to the fan will typically be the highest, adjust the branch volume dampers to a value approximately 10% below design airflow requirements.
d. As the adjustment proceeds to the end of the system, the remaining branch airflow values will increase.
e. Adjust the fan to approximately 110% of design airflow (if not already done above).
f. Balance the GRD's on each branch as described in steps (e) through (i) of Section 8.4.2.1.
g. Re-measure all GRD's and record final values.
h. Mark all dampers with a permanent technique, so that adjustment may be restored if necessary.

8.5 CONSTANT VOLUME SUPPLY SYSTEMS

8.5.1 Basic Constant Volume Systems

For the purposes of this *Procedural Standard*, a basic constant volume supply system is defined as having a single fan and connecting ductwork to the outlets and inlets. The following balancing procedures are appropriate for basic constant volume systems:

a. Confirm that the correct air filters have been installed. Review the specifications to determine if a temporary filter blockage is required to simulate partially loaded filters.
b. Barometric dampers are to be checked for free operation. If the dampers are equipped with adjustable weights, the CF should set them to maintain the specified building static pressure and document settings and readings. All air systems are to be balanced before adjusting barometric relief dampers
c. Verify that all manual branch and outlet volume dampers are locked 100% open.
d. Verify correct rotation.
e. Measure the motor operating amperage.
f. Measure motor voltage.
g. Confirm that the voltage and amperage match the motor rating.
h. Check for unusual noises indicating mechanical malfunction.
i. Measure fan rpm and compare to design rpm.

j. Air handling units (AHU) equipped with a fixed outside air damper is to be set to an approximate position as a starting point. (*Note:* Caution should be used if freezing conditions are expected.)
k. The OA damper for air handling units using mechanical cooling, with an economizer cycle, is to be adjusted to a position estimated to equal the design minimum airflow.
l. The OA damper for units using only ventilation air for cooling is to be positioned 100% open with RA dampers closed. (*Note:* Caution should be used if freezing conditions are expected.)
m. Determine the AHU's design total static pressure (TSP) and/or external static pressure (ESP). If the rating is for TSP, measure suction and discharge static pressure at the inlet and outlet of the fan. If the rating is for ESP, measure the suction and discharge static pressure at the return duct and discharge duct. The suction static pressure measurement point can be immediately adjacent to the unit. The discharge static pressure is to be taken at a point 3 to 5 duct diameters downstream of the fan discharge, and upstream of any elbows or turning vanes.
n. If testing with partially loaded filters is specified, measure the pressure drop across the air filters and adjust a temporary blockage to meet specified requirements.
o. Measure the AHU total air volume. A duct traverse is the most accurate method available. The sum of several traverses may be required.
p. Adjust fan airflow to meet design requirements, if necessary.
q. Determine the method for adjusting outlets – proportional or stepwise and balance the inlets and outlets in accordance with the prescribed procedures.
r. After the supply, return, and exhaust systems are properly balanced, the supply air fan capacity is to be checked with 100 percent outside air, if this alternative is included in the system design. Make appropriate damper adjustments if necessary, to achieve total design supply air volume in all modes.
s. At the conclusion of all inlet and outlet balancing, readjust the AHU minimum outside air ventilation rate, if required.
t. Record final unit data, prepare the report forms, and submit as required (see Section 5).

8.5.2 Complex Constant Volume Systems

For the purposes of this document a complex constant volume supply system is defined as having multiple fans (supply, return, exhaust) and may have active building static pressure control.

Systems with active building static pressure control require special attention by the CP. Building pressure can vary if the return/exhaust air fan volume does not respond adequately to changes in the system operation, such as filter loading. Three common methods used are building static control (regulates return/relief fan), open-loop control (supply/return air volumes fixed), and closed-loop control (fan tracking), which will be discussed later in this section.

Balancing procedures for complex systems follow the same procedures as described for basic systems. The addition of powered return/exhaust fan(s) must be addressed in the setup and balancing process.

There are many variations of unit fan and damper arrangements supplied by manufacturers, which the CP must understand before beginning the balancing process. This document does not attempt to provide specific guidelines for all possible system arrangements. A few of the more common configurations for complex constant volume systems are described below.

8.5.3 Systems With Power Exhaust/Relief

This fan is designed to run in the pressure relief mode only when required to relieve building pressure. For systems with power exhaust, follow the procedures specified previously for a Basic Constant Volume Supply System (see Sections 8.4 and 8.5) with the following modifications:

a. After all procedures specified for a basic constant volume supply system are complete, but before recording final system data, set the system to its maximum OA ventilation rate.
b. Adjust the powered exhaust fan flow rate to achieve the required building static pressure.
c. Measure building static pressure and compare to specified requirements.
d. Complete the final system measurement specified previously for basic systems, including all components of the tested system.

8.5.4 Systems With Return/Exhaust Fans

Constant volume supply systems with return/exhaust fans are essentially two separate constant volume systems, operating in series, linked by an arrangement of dampers. Further, the return/exhaust system may or may not be ducted.

Systems with combination return/exhaust air fans require special attention by the CP. Building pressure will vary substantially if the return/exhaust air fan volume does not respond adequately to changes in the system operation, such as filter loading. Three common methods used are building static control (regulates return/relief fan), open-loop control (supply/return air volumes fixed), and closed-loop control (fan tracking), which will be discussed later in this section. Follow the procedures specified previously for a basic constant volume supply system (see 8.4 and 8.5) with the following modifications:

a. Set the return, outside air and exhaust dampers for the normal operating condition, typically full return with minimum OA.
b. Perform the appropriate procedures described previously on both the supply side and the return/exhaust side of the system. This includes the inlets and outlets of both system components.
c. After the systems have been balanced in the normal operating condition, decouple the supply and exhaust fans so that the two systems operate independently. Set the return damper to closed, the exhaust damper to 100% open and the outside air damper to 100% open.
d. Adjust the return/exhaust fan to the total design flow.
e. Check and adjust the supply air fan to achieve design air flow
f. Measure and record the static pressure in the return/exhaust chamber.
g. Return all control dampers to the normal operating mode. Adjust minimum outside air to design flow and adjust the return air damper so that the return/exhaust chamber pressure is the same as the 100% exhaust mode documented above.
h. Final Measurements: At the conclusion of all inlet and outlet balancing, readjust the AHU minimum outside air ventilation rate as required.
i. In each condition, verify that the system is operating in compliance with specified requirements.
j. Measure building static pressure and compare to specified requirements.
k. Record final unit data, prepare the report forms, and submit as required (see Section 5).

8.6 MULTIZONE SYSTEMS

Follow the procedures specified previously for a basic constant volume supply system (see Sections 8.4 and 8.5) with the following modifications:

a. Confirm that the coils are sized for airflow equal to the fan design. If the coils are sized for less airflow than the fan, the bypass damper, if so equipped, will be left open to an amount equal to the excess fan airflow so that the total airflow will not be restricted.
b. Set the multizone unit dampers for design airflow through the cooling coil.
c. The outside air and return air (OA/RA) dampers should be adjusted prior to balancing. If the air handling unit (AHU) has a fixed outside air damper it is to be set to the appropriate position as a starting point. (Caution will be used if ambient conditions present a risk of damage to the equipment or facility).
d. The OA damper for air handing units using mechanical cooling are to be adjusted to a position estimated to equal the design minimum airflow.
e. The OA damper is to be positioned 100% open, with RA dampers closed, for units using only ventilation air for cooling.
f. If the cooling coil is sized for the full fan airflow, put all zones into full cooling by setting each zone thermostat to its lowest point.
g. Measure the airflow of each zone and total the results. A duct traverse or multiple traverses shall be the preferred choice as it is the most accurate.
h. Make any required fan speed adjustments to obtain the design total airflow.
i. Adjust each manual zone balancing damper to obtain the proper airflow in each zone. This type of system cannot be properly balanced without manual zone balancing dampers. If the dampers are not provided, the CP will notify the appropriate project personnel to have them installed.
j. Once each zone has the correct airflow, the outlets can be balanced by using the previously described methods.
k. At the conclusion of all inlet and outlet balancing, re-adjust the AHU minimum outside air ventilation rate, if required.

l. Record final unit data, prepare the report forms, and submit as required (see Section 5. *Standards for Reports and Forms*). Include all traverses in report.

8.7 INDUCTION UNIT SYSTEMS

8.7.1 Operation

Induction unit systems use high or medium pressure fans to supply primary air to the induction units. Check to see that the induction unit dampers, as well as the system dampers, are wide open before starting the HVAC unit primary air fan.

Airflow readings at induction units are taken by reading the SP at one of the nozzles, then compare the reading to the manufacturer's published data. The design static pressure and airflow will be shown on the manufacturer's submittal data for the various size units on the job. This information is to be verified by performing a duct traverse for each model on the project.

Some systems use the primary air source to power the controls and move a secondary air damper for adjusting room temperature. In such cases, it is extremely important that the manufacturer's minimum static pressure in the plenum of each unit be maintained.

8.7.2 Procedures

Adjust the primary air fan using previously described methods for constant volume systems (see 8.4 and 8.5). With a new or wide-open system, allow for a reduction in airflow while balancing.

Adjust the nozzle pressure according to the manufacturer's specifications to obtain the design primary airflow. Induction units can be balanced by using the proportional method or stepwise method as described previously for balancing diffusers or registers (see Sections 8.4.1 and 8.4.2).

8.8 VARIABLE VOLUME SYSTEM OVERVIEW

Procedures for a Variable Air Volume (VAV) system is like those for constant volume systems. The primary difference is that a mechanism exists in the system to vary system flow in response to demand. The fan capacity is usually controlled to maintain a field determined duct static pressure. A static pressure sensor, usually located two-thirds of the way from the fan to the end of the duct system, senses the supply air duct static pressure and sends a signal back to the apparatus controlling the fan airflow volume. Another method of capacity control utilizes the capability of a DDC system to determine individual terminal unit airflow requirements and adjust the system in response. This control sequence is normally referred to as static pressure reset.

8.8.1 Diversity

The Certified Firm should determine if the VAV system has a diversity factor.

8.8.2 Terminal Units

VAV systems incorporate terminal units that respond to local zone demand by controlling the amount of primary (system) air that is distributed to the local zone. There are two basic types of terminal units, pressure dependent and pressure independent:

Pressure Dependent Terminal unit: A pressure dependent terminal unit is not equipped to measure and maintain primary air volume. Actual airflow through the terminal unit is a function of upstream static pressure and damper position.

Pressure Independent Terminal unit: A pressure independent terminal unit is equipped with a flow sensing controller that can be set to limit maximum and minimum primary air discharge from the terminal unit.

There are many different variations of terminal unit functions, the following list overviews a few of the more common types.

8.8.3 Cooling Only Units

The simplest variety of VAV terminal unit has a damper that responds to zone demand by opening or closing to modulate the amount of primary air delivered to the zone. It may be either pressure dependent (PD) or pressure independent (PI). This type of terminal unit may also serve as a component of a variable volume variable temperature system, typically in a PD application. It is important to consult the manufacturers' specifications to obtain information regarding performance and operating characteristics.

8.8.4 Cooling Units With Reheat

This is a cooling terminal unit with the addition of an electric or hydronic heating coil. Units with electric heating coils are supplied with an airflow switch that shuts off the heating coil if the total pressure at the reheat coil falls below a certain value. The intent of this safety is to prevent damage to the unit or the heating coils, however, it does not assure adequate air flow as the device is currently used. Adequate backpressure on the terminal unit is required to activate the switch, which may require the installation of an additional damper in the terminal unit discharge duct.

8.8.5 Fan Powered VAV Terminal Units

Fan powered VAV terminal units are terminal units that contain individual supply air fans and may be arranged in parallel or series.

Parallel Fan Terminal unit: Primary airflow through the terminal unit does not pass through the fan. The fans are usually equipped with a volume control device, i.e. speed controls, speed taps or discharge dampers. In most applications the fan is only operational in the heating mode, when primary air is at a minimum, or in the minimum ventilation mode to keep air circulation up in the zone. When demand for primary air increases the parallel fan is shut off by the terminal unit controls. At a predetermined set-point, the fan is energized and plenum air or return air is mixed with the primary air. In the full heating mode, primary air may be completely shut off. Consult project specifications for the sequence specified. Most parallel fan terminal units are pressure independent and include a primary air velocity sensor and controller. Heating coils may be provided at the fan inlet or at the terminal unit discharge.

Series Fan Terminal unit: Primary airflow through the terminal unit passes through the fan. The fans are usually equipped with a volume control device, i.e., speed controls or speed taps. The fan operates while the terminal unit is in normal operation. The fan mixes plenum or return air from the space with primary air from the system to maintain a constant flow of air to the conditioned zone. This type of terminal unit can be equipped with electric or hydronic heat capability. Heating coils may be provided at the return inlet or at the terminal unit discharge. Improper adjustment of the terminal unit may allow primary air to short circuit into the return air plenum or plenum air to mix with primary air. Fan rotation should be verified. Improper start-up may cause the fan to run in reverse. A proper start sequence will start the fan prior to introducing the primary air.

8.8.6 Dual Duct (DD) Terminal Units

A dual duct terminal unit consists of a plenum box with two primary air inlets, dampers or air valves with actuators and an air discharge. When the DD terminal unit is pressure independent, a primary air velocity sensor and controller also will be included, usually for each primary air inlet but other arrangements are possible. Each terminal unit in dual duct systems is thermostatically controlled to satisfy the space and temperature requirements. The available sequences are numerous, and it is imperative that the CP reviews the manufacturer's operating sequence for the type of terminal unit being balanced. Dual duct terminal units achieve the same result by utilizing a flow control device on the discharge of the box to control the total air delivered by the box, and a flow sensor on one of the two primary inlets, usually the primary heating inlet.

8.8.7 Constant Air Volume (CAV) Terminal Units

Some terminal unit applications use the previously described VAV terminals as Constant Air Volume devices. This is usually accomplished by setting the maximum and minimum primary air volumes to the same value.

8.8.8 Induction VAV Terminal Units

Induction VAV terminal units use primary air from a central fan system to create a low-pressure area within the box by discharging the primary air at high velocities into a plenum. This low-pressure area usually is separated from a ceiling return air plenum by an automatic damper. The induced air from the ceiling is mixed with the primary air, so that the actual airflow being discharged from the box is considerably more than the primary air airflow. Most of these induction boxes are designed for VAV operation; however, a few are constant volume.

Study available operating sequences in the manufacturer's data before attempting to do the TAB work. Balancing will consist of setting the primary airflow, both maximum and minimum. The discharge air is a total of the primary air and the induced air. Some boxes have adjustments for the induction damper setting. After the box is set, the downstream air outlets can be balanced in the conventional manner.

8.9 VARIABLE AIR VOLUME SYSTEM PROCEDURES

8.9.1 Pressure Dependent VAV Procedures Without Diversity

It is important to note that terminal units on pressure dependent systems may have airflow significantly different than design requirements. In this condition, the total existing airflow at the time of the balancing procedure becomes the design flow condition. The outlets may end up being proportioned, for example, at 75% or 125% of nominal design requirements. This is to be expected and should be reported. System conditions are to be included in the project summary.

To eliminate possible misunderstandings later, it is recommended that an agenda with the proposed balancing procedures be submitted before the TAB work is started.

The following balancing procedures are generally appropriate for variable volume systems with pressure dependent terminal units without diversity:

a. Verify the construction team responsibilities for system installation and startup as discussed in Section 3 are complete.
b. Verify that the temperature control contractor's sequence of operation complements the terminal unit or terminal unit manufacturer's installed control system.
c. Confirm that the correct air filters have been installed. Review the specifications to determine if a temporary filter blockage is required to simulate partially loaded filters.
d. Barometric dampers are to be checked for free operation. If the dampers are equipped with adjustable weights, they are to be set to maintain the specified building static pressure. All exhaust systems are to be balanced before adjusting barometric relief dampers.
e. Verify that all manual volume dampers are locked 100% open.
f. Inspect primary air ducts to ensure manufacturer recommended entry conditions to the terminal unit.
g. Measure the air handler motor amperage.
h. Measure the air handler motor voltage.
i. Confirm that the voltage and amperage match the air handler motor nameplate.
j. Verify correct rotation.
k. Measure fan RPM and compare to submitted RPM.
l. At fan powered terminal unit, verify that fan is operational.
m. Verify that adequate supply duct static pressure is available to allow balancing of terminal unit.
n. Posture all terminal units to the maximum demand position.
o. Posture the OA and RA dampers to provide minimum design OA.
p. If manual volume dampers are present at the inlet to each terminal unit, adjust the dampers to achieve the design air flow at each terminal unit being balanced.
q. Balance the outlets on each terminal unit using either of the two recommended proportioning methods.
r. If the terminal unit controls allow a minimum airflow, adjust each terminal unit to deliver the correct minimum airflow. This is a problematic issue with pressure dependent systems, as actual minimum flow rates are not controlled and may under or over ventilate the spaces served in minimum mode. Test and record the values of the downstream terminals with minimum airflow.
s. Identify the VAV terminal unit(s) that is (are) the most difficult to satisfy at the current supply fan airflow and static pressure. Measure the static pressure at this unit. The entering static pressure at this terminal unit should be no less than the sum of the terminal unit manufacturer recommended minimum inlet static pressure plus the static pressure or resistance

of the ductwork and the terminals on the discharge side of the terminal unit. Adjust system static pressure to the minimum value necessary to maintain design airflow at this terminal unit(s). This set-point information should be provided to the appropriate project personnel.

t. Measure the AHU total air volume. A duct traverse is the preferred method. The sum of several traverses may be required.
u. If necessary, adjust fan airflow to meet design requirements.
v. Determine the AHU's design total static pressure (TSP) or external static pressure (ESP). If the rating is for TSP, measure the suction and discharge static pressure at the inlet and outlet of the fan. If the rating is for ESP, measure the suction and discharge static pressure at the return duct and discharge duct. The suction static pressure measurement point can be immediately adjacent to the unit. The discharge measurement point should be taken 3 to 5 duct diameters from the discharge of the fan.
w. Test and record the operating static pressure at the sensor that controls the HVAC unit fan, if provided, and verify the operation of the static pressure controller.
x. If testing with partially loaded filters is specified, measure pressure drop across air filters and adjust a temporary blockage to meet specified requirements.
y. A return air fan (if used) should be adjusted to maintain a slightly positive pressure in the building. This may be accomplished by damper adjustment and/or fan speed adjustment.
z. At the conclusion of all system balancing, adjust and verify the AHU minimum outside air ventilation rate.
aa. Record final unit data, complete the report forms, and submit as required.

8.9.2 Pressure Dependent VAV Procedures with Diversity

The CF is to determine if the VAV system has a diversity factor. The diversity factor is an arithmetic ratio of the fan's rated airflow capacity divided by a summation of all VAV terminal unit's design maximum airflow. A system with a fan rated at 8,000 CFM (4000 L/s) and a VAV terminal combined maximum design of 10,000 CFM (5000 L/s) would be considered to have a diversity factor of 80%.

VAV systems with diversity can be the most difficult to balance satisfactorily. Any procedure used will be a compromise, and shortcomings will appear somewhere in the system under certain operating conditions. The CP should expect that some fine-tuning will be necessary after the initial TAB work is complete.

The following balancing procedures are generally appropriate for variable volume systems with pressure dependent terminal units with diversity:

a. Verify the construction team responsibilities for system installation and startup as discussed in Section 3 are complete.
b. Verify that the temperature control contractor's sequence of operation complements the terminal unit manufacturer's installed control system.
c. Confirm that the correct air filters have been installed. Review the specifications to determine if a temporary filter blockage is required to simulate partially loaded filters.
d. Barometric dampers are to be checked for free operation. If the dampers are equipped with adjustable weights, they are to be set to maintain the specified building static pressure. All exhaust systems are to be balanced before adjusting barometric relief dampers.
e. Verify that all manual volume dampers are locked 100% open.
f. Inspect primary air ducts to ensure manufacturer recommended entry conditions to the terminal units.
g. Measure air handler motor amperage.
h. Measure air handler voltage.
i. Confirm that the voltage and amperage match the air handler's motor rating.
j. Verify correct rotation.
k. Measure fan RPM and compare to design RPM.
l. At fan-powered terminal units, verify that fan is operational.
m. Posture the system OA and RA dampers to provide the minimum design ventilation airflow.
n. Verify that adequate supply duct static pressure is available to allow balancing of terminal units.
o. VAV systems with diversity factors should be initially postured to operate at maximum system airflow with all peak load terminal units wide open and all non-peak terminal units closed to the minimum position. Distribute the reduced airflow terminal units throughout the system so that they are not all one major branch.

p. If manual volume dampers are present at the inlet to each box, adjust the dampers to achieve the design airflow at each terminal unit being balanced.
q. Balance the outlets on each terminal unit using either of the two recommended balancing procedures.
r. Set the non-peak terminal units to a full flow condition, and close as many peak boxes as necessary to match the design flow of the non-peak boxes.
s. Balance the outlets on each terminal unit using either of the two recommended balancing procedures.
t. If the existing terminal unit controls allow a minimum airflow, adjust each terminal unit to deliver the correct minimum airflow. This is a problematic issue with pressure dependent systems, as actual minimum flow rates are not controlled and may under or over ventilate the spaces served in minimum mode. Test and record the values of the downstream terminals with minimum airflow.
u. Identify the terminal unit(s) that is (are) the most difficult to satisfy at the existing supply fan airflow and static pressure. Measure the static pressure at this unit. The entering static pressure at this Terminal unit should be no less than the sum of the terminal unit manufacturer recommended minimum inlet static pressure plus the static pressure or resistance of the ductwork and the terminals on the discharge side of the terminal unit. Adjust system static pressure to the minimum value necessary to maintain design airflow at this terminal unit(s). This set point information should be provided to the appropriate project personnel.
v. Measure the AHU total air volume. A duct traverse is the preferred method. The sum of several traverses may be required.
w. If necessary, adjust fan airflow to meet design requirements.
x. Determine the AHU's design total static pressure (TSP) or external static pressure (ESP). If the rating is for TSP, measure the suction and discharge static pressure at the inlet and outlet of the fan. If the rating is for ESP, measure the suction and discharge static pressure at the return duct and discharge duct. The suction static pressure measurement point can be immediately adjacent to the unit. The discharge static pressure measurement should be taken 3 to 5 duct diameters from the discharge of the fan.
y. Test and record the operating static pressure at the sensor that controls the HVAC unit fan, if provided, and verify the operation of the static pressure controller.
z. If testing with partially loaded filters is specified, measure pressure drop across air filters and adjust a temporary blockage to meet specified requirements.
aa. A return air fan (if used) should be adjusted to maintain a slightly positive pressure in the building. This may be accomplished by damper adjustment and/or fan speed adjustment.
bb. At the conclusion of all system balancing, adjust and verify the AHU minimum outside air ventilation rate, if required.
cc. Record final unit data, prepare the report forms, and submit as required (see Section 5).

8.9.3 Pressure Independent VAV Procedures Without Diversity

The manufacturer's published data provides the static pressure operating range and the minimum static pressure drop across each terminal unit for a given airflow. Use this data to verify that adequate pressure is available for the terminal unit to function properly.

The objective of balancing pressure independent terminal units is the same, regardless of the type of controls used. They must be adjusted to deliver the specified maximum and minimum airflows.

For simplification, consider each pressure independent terminal unit and its associated downstream ductwork to be a separate supply air duct system. Because of terminal unit pressure independent characteristics, it is possible to balance all the boxes on a system, even if the system pressure is low. If there is adequate static pressure and airflow available at the terminal unit inlet, the box and its associated outlets can be balanced. When there is inadequate static pressure, set the adjacent boxes into the minimum airflow position to increase the static pressure to simulate design conditions. This method of simulating or providing adequate static pressure also applies to balancing systems with diversity.

The following balancing procedures are generally appropriate for variable volume systems with pressure independent terminal units without diversity:

a. Verify the construction team responsibilities for system installation and startup as discussed in Section 3 are complete.
b. Verify that the temperature control contractor's sequence of operation complements the terminal unit or terminal unit manufacturer's installed control system.

c. Confirm that the correct air filters have been installed. Review the specifications to determine if a temporary filter blockage is required to simulate partially loaded filters.
d. Barometric dampers should be checked for free operation. If the dampers are equipped with adjustable weights, they should be set to maintain the specified building static pressure. All exhaust systems should be balanced before adjusting barometric relief dampers.
e. Verify that all manual volume dampers are locked 100% open.
f. Inspect primary air ducts to ensure manufacturer recommended entry conditions to the terminal unit.
g. Measure the air handler motor amperage.
h. Measure the air handler motor voltage.
i. Confirm that the voltage and amperage match the air handler motor rating.
j. Verify correct rotation.
k. Measure fan RPM and compare to design RPM.
l. At fan powered terminal units, verify that fan is operational.
m. Posture the system OA and RA dampers to provide minimum design OA volume.
n. Verify that adequate supply duct static pressure is available to allow balancing of terminal units.
o. Calibrate the volume controllers on each terminal unit using the manufacturer's recommended procedures.
p. Balance the outlets on each terminal unit using either of the two recommended balancing procedures.
q. Identify the terminal unit(s) that is/are the most difficult to satisfy at the existing supply fan airflow and static pressure at this terminal unit. The entering static pressure at this terminal unit should be no less than the sum of the terminal unit manufacturer recommended minimum inlet static pressure plus the static pressure or resistance of the ductwork and the terminals on the discharge side of the terminal unit. Adjust system static pressure to the minimum value necessary to maintain design airflow at this terminal unit(s). This set point information should be provided to the appropriate project personnel.
r. Measure the AHU total air volume. A duct traverse is the preferred method. The sum of several traverses may be required.
s. If necessary, adjust the fan airflow to meet design requirements.
t. Determine the AHU's design total static pressure (TSP) or external static pressure (ESP). If the rating is for TSP, measure the suction and discharge static pressure at the inlet and outlet of the fan. If the rating is for ESP, measure the suction and discharge pressure at the return duct and discharge duct. The suction static pressure measurement point can be immediately adjacent to the unit. The discharge measurement point should be taken 3 to 5 duct diameters from the discharge of the fan.
u. Test and record the operating static pressure at the sensor that controls the HVAC unit fan if provided and verify the operation of the static pressure controller.
v. If testing with partially loaded filters is specified, measure the pressure drop across air filters and adjust a temporary blockage to meet specified requirements.
w. A return air fan (if used) should be adjusted to maintain a slightly positive pressure in the building. This may be accomplished by damper adjustment and/or fan speed adjustment.
x. At the conclusion of all system balancing, adjust and verify the AHU minimum OA ventilation rate, if required.
y. Record final unit data, complete the report forms, and submit as required.

8.9.4 Pressure Independent VAV Procedures With Diversity

Follow the procedures for pressure independent VAV systems without diversity. When the terminal unit balancing procedures are complete, the total system airflow is measured by adjusting a combination of terminal units to maximum and minimum airflows to match the design fan airflow. Fan performance is then measured by methods previously described (see Sections 8.9.1 and 8.9.2).

Complete the reporting requirements as previously specified.

8.9.5 Combination Systems

Some system applications may incorporate pressure independent terminal units and pressure dependent terminal units on the same system, either with or without diversity. Balancing procedures will have to be tailored to each job. It is recommended that the pressure independent boxes are balanced first, since once they are balanced, they will not be affected by changing static pressures as the rest of the system is being balanced, provided that adequate main duct static pressure doesn't drop below a minimum value.

If a system has many pressure dependent boxes, they may consume most of the system airflow and static pressure on the initial system start up, since they will be wide open. Either set some of these boxes to a minimum airflow position or partially close the inlet dampers on some boxes to build up the static pressure in the system. After setting all the pressure independent terminal units, use the procedures detailed previously for pressure dependent systems and balance the downstream air outlets.

8.10 DUAL DUCT SYSTEMS

Dual duct systems use both a hot air duct and a cold air duct to supply air to mixing boxes. Mixing boxes may operate in a constant air volume mode or in a variable air volume mode. They are usually pressure independent, but they may be either system powered or have external control systems. There are many operational schemes for these types of units. The CP is to review the specific manufacturer's setup instructions for these units.

8.10.1 Constant Volume Dual Duct Systems

Each constant volume mixing box has a thermostatically controlled mixing damper to satisfy the space temperature requirements. A mixture of the hot and cold air is controlled to maintain a constant airflow to the space.

The following balancing procedures are appropriate for constant volume dual duct systems:

a. Verify the construction team responsibilities for system installation and startup as discussed in Section 3 are complete.
b. Verify that the temperature control contractor's sequence of operation complements the terminal unit or terminal unit manufacturer's installed control system.
c. Confirm that the correct air filters have been installed. Review the specifications to determine if a temporary filter blockage is required to simulate partially loaded filters.
d. Barometric dampers should be checked for free operation. If the dampers are equipped with adjustable weights, they should be set to maintain the specified building static pressure. All exhaust systems should be balanced before adjusting barometric relief dampers.
e. Verify that all manual volume dampers are locked 100% open.
f. Inspect primary air ducts to ensure adequate entry conditions to the terminal units.
g. Start the fan and immediately measure the motor running amperage.
h. Complete all fan and motor data in accordance with Section 5 reporting requirements.
i. Posture the system OA and RA dampers to provide the minimum design ventilation airflow.
j. Determine the AHU's design total static pressure (TSP) or external static pressure (ESP). If the rating is for TSP, measure suction and discharge static pressure at the inlet and outlet of the fan. If the rating is for ESP, measure the suction and discharge static pressure at the return duct and discharge duct. The suction pressure static measurement point can be immediately adjacent to the unit. The discharge measurement point should be taken no closer to the discharge than 3 to 5 duct diameters.
k. If testing with partially loaded filters is specified, measure pressure drop across air filters and adjust a temporary blockage to meet specified requirements.
l. Place all the dual duct boxes and the supply air fan in a full flow condition. It is common practice to set all the mixing boxes to their full cold airflow position for setting the fan volume, but first verify that the cooling coil is designed to handle the same airflow as the HVAC duct system. It may be designed for less airflow creating a diversity that will require some mixing boxes to be set in a heating position for a total system flow test.
m. Measure the AHU total air volume. A duct traverse is the most accurate method available. The sum of several traverses may be required.
n. If necessary, adjust fan airflow to meet design requirements.
o. Balance the dual duct boxes using procedures described in the following Paragraph 8.11.4. The CP should use these procedures as a guide, and modify the procedures as required by the individual projects.
p. Test and record the operating static pressure at the sensors that control the HVAC unit fan or fans, if provided, and verify the operation of the static pressure controllers.
q. Final System measurements: At the conclusion of all system balancing, adjust and verify the AHU minimum outside air ventilation rate, if required.
r. Record final unit data, complete the report forms, and submit as required.

8.10.2 Variable Volume Duct Systems

The procedures to TAB variable volume dual duct systems are like that of dual duct constant volume systems, with minor variations:

- a. The boxes are calibrated in both heating and cooling modes.
- b. The terminal outlets are to be balanced in only one mode.
- c. System setup procedures are like those required for constant volume dual duct systems and are to be adapted as necessary by the CP to conform to the system being balanced.

8.11 VARIABLE AIR VOLUME TERMINAL (VAV) UNIT PROCEDURES

8.11.1 Cooling Only Terminal Units

Pressure Dependent:

- a. Set the terminal unit to maximum airflow.
- b. Test the total airflow delivered by the terminal unit using one of the following methods:
  - Perform a duct traverse
  - Total of air being delivered from the outlets.
- c. Adjust the terminal unit total airflow with available devices, manual stops, or control system.
- d. Adjust the outlets using either the proportional or the stepwise method.
- e. Adjust the terminal unit minimum airflow using the methods listed above.

Pressure Independent:

- a. Set the volume controller to design maximum airflow.
- b. Test the total airflow delivered by the terminal unit using one of the following methods:
  - Perform a duct traverse
  - Total of air being delivered from the outlets.
- c. Calibrate the controller, by appropriate methods, to the measured airflow.
- d. Balance the outlets using either the proportional or the stepwise method.
- e. Set the volume controller to the design minimum airflow.
- f. Calibrate the controller for the required minimum using the methods above for calibrating maximum.

Note: Some VAV control systems may require the minimum airflow set point to be calibrated before the maximum airflow set point; confirm with the control system supplier.

8.11.2 Cooling Only Terminal Units With Reheat

These units are balanced as described for cooling only terminal units, with the possibility of distinct heating airflow set point(s). The heating airflows are verified and reported.

8.11.3 Fan Terminal VAV/CAV Units

Parallel Type (Pressure Independent or Dependent):

- a. The primary airflows are balanced as discussed previously for a cooling only terminal unit.
- b. Set the controls to operate the fan with the primary air valve at minimum flow.
- c. Adjust the fan airflow to design airflow by adjusting the fan speed or dampers, whichever is provided.
- d. Verify heating airflow and report.

Series Type (Pressure Independent):

- a. Set the terminal unit to the design maximum cooling set point.
- b. Set the fan speed to design airflow by measuring the outlet total airflow and comparing to design requirements.
- c. Adjust the primary damper to obtain a neutral condition at the return inlet. When the inlet is neutral, the fan airflow is equal to primary airflow.

d. Balance the air outlets using an appropriate method.
e. Place the terminal unit to the minimum position and adjust the primary airflow to design requirements.
f. Verify the heating airflow and report.
g. On series terminal unit systems only, volume dampers may be used to restrict airflow if fan airflow cannot be reduced, provided that a noise problem is not created.

Note: Some VAV control systems may require the minimum airflow set point to be calibrated before the maximum airflow set point; confirm with the control system supplier. Design primary airflow may not always equal design fan airflow.

Some manufacturers have their own required test procedures for measurement and balancing of airflows. It is up to the TAB Firm to obtain and apply to appropriate method for calibration and balancing of specific terminal units that will be acceptable to the project.

8.11.4 Dual Duct Terminal Units (Constant or Variable Volume)

It is not practical to cover all the various operating sequences here, and it is very important that the CF review the control manufacturer's balancing procedures. If the control manufacturer's specifications do not address TAB procedures, the appropriate procedures should be developed. A generic pressure independent procedure is described below:

a. Set the cooling volume controller to design maximum airflow.
b. Set the heating volume controller to a fully closed position.
c. Test the total airflow delivered by the terminal unit using one of the following methods:
    - Perform a duct traverse
    - Total of air being delivered from the outlets
d. Calibrate the cooling volume controller, by appropriate methods, to measured airflow.
e. Balance the outlets using either the proportional or the stepwise method.
f. Set the cooling volume controller to a fully closed position.
g. Set the heating volume controller to design maximum airflow.
h. Calibrate the heating volume controller by appropriate methods, to measured airflow.
i. The control sequence is to be tested to verify that the minimum ventilation requirements are provided.

8.12 UNDERFLOOR PLENUM SUPPLY AIR SYSTEMS

Underfloor plenum supply air systems require extensive cooperation from all members of the construction team. The design team is responsible to specify carefully and completely what is required of all participating members of the construction team. The underfloor system relies on the integrity of the floor plenum to transport the conditioned air to the occupied zone above the floor. Air leakage in the underfloor plenum is a critical determinant of system performance. The integrity of the underfloor plenum is commonly compromised by poor wall construction; penetrations of the plenum walls by electrical conduit, plumbing and piping systems; communication cabling, etc. It is the responsibility of the design team and construction team to specify and construct a plenum with minimal air leakage.

Floor tiles are usually designed to be removable; however, the carpet tiles are frequently not compatible with the floor tiles and complicate the removal and replacement procedures. The installation of VAV terminals, for perimeter heating or special load applications, below the floor will require provisions for maintenance, especially if those terminals are equipped with filters for the plenum inlets.

Buildings with VAV floor diffusers, served by central station air handling systems typically have underfloor static pressure control systems. These control systems operate to maintain a constant static pressure in the underfloor plenum. Control of the underfloor static pressure allows the VAV diffusers to operate without adversely affecting the constant volume floor diffusers. In general, an underfloor system can be treated as a special case of a constant volume system. The CP is to communicate the importance of the construction requirements regarding underfloor leakage to the design and construction teams. These systems often have hundreds of diffusers. In this case, it may be appropriate to report room or zone total airflows, rather than trying to provide a unique identifier for each of hundreds of floor diffusers.

8.13 RETURN AIR SYSTEMS

Constant volume ducted return air systems are balanced using the same principles and guidelines as for constant volume supply air systems. Follow NEBB procedures and incorporate the appropriate modifications to the procedures to accomplish the specified requirements.

Individual return grilles in open non-ducted return air systems cannot be balanced, even if design return airflows are indicated on the plans.

8.14 EXHAUST AIR SYSTEMS

8.14.1 General Exhaust Air Systems

Constant volume exhaust air systems are balanced using the same principles and guidelines as for constant volume supply systems. Follow NEBB procedures and incorporate the appropriate modifications to the procedures to accomplish the specified requirements.

8.14.2 Kitchen Exhaust Air/Makeup Air Systems

Kitchen makeup air systems must be in operation when the balancing takes place. Makeup air is achieved by means of relief or transfer grilles from adjoining areas, or by a dedicated makeup air system.

Velocity readings of the grease filters or slots, performed in accordance with the manufacturer's specifications, are the most appropriate and generally accepted method to perform TAB procedures on a kitchen hood. Most kitchen hood exhaust ducts are made of heavy gauge metal and are covered with a thick fire-resistant insulation. Traverses of grease exhaust ducts are not recommended. If a traverse of the exhaust duct is necessary, access to the duct is provided by others. When the testing is complete, repair to the duct and fire-retardant enclosure is provided by others and is in accordance with applicable codes and industry practices.

When making velocity readings a correction for air density may be required if elevated temperatures are present or predicted.

8.15 VARIABLE FLOW SYSTEMS/VARIABLE SPEED DRIVES (VFD)

8.15.1 General: Variable Airflow Systems

Typically, variable volume air systems are balanced using the same principles and guidelines as for constant volume supply systems. NEBB procedures should be followed and incorporate the appropriate modifications to accomplish the specified requirements.

System fans fitted with VFDs normally modulate from a maximum design airflow to a minimum design airflow. It is generally the expectation of the TAB firm that the maximum design airflow will be achieved at or near 100% motor speed and that the minimum flow will be achieved well above the minimum motor speed recommended by the manufacturer or supplier. There are occasions when either an acceptable maximum or minimum speed/flow combination cannot be accomplished with the provided sheave sets, thus requiring sheave changes.

8.15.2 NEBB TAB Responsibilities

By these standards (Section 8.3.4) the TAB firm is responsible for all fan and system related adjustments and reporting.

The TAB firm is not required by these *Procedural Standard* to provide or install new sheave sets, however the specification and contract documents may assign this responsibility to the TAB CF.

8.15.3 Speed Change Procedures

8.15.3.1
Determine system diversity (if applicable), maximum operating pressures, maximum BHP and other factors that affect setting of final speed.

8.15.3.2
Verify Manufacturer's maximum fan RPM to assure that an increase in speed does not exceed the maximum RPM of the fan wheel at any time (This is critical). The maximum fan wheel RPM can be found in the manufacturer's submittal data.

8.15.3.3
Verify that an increase in maximum RPM does not exceed the fan class rating (I, II, III). If calculations show that this is a possibility, the manufacturer and A/E should make the final decision. Authorization to proceed should be in writing.

8.15.3.4
Never exceed the corrected full load amperage on the motor regardless of the motor's rated service factor. Authorization to run a motor in the service factor should come from the manufacturer, A/E, or contractor, and should be in writing.

8.15.3.5
Verify the need to pre-load the filters to a designated filter pressure differential at maximum air flow. If no pre-loading is specified, operate the system with clean filters and report.

8.15.3.6
When the system is variable speed, take care to not operate the system at a minimum frequency that can be harmful to the motor. This setting should be coordinated with the party responsible for programming the VFD.

8.15.3.7
Before operating a variable speed system above 60Hz, verify with the interested parties that this is acceptable and is within the limits of all system components such as maximum fan wheel rpm.

8.15.3.8
When the CF is required to recommend a new drive package, the information provided to the contractor should meet all the requirements in the specification such as, horsepower rating of the drive package (example: 150% of motor nameplate horsepower).

8.15.3.9
When slowing a system down, it is acceptable to reduce the number of belts if the final package meets the horse- power requirements of the specification. When reducing the number of belts, both sheaves should be changed. Do not run with one or two empty grooves on a sheave.

8.15.3.10
Direct drive fans operating with VFDs often will be specified to operate above 60 Hz. Any adjustment to this maximum frequency should adhere to all the above limitations of fan maximum RPM, fan class or motor nameplate amps. Do not exceed 120 Hz or any frequency limit published by the fan/motor manufacturer.

8.15.3.11
If a variable speed system at minimum air flow requires the fan motor run at a "near stall" condition where it may or may not initiate rotation on startup, or the motor overheats due to an extremely slow RPM, the manufacturer, A/E and contractor should be notified immediately. An auxiliary cooling fan may be required to protect the motor.

8.15.3.12
Before restarting the fan, all sheave components must be tightened to the manufacturer's recommended torque. This includes set screws and tapered bushing bolts.

8.15.3.13

Multiple belt drive packages must be equipped with a "matched" set of belts to assure equal loading on all belts.

8.15.3.14

The drive belts should be properly aligned and tensioned to the manufacturer's recommended tension using a belt tension measuring instrument that provides the proper deflection with the recommended pressure applied to the belt.

8.15.3.15

The belts should be re-tensioned after they have been in operation for 24 hours or more to take the initial "stretch" out of them.

Note: If a system is equipped with DX cooling, closely match operational airflow to system tonnage. Consult the Engineer and Equipment Supplier for speed/airflow selections.

8.16 ENERGY RECOVERY SYSTEMS

8.16.1 General Energy Recovery Systems

Energy Recovery Units (ERU) are a type of HVAC equipment (and system) that feature a heat exchanger combined with a building exhaust and ventilation system for providing controlled ventilation into a building while reclaiming some of the heating or cooling from the exhausted air.

These systems are typically installed where large volumes of ventilation (outside) air is required to meet code standards.

Testing, adjusting, and balancing the air delivery of these systems is the same procedure as any air handling unit or exhaust sys- tem. The added effort required by the TABCF is defining the flow across the exchanger and evaluating its performance.

There are two distinct types of energy recovery units:

8.16.1.1 Total Energy Recovery Systems

Total Energy Recovery units exchange both sensible heat (dry bulb) and latent heat (moisture removal/adding) across the exchanger. The exchanger is typically
a rotating wheel of desiccant material that rotates between the exhaust air path and the outside air path.

In the cooling season this rotation transfers the heat and moisture of incoming air into the building exhaust air, thus reducing the cooling load.

In the heating season this rotation transfers the heat and moisture of building exhaust air to the incoming air, thus reducing the heating load.

To insure there is no cross contamination of air between the exhaust and the incoming ventilation air the systems have a prescribed requirement for "purge" air. Purge air flows from the incoming air stream (clean) to the exhaust air stream (dirty) to minimize cross contamination in the system. The CF must determine this quantity and adjust to the specified amount. Complete all TAB work and Report Data in accordance with Section 5 of this *Standard*.

8.16.1.2 Sensible Energy Recovery Systems

Sensible Energy Recovery units exchange only sensible heat (dry bulb) across the exchanger. The exchanger is typically a cross flow heat exchanger that allows heat transfer between two totally isolated air paths thus eliminating the possibility of cross contamination. This type system is commonly used in laboratory environments.

The TAB firm will adjust, balance, and record the performance of the Sensible Energy Recovery System using the same proce- dures as described above. Reporting requirements shall be per Section 5 of this edition.

8.17 LABORATORY BIOSAFETY & FUME HOODS

Never enter or work in a laboratory, clean space, or biological laboratory without permission. Only do so after appropriate safety awareness training.

Refer to NEBB *Procedural Standard for Fume Hood Testing* and the NEBB *Procedural Standard for Cleanroom Testing*.

8.18 INDUSTRIAL EXHAUST HOODS AND EQUIPMENT

8.18.1 Air and Fume Exhaust Systems

NEBB *Procedural Standard for Fume Hoods Performance Testing* should be referenced for proper testing techniques.

The balancing procedure is basically the same as any other exhaust air system. A duct traverse is the preferred method. The sum of several traverses may be required. The differences are mainly in how to test the various inlet openings. If an inlet opening velocity must be measured, obtain the free area opening by measuring it and then calculate what the velocity is to be. Quite often this will not be possible due to irregular shapes and/or obstructions.

A thermal anemometer is a very valuable instrument for this type of work as the probe is small enough to get into obstructed places. Proper testing in these situations may require review of the equipment manufacturer's data, as the procedures for setting up and testing the equipment may be available.

8.19 BUILDING STATIC PRESSURE CONTROL METHODS

There are three commonly applied methods of controlling building static pressure:

8.19.1 Active Building Static Pressure Control

Building static pressure controllers sense differential pressures between a typical room and outdoors and increase the volume of air handled by the return/exhaust air fan as building pressure increases. This method controls buildings by sensing the value of the variable being controlled, and adjusting return or exhaust fan flow, as necessary. Typical commercial building static pressures range from +0.02 in. w.g. to +0.05 in. w.g. (5 Pa to 12.5 Pa).

8.19.2 Open Loop Control

Open loop (or "non-feedback") control uses an adjustable span and start-point on the supply air and return air fan controls to sequence the return air fan operation with the supply air fan. This system requires close attention by the CP. If the system load varies significantly among the major zones the supply air fan serves, resistance in the return air system may not vary in direct proportion to resistance in the supply air system. Open loop control does not sense the effect of resistance variance between the supply air and return air systems and building pressures may vary when major load variation occurs.

8.19.3 Closed Loop Control (Fan Tracking)

The closed loop control senses changes in the volume of air the supply air fan delivers and uses a controller having a second input proportional to the return air fan flow to reset the return air fan. This is commonly referred to as fan tracking. Controlling return flow in response to changes to supply fan flow requires a thorough understanding of system and building performance for the resulting fan performance to be acceptable.

Section 9. HYDRONIC SYSTEM TESTING, ADJUSTING & BALANCING PROCEDURES

9.1 INTRODUCTION

This section describes procedures necessary for testing, adjusting, and balancing (TAB) of commonly installed HVAC systems. It is the responsibility of the NEBB Certified TAB Firm (CF) or NEBB Certified TAB Professional (CP) to determine appropriate procedures for systems not covered in this section.

Domestic Hot Water Recirculation systems are not a requirement of this standard. If balancing is required for domestic hot water recirculation systems, the EOR must include the requirements within the scope detailed in the contract documents.

9.2 PRELIMINARY SYSTEM PROCEDURES

9.2.1

Each type of HVAC system is designed to meet a set of performance parameters. This usually includes maximum heating capacity, maximum cooling capacity and ventilation effectiveness. Prior to the TAB process, the CF should normally set up a system to its 'full load' condition (or maximum capacity). The full load condition presents the greatest challenge to a system's capacity meeting its design airflow requirements.

9.2.2

Not all systems are covered in this section, only those most commonly installed. Confer with the EOR to establish the proper set up conditions for specific systems.

9.2.3

The following TAB procedures are basic to all types of hydronic systems:

a. Verify that the construction team responsibilities for system installation and startup as discussed in Section 3 are complete.
b. Confirm that every item affecting the hydronic flow in a piping system is ready for the TAB work, i.e. pumps started and operating, piping systems flushed, vented, chemical treatment complete, air vents installed and operating. Startup strainer screens removed and replaced with final strainer screens. Expansion tank properly installed, and system properly filled to design pressure.
c. Prepare and submit, if required, the TAB plan that includes specific hydronic procedures to be implemented.
d. Prepare TAB forms in compliance with Section 5 of this edition of *Procedural Standard* and the project's drawings and specifications.
e. Confirm that automatic control system is complete and available for use in completing TAB operations.
f. Simulate the conditions for design maximum system requirements.
g. Verify that all valves are open or set, all related systems are operating, motors are operating at or below full load amperage ratings, and pump rotation is correct.

9.3 HYDRONIC SYSTEM MEASUREMENT METHODS

9.3.1 Basic Flow Measurement Methods

The appropriate techniques for flow measurement of hydronic systems are to be determined by reviewing the system(s) to be tested. There are six basic methods available for measuring the flow quantity in a piping system:

1. Flow meters or flow fittings
2. Calibrated balancing valves
3. Pump curves

4. Equipment pressure loss
5. Heat transfer method
6. Ultrasonic Flowmeter

It is preferable to balance hydronic systems using calibrated flow measuring devices. Flow measurement is accomplished using differential pressure meters and calibrated balancing valves, venturis and/or ultrasonic flow meters. Balancing flow measurement eliminates compounding errors introduced by the temperature difference or equipment pressure drop procedures. This measurement approach also allows the pump to be matched to the actual system requirements. Proper instrumentation and good preplanning are needed.

9.3.2 Calibrated Flow Measuring Devices

Calibrated flow measuring devices are the preferred method of flow measurement. The CF will verify that installation of the calibrated flow measuring devices is in accordance with recommended practices given by the manufacturer. Calibrated flow measuring devices include orifice plates, venturis, Pitot tubes, turbine meters, ultrasonic meters, etc.

Note: Verify that the pressure units of the differential pressure gauge and the pressure units found on the flow charts provided by the manufacturer are identical. If pressure units are not the same (i.e. psi, in. w.g., ft. w.g., Pa, kPa, mm, m^3/h), pressure conversions will be required.

9.3.3 Calibrated Balancing Valves

The three types of calibrated balancing valves are: self-adjusting, adjustable orifice, and fixed orifice valves.

Self-Adjusting Valves

A self-adjusting valve/flow sensing device utilizes internal mechanisms that constantly change internal orifice openings to compensate for varying system differential pressures while maintaining a preset flow rate. No external adjustment is available with this device. Pressure taps allow for measurement of valve differential pressure which is an indirect indication of system flow.

The CF will verify the valve flow rating from the data tag, and verify by differential pressure measurements, if available, that the pressure drop across the valve is within the control range of the valve.

Adjustable Orifice Valves

Some calibrated balancing valves are adjustable orifice devices. A chart or graph, provided by the valve manufacturer, indicates actual flow rates at various valve positions and differential pressures. Measurement of the actual flow requires knowledge of the valve position, valve size, and pressure differential of the valve.

Fixed Orifice Valves

Some calibrated balancing valves are fixed orifice devices. A chart or graph, provided by the valve manufacturer, indicates actual flow rates at various valve positions and differential pressures. Measurement of the actual flow requires knowledge of valve size, and pressure differential of the valve.

9.3.4 Pump Curve Method

Actual system flow can be determined with the manufacturer's pump curve provided with the pump or provided as part of the certified submittal data. If a certified curve is not available, pump flow may be approximated by a catalog pump curve. Pump pressure readings shall be taken at the same test locations used by the manufacturer.

The pump impeller size is verified by measurement of the pump shut-off (no flow) differential head. The shut-off head value is compared to pump curve data to determine the size of the pump impeller. After opening the pump discharge valve, the pump total head is determined by calculating the difference between the pump discharge pressure and pump suction pressure. Using the total head, in appropriate units, determine the pump water flow from the corrected pump curve established previously. Verify the pump curve data with data from flow meters and/or calibrated balancing valves.

9.3.5 Equipment Pressure Loss Method

System flow rates may be calculated by using the HVAC equipment pressure loss, provided that certified data is obtained from the equipment manufacturer indicating rated flow and pressure losses; and provided that there is an accurate means for determining the actual equipment pressure losses. Equipment pressure readings shall be taken at similar test locations used by the manufacturer. Inaccurate measurements will result if dirt, debris, or scaling is present. Measurements will also be inaccurate if the test ports are placed such that the measured pressures include pressure drops across valves, elbows, tees, etc. If available, verify the equipment pressure loss data with data from flow meters and/or calibrated balancing valves.

When the design criteria of the equipment and the pressure loss are known, the flow rate may be calculated by using the pump affinity laws.

9.3.6 Heat Transfer Method

Approximate flow rates may be established at heating and cooling terminals by using both air and hydronic measured heat transfer data. This is the least accurate method for determining flow in hydronic systems.

9.3.7 Ultrasonic Flow Method

Liquid flow rates may be established using a clamp-on ultrasonic transit time flow measuring device. The technology needs be programmable for different pipe materials, process liquids, pipe sizes, and actual pipe thickness (thickness gage may need to be used depending on corrosion or build up in the pipe). With regards to installation, adequate straight run of pipe is to be considered for optimum performance. Clamp-on Transducers are traditionally located with a total of 15 pipe diameters of straight run (10 + 5) of pipe between elbows at flow rates of 10 fps, more for greater flow rates and invasive obstructions and less for lower flow rates (manufacturer guidelines should be followed for the instrument being used). Flow meters' typical optimum accuracies are 1% of rate between 0.5 to 20 fps. Flow meters do not require to be zeroed in the field. Flow meters shall have the ability to be programmed for different frequency transducers supplied by manufactures.

9.4 BASIC HYDRONIC SYSTEM PROCEDURES

Balancing hydronic systems may be accomplished in various ways. Two methods for balancing systems are presented below. Regardless of the method, the objectives remain the same and the system will be considered balanced in accordance with this edition of NEBB *Procedural Standard for Testing, Adjusting and Balancing of Environmental System (Procedural Standard)* when the following conditions are satisfied:

1. All measured hydronic flow quantities are within ±10% of the design flow quantities unless there are reasons beyond the control of the CF. (Known factors in system deficiencies will be noted in the TAB report summary.)

2. There is at least one path with fully open balancing valves from the pump to a terminal device. Additionally, if a system contains branch-balancing valves, there will be at least one wide-open path downstream of every adjusted branch-balancing valve.

9.4.1 Proportional Balancing Method (Ratio Method)

9.4.1.1 For A Hydronic System Without Branch Controls:

a. Verify that all balancing, control, and isolation valves are wide open.
b. Determine total system volume by the most appropriate method.
c. Calculate the percentage of actual hydronic flow to design flow requirements.
d. Adjust the pump to approximately 110% of design flow, if possible.

e. Measure the flow at all balancing valves.
f. Compute the ratio of measured flow to design flow for each terminal device.
g. The balancing valve serving the terminal at the lowest percentage of design flow is not adjusted in this procedure.
h. Adjust the balancing valve serving the terminal with the next (second) lowest percentage of design until both terminals are the same percentage of design. These terminals are now in balance.
i. Adjust the balancing valve serving the terminal with the next (third) lowest percentage of design until all three terminals are at the same percentage of design, and in balance.
j. Continue this procedure until all remaining terminals have been adjusted to be in balance at approximately the same percentage of design flow.
k. If necessary, adjust the pump volume to set all terminals at design flow ±10%.
l. Re-measure all terminals and record final values.
m. Mark or set all memory stops (see Section1) on all the balancing valves so that the adjustment may be restored if necessary.

9.4.1.2 For A Hydronic System With Branch Circuits That Have Balancing Valves:

a. Follow above steps in 9.4.1.1 (a) through (e) for the terminals on each branch.
b. Compute the ratio of measured branch flow to design branch flow.
c. The balancing valve serving the branch at the lowest percentage of design flow is not adjusted in this procedure.
d. Adjust the balancing valve serving the branch with the next (second) lowest percentage of design until both branches are the same percentage of design and in balance.
e. Adjust the balancing valve serving the branch with the next (third) lowest percentage of design until all three branches are at the same percentage of design, and in balance.
f. Continue this procedure until all remaining branches have been adjusted to be in balance at approximately the same percentage of design flow.
g. If necessary, adjust the pump volume to set all branches at design flow, ±10%.
h. Perform the proportioning techniques specified in above steps (a) through (m) for the terminals on each branch.
i. Re-measure all terminals and record final values.
j. Mark or set all memory stops on all the balancing valves so that the adjustment may be restored if necessary.

9.4.2 Stepwise Balancing Method

9.4.2.1 For A Hydronic System Without Branch Circuits:

a. Verify that all balancing, control, and isolation valves are wide open.
b. Determine total system volume by the most appropriate method.
c. Calculate the percentage of actual hydronic flow to design hydronic flow.
d. Adjust the pump volume to approximately 110% of design flow or as required.
e. Measure the flow at all balancing valves.
f. Starting at the pump, as the terminals closest to the pump will typically be the highest, adjust the balancing valves to a value approximately 10% below design flow requirements.
g. As the adjustment proceeds to the end of the system the remaining terminal flow values will increase.
h. Repeat the adjustment passes through the system until all terminals are within ±10% of design flow requirements and at least one balancing valve is wide open.
i. If necessary, adjust the pump volume to set all terminals at design flow, ±10%.
j. Re-measure all terminals and record final values.
k. Mark or set all memory stops on all the balancing valves so that the adjustment may be restored, if necessary.

9.4.2.2 For A Hydronic System With Branch Circuits That Have Branch Balancing Valves:

a. Follow steps (a) through (e) in Section 9.4.2.1 for the terminals on each branch.
b. Compute the ratio of measured branch flow to design branch flow.
c. Starting at the pump, as the branches closest to the pump will typically be the highest, adjust the branch balancing valves to a value approximately 10% below design requirements.

d. As the adjustment proceeds to the end of the system the remaining branch flow values will increase.
e. If necessary, adjust the pump volume to set all branches at design flow, ±10%.
f. Balance the equipment on each branch as described in above steps (e) through (i) in Section 9.4.2.1.
g. Re-measure all equipment and record final values.
h. Mark or set all memory stops on all the balancing valves so that the adjustment may be restored, if necessary.

9.4.3 Systems With Self-Adjusting Valves

a. Verify that all balancing, control, and isolation valves are wide open.
b. Determine total system flow by the most appropriate method.
c. Calculate the percentage of actual hydronic flow to design hydronic flow.
d. Measure the differential pressure at each self-adjusting balancing valve.
e. Pump differential pressures in systems with self-adjusting valves should be adjusted so that the differential pressure developed within the system does not over-range the valve cartridges, which may result in noise or oscillations.
f. System pumps should also be adjusted to ensure at least one self-adjusting valve is at or near its minimum rating. This is consistent with the requirement that there be one wide open path available (or as close to wide open as possible with auto-flow valves).

9.5 HYDRONIC SYSTEM BALANCING PROCEDURES

9.5.1 BASIC PROCEDURES

The following balancing procedures are basic to all types of hydronic distribution systems:

a. Verify that the construction team responsibilities for system installation and startup are complete, as discussed in Section 3.2.
b. Verify that all manual valves are open or preset as required, and all temperature control (automatic) valves are in a normal or desired position.
c. Verify that all automatically controlled devices in the piping or duct systems will not adversely affect the balancing procedures.
d. With the pump(s) off, observe and record system static pressure at the pump(s).
e. Verify that the system compression tank(s) airside and automatic water fill valve are operating and set properly.
f. Record the operating voltage and amperage of the pump(s) and compare these with nameplate ratings and thermal overload heater ratings. Verify the speed (rpm) of each pump.
g. Check pump rotation.
h. Place the systems into operation, check that all air has been vented from the piping systems and allow flow conditions to stabilize.
i. If flow meters or calibrated balancing valves are installed, that allow the flow rate of the pump circuit(s) to be measured, perform the necessary work, and record the data.
j. Measure the shut-off head of the operating pump by slowly closing a valve or balancing cock in the pump discharge piping. Record the discharge and suction pressures at the pump gauge connections and determine shut-off head. Preferably, one gauge should be used to read differential pressure. It is important that gauge readings be corrected to the center-line elevation of the pump. (*Note:* Do not fully close any valves in the discharge piping of a positive displacement pump. Severe damage may occur.)
k. Using shut-off head, determine and verify each pump's impeller size and operating curve. Compare this data with the submittal data curves. If the test point falls on the design curve, proceed to the next step; if not, plot a new curve parallel with other curves on the chart, from zero flow to maximum flow. Open the discharge-balancing valve slowly to the fully open position; record the discharge pressure, suction pressure, and determine total operating head.
l. Using the total operating head, read the pump water flow from the previously established corrected pump curve. If available, verify the pump curve data with data from flow meters and/or calibrated balancing valves.
m. If the measured total head is greater than the design total head, the water flow will be lower than designed.
n. If the measured total head is less than design, water flow will be greater; in which case the pump discharge pressure should be increased by partially closing the discharge balancing valve until the system water flow is approximately 110% of design.

o. Record the suction and discharge pressures and the water flow.
p. An initial recording of the flow distribution throughout the system shall be made without making any adjustments. This can be performed by using the existing flow measuring devices, or pressure/temperature ports, in the system, including any balancing devices at equipment (i.e., chillers, boilers, hot water exchangers, hot water coils, chilled water coils, etc.).
q. Determine which circuits have high or low water flow. Low flow circuits may be air bound. Check and vent air if present in low flow circuits and retake readings.
r. Compare actual total system flow with design requirements.
s. Use the proportional balancing method or the stepwise method described previously to adjust the flow rates through the equipment.
t. After all final adjustments have been completed, perform a final check of the pressures and the flow of all pumps and equipment. Re-measure the voltage and amperage of pump motors and record the data.
u. After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.
v. Record final unit data, prepare the report forms, and submit as required (see Section 5).

9.5.2 Bypass Valves

Where three-way automatic valves are used, set all bypass line balancing valves to the specified values. If there is no specified value for the bypass flow, adjust the bypassed flow to match the coil pressure drop.

9.5.3 Variable Flow Hydronic Systems

TAB procedures for a variable flow system are similar to those for constant flow systems. The main difference is that a mechanism exists in the system to vary system flow in response to demand. Three methods of controlling variable flow systems are:

1. Controlling the pump speed by a variable frequency drive.
2. Using bypass valves.
3. Allowing the pump to operate at a constant speed on its curve.

The basic steps previously outlined form the foundation for balancing a variable flow hydronic distribution system. In this subsection, additional balancing procedures are outlined for use in balancing variable flow hydronic distribution systems.

Variable flow systems are balanced under simulated full load system conditions. The procedures to balance a variable flow hydronic system are:

a. Verify that the construction team responsibilities for system installation and startup are complete, as discussed in Section 3.2.
b. Place the system in a simulated full load condition. If diversity is present in the system, temporary isolation of portions of the system piping and terminals may be required.
c. Conduct the basic pump testing and flow procedures as outlined previously. If the pump is controlled by a VFD, verify the pump is operating at its rated speed. Caution should be used when conducting the required pump "wide open test" on a system with diversity. Ensure that a motor overload condition does not occur.
d. The terminals are balanced using one of the balancing methods described previously.
e. When diversity is present in the system, upon completion of balancing procedures with a portion of the system isolated, the isolated units are then opened, and an equal capacity of units closed.
f. Units isolated for the initial balancing procedure are then balanced to design flow rates.
g. Slow the VFD down to achieve design flow while keeping the pump discharge balancing valve wide open.
h. The value of the variable flow control setpoint shall be measured and recorded. The control contractor shall be provided with this information. The system operating pressure should always be adjusted to the minimum value necessary to meet the design conditions.
i. After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.
j. Record final system data, prepare the report forms, and submit as required.

Diversity is a design concept in a variable flow system that allows a system of terminals to be served by a pump that is rated for a fraction of the total system capacity. Variable flow systems with diversity may be encountered in TAB work.

The CP should determine if the variable flow system has a diversity factor. The diversity factor is an arithmetic ratio of the pump's rated hydronic flow capacity divided by a summation of all terminals' design maximum hydronic flow.

Variable flow systems with diversity can be the most difficult to balance satisfactorily. Any procedure used will be a compromise, and shortcomings will appear somewhere in the system under certain operating conditions. The CP should expect that some fine-tuning will be necessary after the initial TAB work is complete.

9.5.4 Primary-Secondary Hydronic Systems

Initial balancing should be restricted to the primary loop and its components. Secondary systems should be in full-flow operation during primary loop balancing.

Primary-Secondary hydronic systems are balanced as follows:

a. Verify that the construction team responsibilities for system installation and startup are complete, as discussed in Section 3.2.
b. Place the secondary system in a simulated full load condition.
c. In Primary-Secondary systems there is a neutral bridge (or decoupler) that is a bidirectional flow pipe that can allow flow to either the primary or secondary loop as needed. During balancing, this decoupler should never be closed.
d. Conduct the basic pump testing and flow procedures on the primary pumps as outlined previously. If the pump is controlled by a VFD, verify the pump is operating at its rated speed. Caution should be used when conducting the required pump "wide open test" on a system with diversity. Ensure that an overload condition cannot be reached.
e. With the primary system off, conduct the basic pump testing and flow procedures on the secondary system as outlined previously.
f. The terminals are balanced using either the stepwise or the proportional balancing methods described previously.
g. When diversity is present in the system, upon completion of balancing procedures with a portion of the system isolated, the isolated units are then opened, and an equal capacity of units closed. Units isolated for the initial balancing procedure are then balanced to design flow rates.
h. With all final adjustments made, perform a final check of the pressures and the flow of all pumps and equipment. Re-measure the voltage and amperage of pump motors and record the data.
i. After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.
j. Record final system data, prepare the report forms, and submit as required.

Note: Primary/Secondary/Tertiary systems are balanced in a similar manner.

9.6 BALANCING SPECIFIC SYSTEMS

The basic steps previously outlined form the foundation for balancing any hydronic distribution system. In this subsection, additional or special balancing procedures are outlined for use in balancing specific types of hydronic distribution systems.

9.6.1 Cooling Tower (Condenser Water) Systems

With an open condenser water pumping system in operation, perform the following steps:

a. Verify that the construction team responsibilities for system installation and startup are complete, as discussed in Section 3.2.
b. Conduct the basic pump testing and flow procedures as outlined previously.
c. Record the flow and/or inlet and outlet pressures of the tower piping if applicable. Check against the manufacturer's design information.
d. Verify proper water levels in the tower(s) sump, that the tower water make-up source is functioning, and confirm that the flow through the spray headers or header distribution pans is balanced.
e. When a tower bypass control is used in the condenser water piping at the tower, measure the pressure difference with full water flow going both through the tower and/or through the bypass line. Set the bypass line balancing valve to maintain a constant pressure at the pump discharge with the control valve in either position.
f. After all final adjustments have been made, perform a final check of the hydronic pressures and the flow of all pumps and equipment. Re-measure the voltage and amperage of pump motors and record the data.

g. After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.
h. Record final system data, prepare the report forms, and submit as required.

9.6.2 Chilled Water Systems

a. Verify that the construction team responsibilities for system installation and startup are complete, as discussed in Section 3.2.
b. With pump(s) off, observe and record the system static pressure at the pump(s).
c. Energize the pumping system.
d. Conduct the basic pump testing and flow procedures as outlined previously.
e. Determine the water flow through the evaporator, and condenser if present, using flow meters, calibrated balancing valves, or pressure/temperature ports. If the measured differential pressure is used, the flow data can be obtained from the manufacturer's submittal data curves or tables. Adjust the flow to design conditions and record the data.
f. After all final adjustments have been completed, perform a final check of the hydronic pressures and the flow of all pumps and equipment. Re-measure the voltage and amperage of pump motors and record the data.
g. After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.
h. Record final system data, prepare the report forms, and submit as required.

9.6.3 Heat Exchangers and Boiler Systems

Energize the water heater or boiler pumping system and perform the following steps:

a. Verify that the construction team responsibilities for system installation and startup are complete as discussed in Section 3.2.
b. Conduct the basic pump testing and flow procedures as outlined previously.
c. Record the water flow and/or inlet and outlet pressures of the water heater(s) or boiler(s). Check against the manufacturer's design information.
d. When a temperature control valve is used in the water piping at the boiler to control heating water loop temperature, measure the pressure difference with full water flow going both through the boiler and/or through the bypass line. Set the bypass line balancing valve, if present, to maintain a constant pressure at the pump discharge with the control valve in either position.
e. After all final adjustments have been completed, perform a final check of the hydronic pressures and the flow of all pumps and equipment. Re-measure the voltage and amperage of pump motors and record the data.
f. After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.
g. Record final system data, prepare the report forms, and submit as required.

9.6.4 Heat Transfer Components

Heat transfer components include but are not limited to heat exchangers, fin tube radiators, coils, unit ventilators, etc.

a. Verify that the construction team responsibilities for system installation and startup are complete, as discussed in Section 3.2.
b. Determine the water flow through all heat exchangers in all circuits using flow meters or calibrated balancing valves. If the measured differential pressure must be used, the flow data can be obtained from the manufacturer's submittal data curves or tables.
c. Adjust the flow to design conditions at all heat transfer components as discussed in Section 9.5.
d. After all final adjustments have been completed, perform a final check of the hydronic pressures and the flow of all pumps and equipment.
e. After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.
f. Record final system data, prepare the report forms, and submit as required

Section 10. SPECIAL SYSTEMS

10.1 CHILLED BEAM SYSTEMS

10.1.1 Chilled Beam

Chilled beams are hydronic coil heat transfer devices that are typically ceiling mounted, however other mounting and location variations are available. This technology utilizes the concept that hydronic system heat transfer is more efficient than air system heat transfer thus allowing for more design flexibility. While referred to as chilled beams in this *Standard* and elsewhere in the industry, they can also have heating water coils depending on the heat transfer requirements of the space and the design of the system. Chilled beams are classified as passive or active depending on the method of developing air flow across the coil. The temperature of chilled water supplied to ceiling mounted chilled beams must be controlled to avoid reaching dew point at the cooling coil surface, to prevent condensation formation during start-up, testing, and normal operation.

10.1.2 Passive Chilled Beam

Passive chilled beams rely entirely on the natural convective properties air exhibits during the heat transfer processes while providing for sensible load control in a zone. These devices are best utilized in spaces with thermally stratified or near stratified conditions. Efficiency is adversely affected by air discharge patterns across the face of the beam that cause interruptions or inhibit the natural convection airflow process. Spacing, location, and ceiling heights are critical in the performance capabilities of a passive chilled beam system. Volumetric testing and balancing are limited to adjustments to the water flow through the hydronic coils as described in Section 9 of this *Standard*.

10.1.3 Active Chilled Beam

Active chilled beams are ducted with supply air at a low moisture content through a series of nozzles within the beam casing. A low pressure is created via the nozzles which induces secondary airflow across the hydronic coils. Supply air can be delivered via traditional constant volume duct systems or via terminal units for additional zone control. The coils are designed for sensible heat transfer only; however, due to the use of primary air with low moisture content these devices also provide latent heat transfer due to the mixing of primary and secondary airstreams. The primary air for these active chilled beams will typically have a high concentration of, or a complete make up of, outside air and are therefore useful in distributing required ventilation air to a space. Heating can be accomplished via in duct heating coils for the primary air, or via heating coils within the chilled beam. Volumetric testing and balancing are conducted on the hydronic coils as described in Section 9 of this *Standard*, and for the primary air as described below.

10.1.4 Testing of Active Chilled Beam

a. Adjust the primary air fan using methods for constant or variable volume systems per Section 8 of this *Standard.* Determine total system volume by the most appropriate method. A duct traverse is the preferred method. The sum of several traverses may be required.
b. Airflow at a chilled beam is calculated by measuring the static pressure at the specified location, then computing the airflow via the manufacture's published data. The design static pressure and airflow will be shown on the manufacture's submittal data for the various size and type units on the project. This information will be verified by performing a duct traverse on a branch and/or zone for comparison to the airflow calculations of the chilled beams on that branch and/or zone; this shall be done for each model/type chilled beam on the project. Duct traverses should not be used to set or check primary airflow to an individual chilled beam due to the low airflow and inherent errors that result from such low range measurements of duct velocities. If discrepancies are discovered during the verification of the airflow performance charts, they need to be brought to the attention of the construction/design team and noted within the TAB report testing descriptions.
c. Air volume controllers or inlet volume dampers are utilized in the proportional balancing of individual chilled beams following the constant volume "ratio or stepwise" balancing methods located within Section 8 of this *Standard*.
d. Direct measurement of chilled beam airflow with a capture device such as a flow hood is not a practical or accurate method to determine either primary or total airflow performance of a chilled beam.

e. Chilled beam performance criteria are specified by the manufacturer. Tolerances of +/-10% may not be suitable for all ap- plications. Confer with the design engineer on the percent variance that will be acceptable for the satisfactory operation of the chilled beams.
f. Record final system data, prepare the report forms, and submit as required. See Section 5 for TAB reporting on both pas- sive and active chilled beams.

10.2 STAIRWELL PRESSURIZATION TESTING

Stairwell pressurization systems are designed to provide a smoke proof enclosure and a means of egress during a smoke control event. Stairwell pressurization testing is conducted to verify that shaft pressurization meets minimum requirements when the system is in operation. The local authority having jurisdiction (AHJ) is the ultimate source of approved testing protocols. This section is intended as a general guide procedure, to be used or modified as deemed appropriate by the AHJ.

In new construction, testing of the stairwell system is to be conducted with the cooperation of the construction team.

The EOR and the AHJ will specify the minimum pressure differentials to be achieved, as well as the total number and locations of the pressure measurements to be performed. Complete the testing as follows:

a. Verify the construction team responsibilities for system installation and startup as discussed in Section 3 are complete.
b. Verify that all related building construction is complete. If these conditions are not present, the test report will include a summary of test condition deficiencies. Stairwells shall be complete with all doors and exit hardware in their final condition.
c. Determine whether the AHJ or EOR specifies testing with the stairwell exit door closed or open. Testing with the exit door open simulates a real condition (i.e., occupants leaving a building due to a smoke control event are unlikely to close the stairwell exit door behind them).
d. Record unit nameplate data as described in Section 6.
e. Others shall start the shaft pressurization system. A smoke control event can usually be started by applying canned smoke or a magnet to a smoke detector.
f. All shaft pressurization systems shall be operational at time of testing. Additionally, all other HVAC systems shall be properly postured for a fire and smoke control event.
g. Take extra caution to avoid generating a false alarm call to the occupants or Fire Department.
h. Confirm that the fan rotation is correct.
i. Measure fan motor amperage and voltage.
j. Verify that the motor is not overloaded.
k. Verify that all appropriate stairwell pressurization fans and dampers operate according to the approved sequence of operation.
l. Measure the pressure(s) from the stairwell to the reference point(s) as specified by the AHJ or the EOR.
m. Adjust the fan speed, if required, to change the shaft pressurization to meet specified requirements
n. Verify that the maximum door opening force does not exceed 30 pounds (13.6 kg) or a locally specified value. Use an appropriate device to test door-opening forces.
o. If the stairwell is equipped with a relief damper(s), verify its operation and report discrepancies.
p. Report the actual test conditions and results to the AHJ and EOR.

10.3 ELEVATOR PRESSURIZATION TESTING

Elevator pressurization systems are designed to provide a smoke proof enclosure during a smoke control event. Elevator pressurization testing is conducted to verify that shaft pressurization meets minimum requirements when the system is in operation. The local authority having jurisdiction (AHJ) is the ultimate source of approved testing protocols. This section is intended as a general guide procedure, to be used or modified as deemed appropriate by the AHJ and/or the design EOR.

In new construction, testing of the elevator pressurization system is to be conducted with the cooperation of the construction team. The presence of the elevator contractor is required due to the complexity of elevator systems. A preliminary test should be conducted before scheduling the AHJ to witness a final test.

A review of minimum pressure differentials and locations of the pressure will be conducted by the CP and the AHJ and/or the EOR. Complete the testing as follows:

a. Verify the construction team responsibilities for system installation and startup as discussed in Section 3 are complete.
b. Verify that all related building construction is complete. If these conditions are not present, the test report should include a summary of test condition deficiencies. Elevator systems shall be complete.
c. Verify that the building shell is complete. Temporary closures of windows and doorways are not acceptable.
d. Record unit nameplate data as described in Section 6.
e. Others shall start the shaft pressurization system. Applying canned smoke or a magnet to a smoke detector can usually start a smoke control event.
f. All shaft pressurization systems shall be operational at the time of testing. Additionally, all other HVAC systems shall be properly postured for a fire and smoke control event.
g. Ensure testing will not generate a false call to the fire department.
h. Confirm that the fan rotation is correct.
i. Measure fan motor amperage and voltage.
j. Verify that the motor is not overloaded.
k. Verify that all appropriate elevator pressurization fans operate. If isolation dampers are present, verify proper operation during the pressurization event.
l. Verify that all elevator cars in the tested shaft return to the recall floor and remain there with the doors open for the duration of the test.
m. Measure the pressure(s) from the elevator shaft to the reference point(s) as required by the AHJ. A pressure differential of 0.05 in. w.g. (12.5 Pa) from the elevator shaft to the reference point is generally considered to be the minimum acceptable pressure difference or as specified in the contract documents.
n. If required, adjust the fan speed to change the shaft pressurization to meet specified requirements.
o. Report the actual test conditions and results to the AHJ and engineer of record.

10.4 MATERIAL HANDLING SYSTEMS

A second group of industrial exhaust air systems is used to remove and convey solid materials. Sawdust, wood chips, paper trimmings, etc. are transported at high velocities through these exhaust systems. These systems must be balanced so that velocities do not fall below predetermined transport velocities. To prevent damage to test instruments, all testing is to be done without materials being transported.

Balancing of these systems is done with blast gates, which are installed in lieu of dampers and are used to temporarily shut off unused branches. In addition to velocity readings, static pressure readings of the pressure differential between the room and the hood should be recorded in a convenient reference point at each hood or intake device. This will permit easy future checks designed to spot any deviation in exhaust volumes from original volumes. When balancing is complete, score or mark all blast gates so that the system balance can be restored if it is disturbed.

Warning: Some industrial exhaust air systems generate an extreme static electricity charge. Contact the plant engineer or system operator to determine that the static electric charge has been dissipated to protect yourself from shock and your test instruments from damage.

Section 11. OUTDOOR AIR VENTILATION PROCEDURES

11.1 Introduction

The controlled introduction of outdoor air into a building's HVAC system is a key element in promoting building occupancy comfort and optimizing energy costs. System designers determine the appropriate amount of outdoor air to be introduced into a building's HVAC system. Systems are typically designed to operate with a scheduled minimum amount of outdoor air whenever the building is occupied. (*Note:* Ventilation/outdoor airflow rates are established by ASHRAE Standard 62.1.)

The strategy for setting the outdoor air quantities will depend on the system design. Where separate minimum and maximum outdoor air dampers are provided, begin the TAB work with the minimum outdoor air dampers open and the maximum outdoor air dampers closed.

Determining the outdoor air quantity can be difficult. The quantities of outdoor air shall be obtained by making a duct traverse of the outdoor air duct where possible. However, if the outdoor air path is not suitable for direct measurement, there are alternative methods for determining outdoor air quantities. These alternatives are discussed below.

11.2 Measurement Options

11.2.1 Direct Measurement Method

The preferred method of outdoor air measurement is direct, which may include but is not limited to, duct traverse, velocity averaging grid, and airflow measuring station. When direct measurement of the outdoor air path is not an option, then a duct traverse of the total supply minus the total return air quantities is deemed acceptable.

11.2.2 Mixed Air Temperature Method

The mixed air temperature method may be used for setting outdoor air dampers to yield the specified percentage of outdoor air. Often, mixed air temperature is very difficult to measure accurately. With regard to this method, it is important to note that air stratification within HVAC units may inhibit accurate airflow temperature measurement. Mixed air temperatures may vary con- siderably depending on where readings are taken. If it is determined that air stratification is present, it would be necessary to take several temperature readings by performing a weighted average temperature *traverse.*

Alternative methods for accurate mixed air temperatures should be considered. Using the Building Automation System (BAS) after calibration should be considered as an alternative.

Accurate readings and large differentials between outdoor air and return air temperatures [over 20°F (12°C) ΔT] are essential to this method.

Equation 11-1 (U.S. and SI)

$$T_m = \frac{[(X_o T_o) + (X_r T_r)]}{100}$$

Equation 11-2 (U.S. and SI)

$$X_o = 100 \frac{(T_r - T_m)}{(T_r - T_o)}$$

Equation 11-3 (U.S. and SI)

$$X_r = 100 \frac{(T_m - T_o)}{(T_r - T_o)}$$

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CERTIFIED TEST, ADJUST & BALANCE REPORT

PROJECT:

NAME
ADDRESS

ETS JOB #
PO#

ENGINEER:

NAME
ADDRESS

ARCHITECT:

NAME
ADDRESS

HVAC CONTRACTOR:

NAME
ADDRESS

NEBB CERTIFIED TAB FIRM:

NAME Environmental Testing Service, Inc.
ADDRESS PO Box 43
Montevallo, AL 35115

NEBB Certification #: ***2622***

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CERTIFICATION PAGE

PROJECT NAME: **0**
ADDRESS: 0
0

The data presented in this report is a record of system measurements and final adjustments that have been obtained in accordance with the current edition of the NEBB Procedural Standard for Testing, Adjusting and Balancing of Environmental Systems. The measurements shown and the information given in this report are certified to be accurate and complete at the time and date the information was gathered. Any variances from design quantities which exceed NEBB tolerances are noted in the TAB report project summary.

NEBB TAB FIRM Environmental Testing Service, Inc.
REG NO. 2622 CERTIFIED BY Scott Kleback DATE

SUBMITTED & CERTIFIED BY:

NEBB TAB FIRM Environmental Testing Service, Inc.
TAB PROFESSIONAL Scott Kleback
REG NO. CP-23537
CERTIFICATION EXPIRATION DATE

SCOTT KLEBACK
CERTIFICATION
2622
Exp. 12/31/25

TABLE OF CONTENTS

ABBREVIATIONS LIST

ABBREVIATIONS	
AHU	AIR HANDLING UNIT
AMP	AMPERAGE
AFMS	AIR FLOW MONITORING STATION
BD	BALANCING DAMPER
BHP	BRAKE HORSE POWER
BTU	BRITISH THERMAL UNIT
BTUh	BTU PER HOUR
BV	BALANCING VALVE
CF	CORRECTION FACTOR (Ak)
CFLA	CORRECTED FULL LOAD AMPS
CFM	CUBIC FEET PER MINUTE
CV	CONSTANT VOLUME
DB	DRY BULB
DFC	DAMPER FULLY CLOSED
DWO	DAMPER WIDE OPEN
EF	EXHAUST FAN
EG	EXHAUST GRILLE
ER	EXHAUST REGISTER
ESP	EXTERNAL STATIC PRESSURE
EA	EXHAUST AIR
F	FAN
FD	FIRE DAMPER
FLA	FULL LOAD AMPS
FPM	FEET PER MINUTE
GPM	GALLONS PER MINUTE
LS	LINEAR SLOT
MBH	1000 BTU PER HOUR
MVD	MANUAL VOLUME DAMPER
N/A	NOT APPLICABLE
N/ACC	NO REASONABLE ACCESS
NDI	NO DAMPER INSTALLED
N.G.	NOT GIVEN
NF	NO FLOW
NPSH	NET POSITIVE SUCTION HEAD
NPSHA	NPSH AVAILABLE
NPSHR	NPSH REQUIRED
OA	OUTSIDE AIR
OBD	OPPOSED BLADE DAMPER
OED	OPEN ENDED DUCT
P	PUMP
PD	PRESSURE DROP
PH	PHASE
PSI	POUNDS PER SQUARE INCH
PSIA	PSI ABSOLUTE
PSIG	PSI GAUGE
RA	RETURN AIR
RAF	RETURN AIR FAN
RG	RETURN GRILLE
RPM	ROTATIONS PER MINUTE
RR	RETURN REGISTER
SA	SUPPLY AIR
SD	SPLITTER DAMPER
SG	SUPPLY GRILLE
SP	STATIC PRESSURE
SR	SUPPLY REGISTER
TB	TERMINAL BOX
TD	TEMPERATURE DIFFERENTIAL
TDH	TOTAL DYNAMIC HEAD
TP	THERMALLY PROTECTED
TSP	TOTAL STATIC PRESSURE
WB	WET BULB
VAV	VARIABLE AIR VOLUME
VD	VOLUME DAMPER
VEL	VELOCITY

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EXECUTIVE SUMMARY / REPORT REMARKS

PROJECT NAME:
REPORT DATE:

PROJECT SUMMARY

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AIR APPARATUS TEST REPORT

Page:

PROJECT NAME:

EQUIPMENT / SYSTEM:

UNIT INFORMATION		
	DESIGN	***ACTUAL***
Manufacturer		
Model Number		
Serial Number		
Location		
Service		
FAN INFORMATION		
	DESIGN	***ACTUAL***
Total Airflow (CFM)		
Total of Terminals (CFM)		
Return Airflow (CFM)	CFM	CFM
Outside Airflow (CFM)		
Total/External (in. w.g.)	/	0.00 in.w.g. / 0.00 in.w.g.
Inlet Pressure (in. w.g.)	/	/
Discharge Pressure (in. w.g.)	/	/
Fan Speed (RPM)		
VFD Speed (Hz)		
OA Damper Position (% Open)		
MOTOR INFORMATION		
	DESIGN / NAMEPLATE	***ACTUAL***
Manufacturer		
Frame		
Horse Power (HP)		
Brake Horse Power (BHP)		FALSE
Volts Phase		
Full Load Amps		
Corrected Nameplate Amps		FALSE
Motor Speed (RPM)		
Service Factor		
Current Overload Size/Setting		
DRIVE INFORMATION		
	DESIGN	***ACTUAL***
Motor Sheave		
Motor Sheave Bore Size		
Motor Sheave Adjustment (PD)		
Fan Sheave		
Fan Sheave Bore Size		
Belt Size and Quantity		
Center to Center Distance (Inches)		

Comments: ______________________________

Technician(s): ______________________________ Date: ______________

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AIR INLET TEST REPORT

Page:

PROJECT NAME:
EQUIPMENT / SYSTEM:

INLET SUMMARY

Area Served	FH / RVA / TRV	ATI #	Outlet Type	Size LxW / D	AK	Design FPM	Design CFM	Initial FPM	Initial CFM	Final FPM	Final CFM	Final %	Notes
												####	
												####	
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RVA = Rotating Vane Anemometer : FH = Flow Hood : TRV = Traverse

Comments:

Technician(s):

Date:

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AIR OUTLET TEST REPORT

Page:

PROJECT NAME:

EQUIPMENT / SYSTEM:

OUTLET SUMMARY

Area Served	FH / RVA / TRV	ATI #	Outlet Type	Size LxW / D	AK	Design FPM	Design CFM	Initial FPM	Initial CFM	Final FPM	Final CFM	Final %	Notes

RVA = Rotating Vane Anemometer : FH = Flow Hood : TRV = Traverse

Comments: ______________________________

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AUTOFLOW BALANCE VALVE TEST REPORT

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	
BV MANUFACTURER:	

VALVE SUMMARY

Tag	Model	Size	Design GPM	Required PD	Actual PD	Tag GPM	%	Notes
							-	
							-	
							-	
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Comments: ____
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Technician(s): ________________________________ Date: ______________

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MANUAL BALANCE VALVE TEST REPORT

Page:

PROJECT NAME:
EQUIPMENT / SYSTEM:
BV MANUFACTURER:

VALVE SUMMARY

Tag	Model	Size	Design GPM	Design PD	Setting	Actual PD	Actual GPM	%	Notes
								-	
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Comments:

Technician(s):

Date:

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ULTRASONIC FLOW TEST REPORT

Page:

PROJECT NAME:
EQUIPMENT / SYSTEM:
METER USED:

VALVE SUMMARY

System	Location	Design Flow	Pipe Size	Material	Trans Size/Type	Config	Spacing	Actual Flow	Wall Thickness

Comments: ____
____

Technician(s): ______________________________ Date: ______________

PROJECT NAME:	TYPE PROJECT NAME HERE
QUIPMENT / SYSTEM:	
SHEET TITLE HERE	

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BOILER TEST REPORT

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

UNIT INFORMATION

Unit Tag				
Location				
Manufacturer				
Model Number				
Serial Number				

TEST DATA

		DESIGN	***ACTUAL***		***DESIGN***	***ACTUAL***
Test Flow (GPM)			#DIV/0!			#DIV/0!
Boiler PD (FT H20)						
Entering Water Temp (°F)						
Leaving Water Temp (°F)						
Water Delta T (°F)		.0°F	.0°F		.0°F	.0°F
Input BTUh						
Output BTUh			#DIV/0!			#DIV/0!

Comments: ____
____
____
____

Technician(s): ______________________________ Date: ______________

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BUILDING PRESSURIZATION TEST SHEET

Page:

PROJECT NAME:

AIR BALANCE SCHEDULE

Mark	**Outside Air**	**Exhaust Air**	**Notes**
Total	CFM	CFM	
Building Airflow Differential	0		
Building Pressure			

Comments: ______________________________
____
____

Technician(s): ______________________________ Date: ______________

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CEILING CASSETTE TEST REPORT

Page:

PROJECT NAME:	

CEILING CASSETTE INFORMATION

Mark	**Loacation**	**CFM**		**COOLING**		**COOLING**		**Heating**		**Notes**
		Design	**Actual**	**EA DB**	**EA WB**	**LA DB**	**LA WB**	**EA DB**	**LA DB**	

Comments: ____

____

____

Technician(s): ______________________________ Date: ______________

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AIR-COOLED CHILLER TEST REPORT

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

UNIT INFORMATION

		DESIGN		***ACTUAL***
Manufacturer				
Model Number				
Serial Number				
Location				
Service				

EVAPORATOR DATA

		DESIGN		***ACTUAL***
Total Flow (GPM)				#DIV/0!
Evaporator PD (FT H20)				
Entering Water Temp (°F)				
Leaving Water Temp (°F)				
Water Delta T (°F)		.0°F		.0°F

AMBIENT TEMPERATURE DATA

		DESIGN		***ACTUAL***
Outdoor Ambient DB (°F)				
Outdoor Ambient WB (°F)				
Outdoor RH (%)				

FAN DATA

Motor Manufacturer		
Horse Power (HP)		
Motor Voltage / Phase		/
Motor Amperage		
Motor Speed (RPM)		

Comments: ____

____

____

____

____

____

Technician(s): ______________________________ Date: ______________

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WATER-COOLED CHILLER TEST REPORT

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

UNIT INFORMATION

		DESIGN		***ACTUAL***
Manufacturer				
Model Number				
Serial Number				
Location				
Service				

EVAPORATOR DATA

		DESIGN		***ACTUAL***
Total Flow (GPM)				#DIV/0!
Evaporator PD (FT H20)				
Entering Water Temp (°F)				
Leaving Water Temp (°F)				
Water Delta T (°F)		.0°F		.0°F

CONDENSER DATA

		DESIGN		***ACTUAL***
Total Flow (GPM)				#DIV/0!
Condenser DP (FT H20)				
Entering Water Temp (°F)				
Leaving Water Temp (°F)				
Water Delta T (°F)		.0°F		.0°F

Comments: ____

Technician(s): ______________________________ Date: ______________

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COIL PERFORMANCE TEST REPORT

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

COOLING COIL TEST DATA

Hydronic		***DESIGN***		***ACTUAL***
Total Airflow (CFM)				
Entering DB Temp (°F)				
Entering WB Temp (°F)				
Leaving DB Temp (°F)				
Leaving WB Temp (°F)				
Air Delta T (°F)		.0°F		.0°F
Entering Water Temp (°F)				
Leaving Water Temp (°F)				
Water Delta T (°F)		#VALUE!		#VALUE!
Hydronic Flow (GPM)				#VALUE!
Water Pressure Drop (FT H20)				
BTUh - Air - Sensible		BTUh		BTUh
BTUh - Water		#VALUE!		#VALUE!

HEATING COIL TEST DATA

Hydronic		***DESIGN***		***ACTUAL***
Total Airflow (CFM)		CFM		CFM
Entering DB Temp (°F)				
Leaving DB Temp (°F)				
Air Delta T (°F)		.0°F		.0°F
Entering Water Temp (°F)				
Leaving Water Temp (°F)				
Water Delta T (°F)		#VALUE!		#VALUE!
Hydronic Flow (GPM)				#VALUE!
Water Pressure Drop (FT H20)				
BTUh - Air - Sensible		BTUh		BTUh
BTUh - Water		#VALUE!		#VALUE!

Air Sensible BTUh = 1.08 x CFM x Delta T (unless otherwise taken from Mechanical Schedule, for design.)
Water BTUh = 500 x GPM x Delta T (unless otherwise taken from Mechanical Schedule, for design.)

Comments: ____
____
____
____
____
____

Technician(s): ______________________________ Date: ______________

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COOLING TOWER TEST REPORT

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

UNIT INFORMATION				
		DESIGN		***ACTUAL***
Manufacturer				
Model Number				
Serial Number				
Location				
Service				

OPERATIONAL DATA				
		DESIGN		***ACTUAL***
Final Flow (GPM)				#DIV/0!
Water Pressure Drop (FT H20)				
Entering Air Temp (°F DB)				
Entering Air Temp (°F WB)				
Entering Water Temp (°F)				
Leaving Water Temp (°F)				
Water Delta T (°F)		.0°F		.0°F

MOTOR DATA							
			DESIGN		***ACTUAL***		
Volts	Phase		/				
Full Load Amps							
Power (HP)							
Motor Speed (RPM)							

Comments: ______________________________

Technician(s): ______________________________ Date: ______________

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DUCT AIR LEAKAGE TEST

Page:

PROJECT NAME:	
TEST SECTION:	

TEST SECTION INFORMATION				
Service / Location			Duct Pressure Class	2.00
Design Seal Class	A		Test Pressure	1.00

TEST SECTION SHEET METAL INFORMATION				
ROUND DUCT SHEET METAL			**RECTANGLE DUCT SHEET METAL**	
Round Metal	785.40		Rectangle Metal	1150.00
Round Leak Class	6.00		Rectangle Leak Class	12.00
Round Leak Factor	6.00		Rectangle Leak Factor	12.00
Allowed Leakage	47.12		Allowed Leakage	138.00

TEST RESULTS		
Total Allowable Leakage (CFM) (Round + Rectangular Duct Sections)		185.12 CFM
Maximum Allowable DP (in W.G.) (Differential Across Flow Tube)		192.29 IN. W.G.
Actual Measured DP (in W.G.) (Differential Across Flow Tube)		0. IN. W.G.
Actual Calculated Leakeg (CFM) (Based on Manufacturer Flow Chart)		.00 CFM
Pass / Fail		**PASS**

DALT KIT INFORMATION				
Manufacturer	Oriflow		Model	C1-Digital
Orifice Tube	5"		Orifice Plate	1-inch
Orifice Serial #	840-1		Ratio	13.35
Calibration Date	1/1/2020		Next Calibration	SEE MANUFACTURER

Comments: ______________________________

Technician(s): ______________________ Date: __________

Witness: ______________________ Date: __________

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DUCT AIR LEAKAGE TEST DUCT PARAMETERS

Page:

PROJECT NAME:

TEST SECTION: 0

SHEET METAL MEASUREMENTS

Duct Size (inches)			Surface (Feet)		Length (Feet)	Linear Square Feet		Notes
Diam	Height	Width	Round	Rectangle		Round	Rectangle	
	14	10	0.00	4.00	100.0	0.00	400.00	Rectangle
10			2.62	0.00	100.0	261.80	0.00	Round
20	-20	65	5.24	7.50	100.0	523.60	750.00	Oval
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
					TOTALS:	**785.40**	**1150.00**	**1935.40**

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DUCT AIR LEAKAGE TEST

Page:

PROJECT NAME:	
TEST SECTION:	

TEST SECTION INFORMATION				
Service / Location			Duct Pressure Class	2.00
Design Seal Class	A		Test Pressure	1.00

TEST SECTION SHEET METAL INFORMATION				
ROUND DUCT SHEET METAL			**RECTANGLE DUCT SHEET METAL**	
Round Metal	785.40		Rectangle Metal	1550.00
Round Leak Class	6.00		Rectangle Leak Class	12.00
Round Leak Factor	6.00		Rectangle Leak Factor	12.00
Allowed Leakage	47.12		Allowed Leakage	186.00

TEST RESULTS		
Total Allowable Leakage (CFM) (Round + Rectangular Duct Sections)		233.12 CFM
Actual Measured DP (In W.G.) (From DM32)		
Actual Measured Leakage (CFM) (From DM32)		
Pass / Fail		**PASS**

DALT KIT INFORMATION				
Manufacturer	Retrotec		Model	440
Fan Speed	50%		Range Plate	18
Calibration Date	1/1/2020		Next Calibration	SEE MANUFACTURER

Comments: ____

Technician(s): ________________________ Date: __________

Witness: ________________________ Date: __________

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DUCT AIR LEAKAGE TEST DUCT PARAMETERS

Page:

PROJECT NAME: 0
TEST SECTION: 0

SHEET METAL MEASUREMENTS

Duct Size (inches)			Surface (Feet)		Length (Feet)	Linear Square Feet		Notes
Diam	Height	Width	Round	Rectangle		Round	Rectangle	
	24	24	0.00	8.00	100.0	0.00	800.00	Rectangle
10			2.62	0.00	100.0	261.80	0.00	Round
20	-20	65	5.24	7.50	100.0	523.60	750.00	Oval
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
			0.00	0.00		0.00	0.00	
					TOTALS:	**785.40**	**1550.00**	**2335.40**

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DUCTLESS SPLIT SYSTEM

Page:

PROJECT NAME:

DUCTLESS SPLIT SYSTEM / FAN COIL INFORMATION

Tag #	**Area Served**	**Model Number**	**Serial Number**	**Temperature °F**				**Speed**
				Actual EAT DB	**Actual EAT WB**	**Actual LAT DB**	**Actual LAT WB**	

Comments: ____

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Technician(s): ______________________________ Date: ______________

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ENERGY RECOVERY AIR APPARATUS TEST REPORT (Exhaust Fan)

Page:

PROJECT NAME:			
EQUIPMENT / SYSTEM:			
UNIT INFORMATION			
		DESIGN	***ACTUAL***
Manufacturer			
Model Number			
Serial Number			
Location			
Service			
FAN INFORMATION			
		DESIGN	***ACTUAL***
Exhaust Airflow (CFM)			
Total of Terminal Airflows (CFM)			
Total/External (in. w.g.)		/	0.00 in.w.g. / 0.00 in.w.g.
Inlet Pressure (in. w.g.)		/	/
Discharge Pressure (in. w.g.)		/	/
Fan Speed (RPM)			
VFD Speed (Hz)			
MOTOR INFORMATION			
		DESIGN / NAMEPLATE	***ACTUAL***
Manufacturer			
Frame			
Horse Power (HP)			
Brake Horse Power (BHP)			FALSE
Volts	Phase		
Full Load Amps			
Corrected Nameplate Amps		-	FALSE
Motor Speed (RPM)			
Service Factor		-	
Current Overload Size/Setting		-	
DRIVE INFORMATION			
		DESIGN	***ACTUAL***
Motor Sheave			
Motor Sheave Bore Size			
Motor Sheave Adjustment (PD)			
Fan Sheave			
Fan Sheave Bore Size			
Belt Size and Quantity			
Center to Center Distance (Inches)			

Comments: ______________________________

Technician(s): ______________________________ Date: ______________

ENERGY RECOVERY AIR APPARATUS TEST REPORT (Supply Fan)

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

UNIT INFORMATION

	DESIGN	***ACTUAL***
Manufacturer		
Model Number		
Serial Number		
Location		
Service		

FAN INFORMATION

	DESIGN			***ACTUAL***		
Supply Airflow (CFM)						
Total of Terminal Airflows (CFM)						
Total/External (in. w.g.)		/		0.00 in.w.g.	/	0.00 in.w.g.
Inlet Pressure (in. w.g.)		/			/	
Discharge Pressure (in. w.g.)		/			/	
Fan Speed (RPM)						
VFD Speed (Hz)						

MOTOR INFORMATION

	DESIGN / NAMEPLATE		***ACTUAL***		
Manufacturer					
Frame					
Horse Power (HP)					
Brake Horse Power (BHP)			FALSE		
Volts Phase					
Full Load Amps					
Corrected Nameplate Amps	-		FALSE		
Motor Speed (RPM)					
Service Factor	-				
Current Overload Size/Setting	-				

DRIVE INFORMATION

	DESIGN	***ACTUAL***
Motor Sheave		
Motor Sheave Bore Size		
Motor Sheave Adjustment (PD)		
Fan Sheave		
Fan Sheave Bore Size		
Belt Size and Quantity		
Center to Center Distance (Inches)		

Comments: ____

____

____

____

Technician(s): ______________________________ Date: ______________

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ENERGY RECOVERY AIR APPARATUS TEST REPORT
(Direct Drive)

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

UNIT INFORMATION

		DESIGN		***ACTUAL***
Manufacturer				
Model Number				
Serial Number				
Location				
Service				

SUPPLY FAN INFORMATION

		DESIGN		***ACTUAL***
Supply Airflow (CFM)				
Total of Terminal Airflows (CFM)				
Total/External (in. w.g.)		/		0.00 in.w.g. / 0.00 in.w.g.
Inlet Pressure (in. w.g.)		/		/
Discharge Pressure (in. w.g.)		/		/

SUPPLY MOTOR INFORMATION

		DESIGN / NAMEPLATE		***ACTUAL***
Horse Power (HP)				
Brake Horse Power (BHP)				#DIV/0!
Volts / Phase				
Full Load Amps				
Motor Speed (RPM)				

EXHAUST FAN INFORMATION

		DESIGN		***ACTUAL***
Exhaust Airflow (CFM)				
Total/External (in. w.g.)		/		0.00 in.w.g. / 0.00 in.w.g.
Inlet Pressure (in. w.g.)		/		/
Discharge Pressure (in. w.g.)		/		/

EXHAUST MOTOR INFORMATION

		DESIGN / NAMEPLATE		***ACTUAL***
Horse Power (HP)				
Brake Horse Power (BHP)				#DIV/0!
Volts / Phase				
Full Load Amps				
Motor Speed (RPM)				

Comments: ______________________________

Technician(s): ______________________ Date: ______________

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THERMAL WHEEL PERFORMANCE - COOLING

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

SUPPLY SIDE TEST DATA				
		DESIGN		***ACTUAL***
Total Airflow (CFM)				
Entering Wheel DB Temp		.0°F		.0°F
Entering Wheel WB Temp		.0°F		.0°F
Leaving Wheel DB Temp		.0°F		.0°F
Leaving Wheel WB Temp		.0°F		.0°F
BTUh - Heat Wheel - Sensible		BTUh		BTUh

EXHAUST SIDE TEST DATA				
		DESIGN		***ACTUAL***
Total Airflow (CFM)				
Entering Wheel DB Temp		.0°F		.0°F
Entering Wheel WB Temp		.0°F		.0°F
Leaving Wheel DB Temp		.0°F		.0°F
Leaving Wheel WB Temp		.0°F		.0°F
BTUh - Heat Wheel - Sensible		BTUh		BTUh

Air Sensible BTUh = 1.08 x CFM x Delta T (unless otherwise taken from Mechanical Schedule, for design.)

Comments: ____

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Technician(s): ______________________________ Date: ______________

THERMAL WHEEL PERFORMANCE - HEATING

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

SUPPLY SIDE TEST DATA				
		DESIGN		***ACTUAL***
Total Airflow (CFM)				
Entering Wheel DB Temp		.0°F		.0°F
Entering Wheel WB Temp		.0°F		.0°F
Leaving Wheel DB Temp		.0°F		.0°F
Leaving Wheel WB Temp		.0°F		.0°F
BTUh - Heat Wheel - Sensible		BTUh		BTUh

EXHAUST SIDE TEST DATA				
		DESIGN		***ACTUAL***
Total Airflow (CFM)				
Entering Wheel DB Temp		.0°F		.0°F
Entering Wheel WB Temp		.0°F		.0°F
Leaving Wheel DB Temp		.0°F		.0°F
Leaving Wheel WB Temp		.0°F		.0°F
BTUh - Heat Wheel - Sensible		BTUh		BTUh

Air Sensible BTUh = 1.08 x CFM x Delta T (unless otherwise taken from Mechanical Schedule, for design.)

Comments: ____

Technician(s): ______________________________ Date: ______________

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EQUIPMENT SETPOINT REPORT

Page:

PROJECT NAME:	

SETPOINT	
DESIGNATION	**SETPOINT**

Comments: ____

____

____

Technician(s): ______________________________ Date: ________________

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EXECUTIVE SUMMARY / REPORT REMARKS

PROJECT NAME:

REPORT DATE:

PROJECT SUMMARY

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FAN COIL TEST REPORT

Page:

PROJECT NAME:	**New Gymnasium & Classroom Additions Wicksburg High School**
EQUIPMENT / SYSTEM:	

UNIT INFORMATION			
Manufacturer:		Model Number:	
Serial Number:		Location/Service:	

FAN INFORMATION							
		DESIGN			***ACTUAL***		
Total Airflow (CFM)							
Return Airflow (CFM)		CFM			CFM		
Outside Airflow (CFM)							
Total/External (in. w.g.)			/		0.00 in.w.g.	/	0.00 in.w.g.
External Static Pressure (in. w.g.)			/			/	
Discharge Pressure (in. w.g.)			/			/	
Fan Speed (RPM)							
Volts	Phase						
Full Load Amps							
Corrected Nameplate Amps					FALSE		

TERMINAL BALANCE INFORMATION

Area Served	FH/RVA /TRV	ATI #	Outlet Type	Size LxW / D	AK	Design FPM	Design CFM	Initial FPM	Initial CFM	Final FPM	Final CFM	Final %	Notes
												####	
												####	
												####	
												####	
												####	
												####	
												####	
												####	
												####	
												####	
												####	
												####	

Hydronic	***Cooling Design***	***Actual***	***Heating Design***	***Actual***
Entering DB Temp (°F)				
Entering WB Temp (°F)			NA	NA
Leaving DB Temp (°F)				
Leaving WB Temp (°F)			NA	NA
Air Delta T (°F)	.0°F	.0°F	.0°F	.0°F
Entering Water Temp (°F)				
Leaving Water Temp (°F)				
Water Delta T (°F)	#VALUE!	#VALUE!	#VALUE!	#VALUE!
Hydronic Flow (GPM)		#VALUE!		#VALUE!
Water Pressure Drop (FT H20)				
BTUh - Air - Sensible	BTUh	BTUh	BTUh	BTUh
BTUh - Water	#VALUE!	#VALUE!	#VALUE!	#VALUE!

RVA = Rotating Vane Anemometer : FH = Flow Hood : TRV = Traverse

Comments: ______________________________

Technician(s): ______________________________ Date: ______________

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CEILING MOUNTED EXHAUST FAN TEST SHEET

Page:

PROJECT NAME:	

FAN SUMMARY

Tag	Area Served	Manufacturer	Model Number	Serial Number	Design CFM	Actual CFM	%	Notes
							#DIV/0!	
							#DIV/0!	
							#DIV/0!	
							#DIV/0!	
							#DIV/0!	
							#DIV/0!	
							#DIV/0!	
							#DIV/0!	
							#DIV/0!	
							#DIV/0!	
							#DIV/0!	
							#DIV/0!	
							#DIV/0!	
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							#DIV/0!	
							#DIV/0!	
							#DIV/0!	
							#DIV/0!	
							#DIV/0!	
							#DIV/0!	
							#DIV/0!	

Comments: ____
____

Technician(s): ______________________________ Date: ______________

FAN TEST REPORT

Page:

PROJECT NAME:	**Improvements Zion Chapel High School Baseball Facility**
EQUIPMENT / SYSTEM:	

UNIT INFORMATION

		DESIGN		***ACTUAL***
Manufacturer				
Model Number				
Serial Number				
Location				
Service				

FAN INFORMATION

		DESIGN		***ACTUAL***
Total Airflow (CFM)				
Total of Terminal Airflows (CFM)				
Total SP / External SP				0.00 in.w.g.
Inlet Pressure				
Discharge Pressure				
Fan Speed (RPM)				
VFD Speed (Hz)				

MOTOR INFORMATION

			DESIGN / NAMEPLATE			***ACTUAL***		
Manufacturer								
Frame								
Horse Power (HP)								
Brake Horse Power (BHP)						FALSE		
Volts	Phase							
Full Load Amps								
Corrected Nameplate Amps			-			FALSE		
Motor Speed (RPM)								
Service Factor			-					
Current Overload Size/Setting			-					

DRIVE INFORMATION

		DESIGN		***ACTUAL***
Motor Sheave				
Motor Sheave Bore Size				
Motor Sheave Adjustment (PD)				
Fan Sheave				
Fan Sheave Bore Size				
Belt Size (Inches) and Quantity				
Center to Center Distance (Inches)				

Comments: ____

Technician(s): ______________________________ Date: ______________

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HEAT EXCHANGER TEST REPORT
(Steam-to-Water)

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

UNIT INFORMATION				
Unit Tag				
Location				
Service				
Manufacturer				
Model Number				
Serial Number				

TEST DATA						
		DESIGN	***ACTUAL***		***DESIGN***	***ACTUAL***
Primary Flow (GPM)			#DIV/0!			#DIV/0!
Primary PD (ft)						
Entering Water Temp (°F)						
Leaving Water Temp (°F)						
Water Delta T (°F)		.0°F	.0°F		.0°F	.0°F
BTUh-Water		BTUh	#DIV/0!		BTUh	#DIV/0!

Comments: ____
____
____
____

Technician(s): ______________________________ Date: ____________

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HEAT EXCHANGER TEST REPORT
(Water-to-Water)

Page:

PROJECT NAME:
EQUIPMENT / SYSTEM:

UNIT INFORMATION						
Unit Tag						
Location						
Service						
Manufacturer						
Model Number						
Serial Number						
TEST DATA						
		DESIGN	***ACTUAL***		***DESIGN***	***ACTUAL***
Primary Flow (GPM)			#DIV/0!			#DIV/0!
Primary PD (ft)						
Entering Water Temp (°F)						
Leaving Water Temp (°F)						
Water Delta T (°F)		.0°F	.0°F		.0°F	.0°F
BTUh-Water		BTUh	#DIV/0!		BTUh	#DIV/0!
Secondary Flow (GPM)			#DIV/0!			#DIV/0!
Secondary PD (ft)						
Entering Water Temp (°F)						
Leaving Water Temp (°F)						
Water Delta T (°F)		.0°F	.0°F		.0°F	.0°F
BTUh-Water		BTUh	#DIV/0!		BTUh	#DIV/0!

Comments: ______________________________

Technician(s): ______________________________ Date: ______________

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HEAT PUMP TEST REPORT

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

UNIT INFORMATION

Manufacturer:		Model Number:	
Serial Number:		Location/Service:	

FAN INFORMATION

		DESIGN			***ACTUAL***			
Total Airflow (CFM)								
Return Airflow (CFM)		CFM			CFM			
Outside Airflow (CFM)								
Total/External (in. w.g.)			/		0.00 in.w.g.	/	0.00 in.w.g.	
External Static Pressure (in. w.g.)			/			/		
Discharge Pressure (in. w.g.)			/			/		
Fan Speed (RPM)								
Volts	Phase							
Full Load Amps								
Corrected Nameplate Amps					FALSE			

TERMINAL BALANCE INFORMATION

Area Served	FH/RVA /TRV	ATI #	Outlet Type	Size LxW / D	AK	Design FPM	Design CFM	Initial FPM	Initial CFM	Final FPM	Final CFM	Final %	Notes
												####	
												####	
												####	
												####	
												####	
												####	
												####	
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												####	
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												####	
												####	
												####	
												####	
												####	
												####	

DX	***Cooling Design|Actual***		***Heating Design|Actual***	
Entering DB Temp (°F)				
Entering WB Temp (°F)			NA	NA
Leaving DB Temp (°F)				
Leaving WB Temp (°F)			NA	NA
Air Delta T (°F)	.0°F	.0°F	.0°F	.0°F
BTUh - Air - Sensible	BTUh	BTUh	BTUh	BTUh

RVA = Rotating Vane Anemometer : FH = Flow Hood : TRV = Traverse

Comments: ____________________

Technician(s): ____________________ Date: __________

INSTRUMENT CALIBRATION LIST

Note: This is just a place holder, actual instruments used on site will be part of the final report.

INSTRUMENT	MANUFACTURER	MODEL / SERIAL #	CALIBRATION DATE	CALIBRATION DUE DATE
AIRDATA MULTIMETER	SHORTRIDGE INSTRUMENTS	ADM-870C / ----	1/1/2019	1/1/2020
HYDRONIC MANOMETER	SHORTRIDGE INSTRUMENTS	HDM-300 / ----	1/1/2019	1/1/2020
ELECTRONIC THERMOMETER HUMIDITY	COOPER	SRH77A / ----	1/1/2019	1/1/2020
TRUE RMS CLAMP METER	FLUKE	337 / ----	1/1/2019	1/1/2020
TACHOMETER	EXTECH	461895 / ----	1/1/2019	1/1/2020
PITOT TUBE 18"	DWYER	PT-118 / ----	N/A	N/A
PITOT TUBE 36"	DWYER	PT-118 / ----	N/A	N/A
ROTATING VANE ANEMOMETER	ALNOR	RVA801 / ----	1/1/2019	1/1/2020

PROJECT NOTES

PROJECT NAME

CONTRACTED BY

POINT OF CONTACT

OFFICE PHONE

CELL PHONE

EMAIL

JOB SITE ADDRESS

BLNC VALVE	HIGH TOLERANCE	10%	PUMP	HIGH TOLERANCE	10%
BLNC VALVE	LOW TOLERANCE	-10%	PUMP	LOW TOLERANCE	-10%
AIR OUTLET	HIGH TOLERANCE	10%	RTU/AHU	HIGH TOLERANCE	10%
AIR OUTLET	LOW TOLERANCE	-10%	RTU/AHU	LOW TOLERANCE	-10%
AIR INLET	HIGH TOLERANCE	10%	EF	HIGH TOLERANCE	10%
AIR INLET	LOW TOLERANCE	-10%	EF	LOW TOLERANCE	-10%

NOTES

PLEASE READ SPECIFICATION BEFORE GOING ON SITE!!!!!

Environmental Testing Service, Inc.
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Email: etstab@gmail.com
Website: etstab.com

PUMP TEST REPORT

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

UNIT INFORMATION				
		DESIGN		***ACTUAL***
Manufacturer				
Service				
Model/Size				
Impeller Size (inches)				
Total Connected Load (GPM)				
OPERATIONAL DATA				
		DESIGN		***ACTUAL***
Final Flow (GPM)				
Final Flow Discharge Pressure (PSI)				
Final Flow Suction Pressure (PSI)				
Total Head (Ft)				.0 FT
Full Flow (GPM)				
Full Flow Discharge Pressure (PSI)				
Full Flow Suction Pressure (PSI)				
Full Flow Total Head (Ft)				.0 FT
Block-Off Discharge Pressure (PSI)				
Block-Off Suction Pressure (PSI)				
Total Head (Ft)				.0 FT
Pump Off (PSI)				
Pump Off (Ft)				.0 FT
MOTOR INFORMATION				
		DESIGN / NAMEPLATE		***ACTUAL***
Manufacturer				
Frame				
Horse Power (HP)				
Brake Horse Power (BHP)				FALSE
Volts Phase				
Full Load Amps				
Corrected Nameplate Amps				FALSE
VFD Speed (Hz)				
Motor Speed (RPM)				
Service Factor				
Current Overload Size/Setting				

Comments: ______________________________

Technician(s): ______________________________ Date: ______________

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ROOM NEGATIVE AIR CHANGE SUMMARY

Page:

PROJECT NAME:

EQUIPMENT / SYSTEM:

ROOM NEGATIVE AIR CHANGE SUMMARY

LOCATION	**VOLUME**	**DESIGN AC/HR**	**ACTUAL AC/HR**	**MIN EA/RA CFM**	**ACT EA/RA CFM**	**ACT SUP CFM**	**DP in.w.g.**
			#DIV/0!	0			
			#DIV/0!	0			
			#DIV/0!	0			
			#DIV/0!	0			
			#DIV/0!	0			
			#DIV/0!	0			
			#DIV/0!	0			
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			#DIV/0!	0			

Comments: ______________________________

Technician(s): ______________________________ Date: ______________

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ROOM POSITIVE AIR CHANGE SUMMARY

Page:

PROJECT NAME:

EQUIPMENT / SYSTEM:

ROOM POSITIVE AIR CHANGE SUMMARY

LOCATION	VOLUME	DESIGN AC/HR	ACTUAL AC/HR	MIN SUP CFM	ACT SUP CFM	RA/EA CFM	DP in.w.g.
			#DIV/0!	0			
			#DIV/0!	0			
			#DIV/0!	0			
			#DIV/0!	0			
			#DIV/0!	0			
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			#DIV/0!	0			
			#DIV/0!	0			

Comments: ______________________________

Technician(s): ______________________ Date: __________

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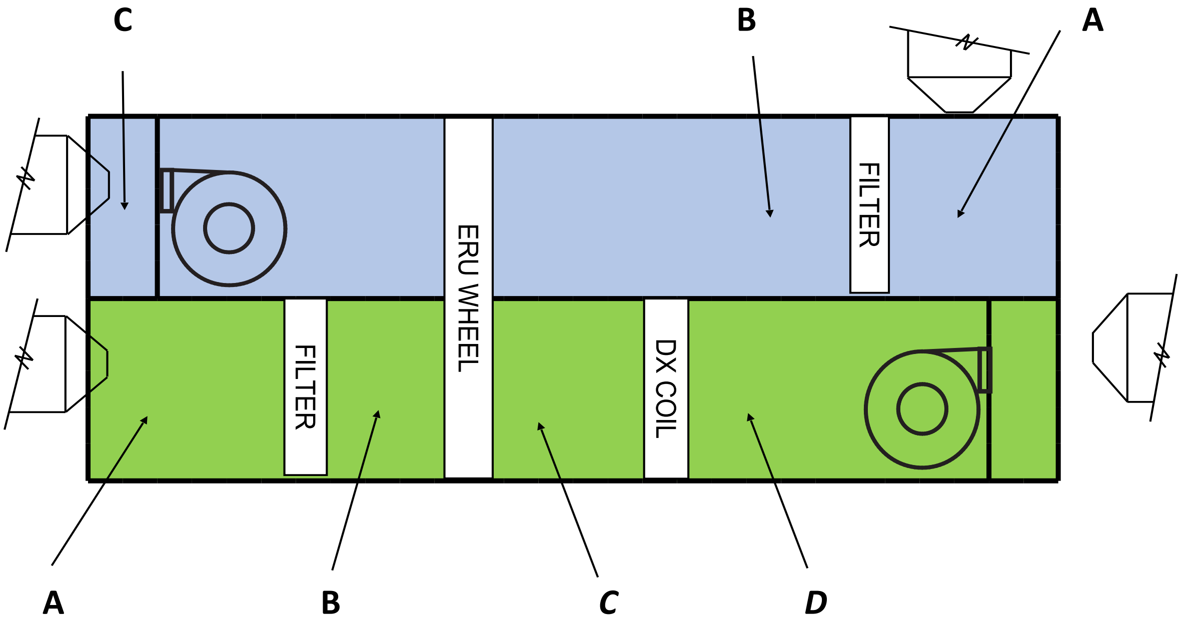
STATIC PRESSURE PROFILE

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

SYSTEM INFORMATION	
Static Pressure Profile Setup:	FULL COOLING
Measured OA Airflow (CFM)	
Measured EA Airflow (CFM)	



STATIC PRESSURE READINGS (in. w.g.)

Location	A	B	C	D	E	F	G	H	I	J	K
OA											
EA											

Comments: ______________________

Technician(s): ______________________ Date: ____________

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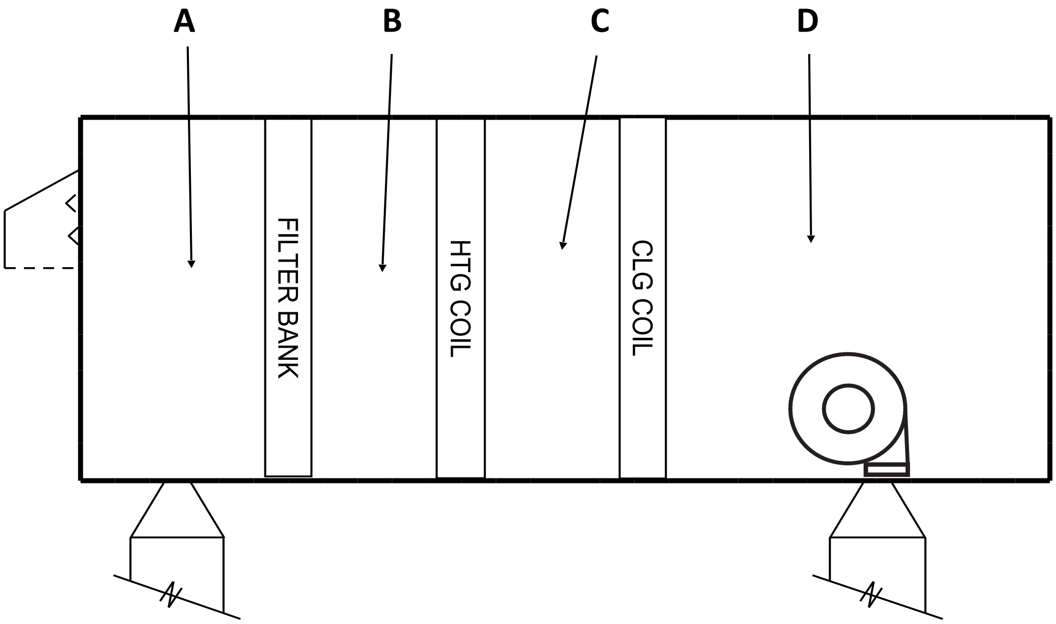
STATIC PRESSURE PROFILE

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

SYSTEM INFORMATION	
Static Pressure Profile Setup:	FULL COOLING
Design Airflow (CFM)	
Measured Airflow (CFM)	



STATIC PRESSURE READINGS (in. w.g.)

Location	A	B	C	D	E	F	G	H	I	J	K

Comments: ____________________

Technician(s): ____________________ Date: __________

NEBB®

TAB DAILY REPORT

Type Project Name Here

Daily Report #:

Date:

	NAME	*COMPANY*
PERSONNEL ONSITE		

GENERAL OBSERVATIONS

TAB DESIGN REVIEW

PROJECT NAME:

REPORT DATE:

REVIEW

NEBB

MASTER TAB ISSUES LOG

Type Project Name Here

Item #	Created		System	Deficiency Issue	Comments	Checked		Open / Closed	Closed	
	Date	By				Date	By		Date	By
001										

PROJECT NAME:	
EQUIPMENT TAG:	

Pre-TAB Checklist			
GENERAL	YES	NO	COMMENT
All exterior building components complete and sealed			
All doors, windows and louvers installed			
All ceilings complete for plenum systems			
Roof access available (if applicable)			
Permenant Power on building			
MECHANICAL - AIR	YES	NO	COMMENT
All Systems online and in automatic operation			
All ductwork complete and accessories installed			
All grilles, registers and diffusers installed			
All volume dampers installed in the OPEN position			
All motors drives and pulleys installed and operating as designed			
All start-up complete and documents available			
Clean filters installed for each system with appropriate size/type			
MECHANICAL - WATER	YES	NO	COMMENT
All pumps installed and started up			
All piping systems filled, flushed and vented			
All valves (shut-off, controls & balancing) installed and OPEN			
Proper standing pressure achieved			*Height of building (feet) / 2.31 = Minimum PSI*
Pump start-up strainers removed			
All system strainers clean and free of debris			
DIRECT DIGITAL CONTROLS	YES	NO	COMMENT
All system programmed and communicating			
All setpoints programmed per construction documents			
All systems 100% complete and operating in automatic mode			

Comments: ____

Verified by: ______________________________ Date: ____________________

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TRAVERSE ZONE TOTALS

Page:

PROJECT NAME:

TRAVERSE ZONE TOTALS

Tag	Duct Size			Area Sq.Ft.	Design FPM	Design CFM	Test 1 FPM	Test 2 FPM	Final CFM	%	Notes
				0.00	#DIV/0!				0	#DIV/0!	
				0.00	#DIV/0!				0	#DIV/0!	
				0.00	#DIV/0!				0	#DIV/0!	
				0.00	#DIV/0!				0	#DIV/0!	
				0.00	#DIV/0!				0	#DIV/0!	
				0.00	#DIV/0!				0	#DIV/0!	
				0.00	#DIV/0!				0	#DIV/0!	
				0.00	#DIV/0!				0	#DIV/0!	
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				0.00	#DIV/0!				0	#DIV/0!	
				0.00	#DIV/0!				0	#DIV/0!	

Comments: ____

____

Technician(s): ______________________________ Date: ______________

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OUTSIDE AIR MEASUREMENT ZONE TOTALS

Page:

PROJECT NAME:

OUTSIDE AIR

Tag	Duct Size			Area Sq.Ft.	Design FPM	Design CFM	Test 1 FPM	Test 2 FPM	Final CFM	%	Notes
				0.00	#DIV/0!				0	#DIV/0!	
				0.00	#DIV/0!				0	#DIV/0!	
				0.00	#DIV/0!				0	#DIV/0!	
				0.00	#DIV/0!				0	#DIV/0!	
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				0.00	#DIV/0!				0	#DIV/0!	

Comments: ____

____

Technician(s): ______________________________ Date: ______________

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Website: etstab.com

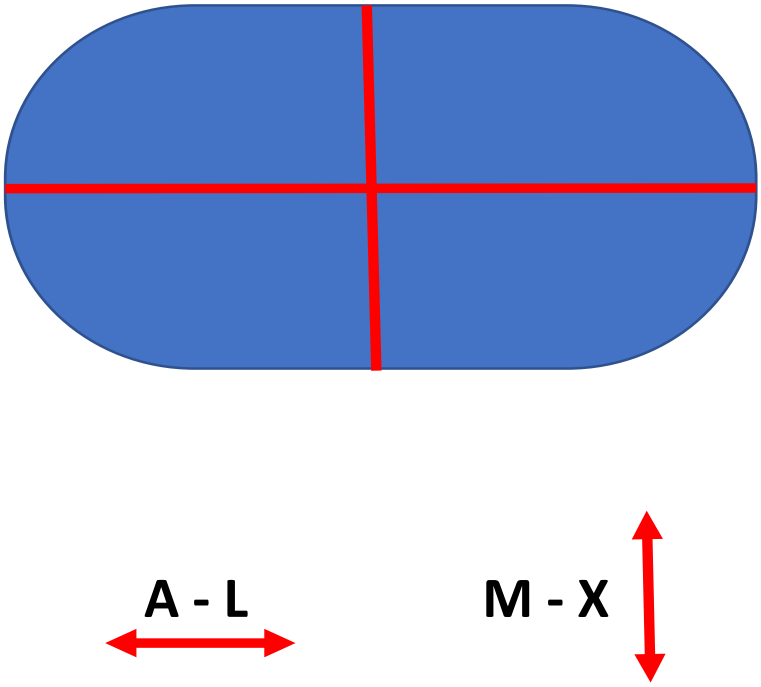
OVAL DUCT TRAVERSE TEST REPORT

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

DUCT TRAVERSE INFORMATION					
Duct Zone:		Required CFM:		Required FPM:	#DIV/0!
Duct Width X Dia:	X	Area:	0.00	Static Pressure:	
Instrument:	Airfoil Corr Factor 1.00	Altitude:	FT	Temperature:	70.0°F
DUCT TRAVERSE MEASUREMENTS					
Velocity Total (FPM):	0	Velocity Average (FPM):	#DIV/0!	Actual Airflow (CFM):	**#DIV/0!**

POS	FPM	Distance	POS	FPM	Distance
A		#DIV/0!	M		#DIV/0!
B		#DIV/0!	N		#DIV/0!
C		#DIV/0!	O		#DIV/0!
D		#DIV/0!	POS		#DIV/0!
E		#DIV/0!	Q		#DIV/0!
F		#DIV/0!	R		#DIV/0!
G		#DIV/0!	S		#DIV/0!
H		#DIV/0!	Total		#DIV/0!
I		#DIV/0!	U		#DIV/0!
J		#DIV/0!	V		#DIV/0!
K		#DIV/0!	W		#DIV/0!
L		#DIV/0!	X		#DIV/0!
Total	0	Inches	Total	0	Inches



Comments: ____

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Technician(s): ______________________________ Date: ______________

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RECTANGLE DUCT TRAVERSE TEST REPORT

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

DUCT TRAVERSE INFORMATION

Duct Zone:					Required CFM:	5000	Required FPM:	#DIV/0!
Duct Size:		X		WxH"	Area:	0.00	Static Pressure:	
Instrument:	Airfoil		Corr Factor	1.00	Altitude:	FT	Temperature:	70.0°F

DUCT TRAVERSE MEASUREMENTS

Velocity Total (FPM):	0	Velocity Average (FPM):	#DIV/0!	Actual Airflow (CFM):	**#DIV/0!**

POS	1	2	3	4	5	6	7	8	9	10	11	Distance Height
1												#DIV/0!
2												#DIV/0!
3												#DIV/0!
4												#DIV/0!
5												#DIV/0!
6												#DIV/0!
7												#DIV/0!
8												#DIV/0!
9												#DIV/0!
10												#DIV/0!
11												#DIV/0!
Distance Width	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	Inches
Totals	0	0	0	0	0	0	0	0	0	0	0	

Comments: ____

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____

Technician(s): ______________________________ Date: ______________

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ROUND DUCT TRAVERSE TEST REPORT

Page:

PROJECT NAME:	
EQUIPMENT / SYSTEM:	

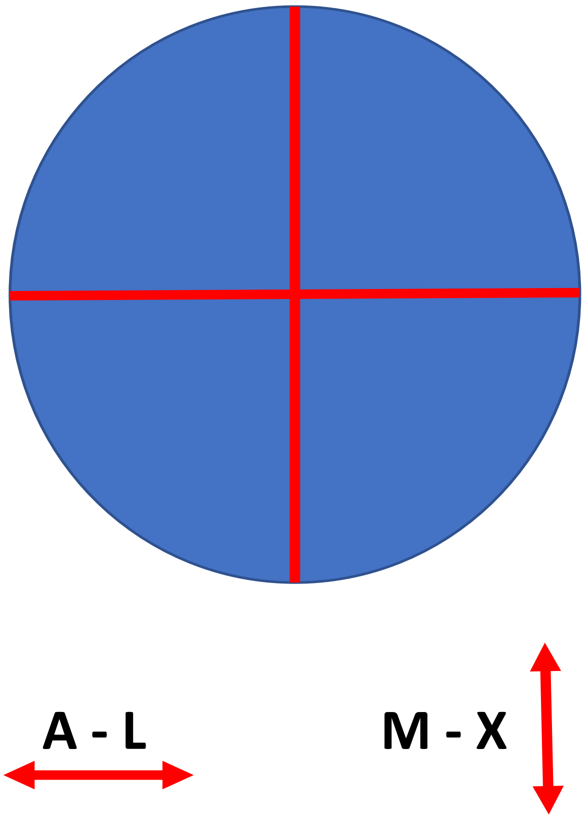
DUCT TRAVERSE INFORMATION

Duct Zone:				Required CFM:		Required FPM:	#DIV/0!
Duct Diameter:				Area:	0.00	Static Pressure:	
Instrument:	Airfoil	Corr Factor	1.00	Altitude:	FT	Temperature:	70.0°F

DUCT TRAVERSE MEASUREMENTS

Velocity Total (FPM):	0	Velocity Average (FPM):	#DIV/0!	Actual Airflow (CFM):	**#DIV/0!**

POS	FPM	POS	FPM	Distance
A		M		#DIV/0!
B		N		#DIV/0!
C		O		#DIV/0!
D		P		#DIV/0!
E		Q		#DIV/0!
F		R		#DIV/0!
G		S		#DIV/0!
H		T		#DIV/0!
I		U		#DIV/0!
J		V		#DIV/0!
K		W		#DIV/0!
L		X		#DIV/0!
Total	0	Total	0	Inches



Comments: ____
____
____
____

Technician(s): ______________________________ Date: ______________

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TERMINAL UNIT CALIBRATION REPORT

Page:

PROJECT NAME:
EQUIPMENT / SYSTEM:

TERMINAL UNIT CALIBRATION REPORT

TERMINAL BOX ID	K FACTOR	TERMINAL BOX ID	K FACTOR

Comments: ____
____
____

Technician(s): ______________________________ Date: ______________

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VAV TERMINAL BOX CALIBRATION TEST REPORT

Page:

PROJECT NAME:

EQUIPMENT / SYSTEM:

TERMINAL BOX INFORMATION

Terminal Box ID	DDC Address	Inlet Size	*As Found			Calibrated			
			AK	MAX CFM Design	MAX CFM Actual	AK	MAX CFM Design	MAX CFM Actual	% of Design
									-
									-
									-
									-
									-
									-
									-
									-
									-
									-
									-
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Comments: ____
____

Technician(s): ______________________________ Date: ______________

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Website: etstab.com

VAV REHEAT COIL TEST REPORT

Page:

PROJECT NAME:
EQUIPMENT / SYSTEM:
MANUFACTURER:

TERMINAL BOX REHEAT INFORMATION

Terminal	**CFM**		**KW**		**EAT DB**		**LAT DB**	
Box ID	**Design**	**Actual**	**Design**	**Actual**	**Design**	**Actual**	**Design**	**Actual**

Comments: ____

____

____

Technician(s): ______________________________ Date: ____________

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VAV REHEAT COIL TEST REPORT

Page:

PROJECT NAME:
EQUIPMENT / SYSTEM:
MANUFACTURER:

TERMINAL BOX REHEAT INFORMATION

Terminal	**CFM**		**GPM**		**EAT DB**		**LAT DB**		**EWT**		**LWT**	
Box ID	**Design**	**Actual**	**Design**	**Actual**	**Design**	**Actual**	**Design**	**Actual**	**Design**	**Actual**	**Design**	**Actual**

Comments: ____
____
____

Technician(s): ______________________ Date: ______________________

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FPB / VAV TERMINAL BOX TEST REPORT

Page:

PROJECT NAME:
EQUIPMENT / SYSTEM:

TERMINAL BOX INFORMATION

Terminal Box ID	DDC Addres	Size	AK	Primary Air **MAX** CFM		Primary Air **MIN** CFM		Fan CFM		Fan Speed
				Design	Actual	Design	Actual	Design	Actual	

Comments:

Technician(s):

Date:

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VAV TERMINAL BOX TEST REPORT

Page:

PROJECT NAME:

EQUIPMENT / SYSTEM:

TERMINAL BOX INFORMATION

Terminal Box ID	DDC Addres	Size	AK	MAX Cool CFM		MIN Cool CFM		MAX Heat CFM		MIN Heat CFM		Notes
				Design	Actual	Design	Actual	Design	Actual	Design	Actual	

Comments: ____

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Technician(s): ________________________________ Date: ______________