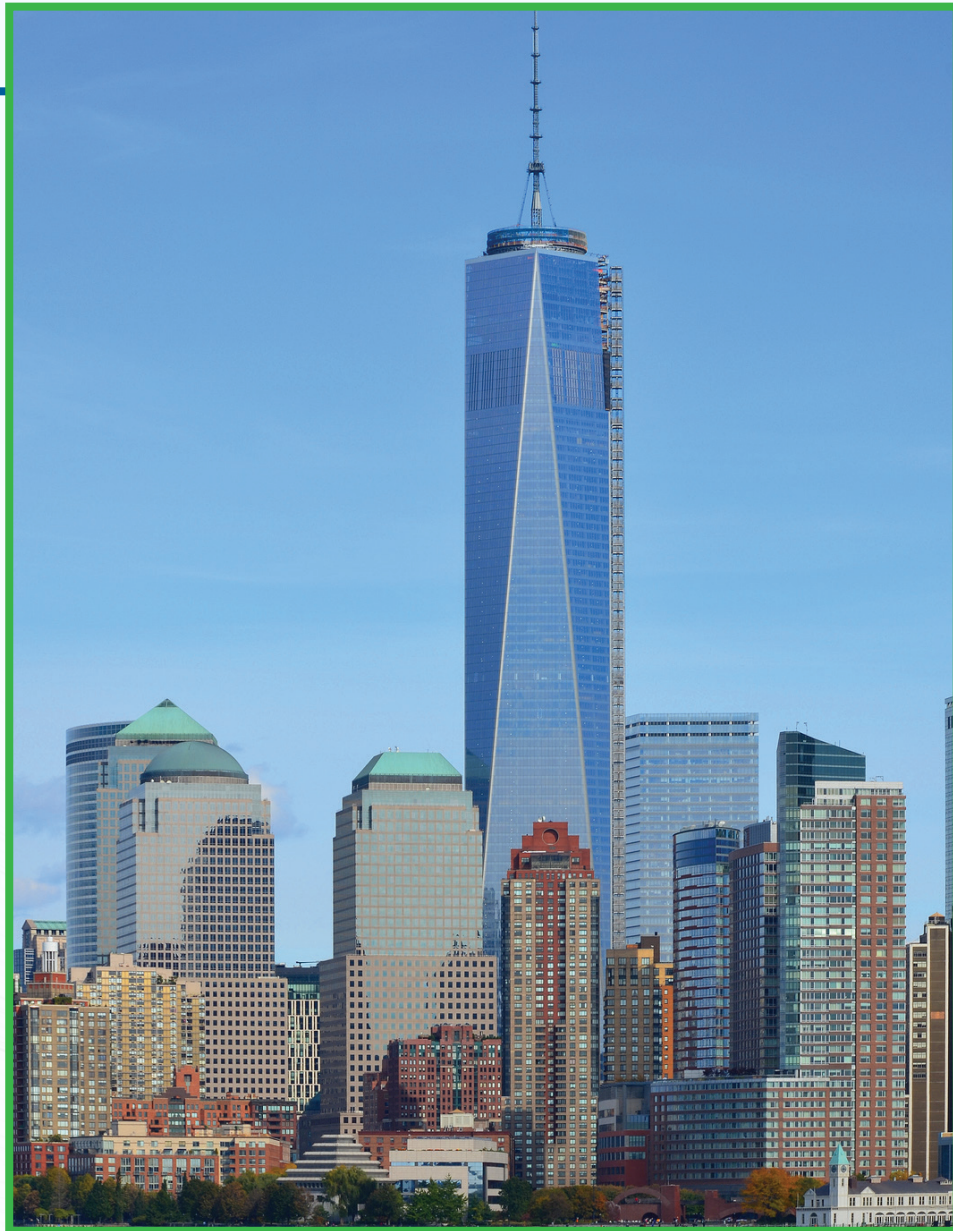


Procedural Standard for Testing, Adjusting and Balancing of Environmental Systems



2015 – Eighth Edition



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PROCEDURAL STANDARD FOR TESTING, ADJUSTING AND BALANCING OF ENVIRONMENTAL SYSTEMS

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2015 EDITION

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Foreword

The NEBB *Procedural Standard for Testing Adjusting and Balancing of Environmental Systems (Procedural Standard)* establishes a uniform and systematic set of criteria for the performance of the testing, adjusting and balancing of environmental or Heating, Ventilating and Air-Conditioning (HVAC) systems.

Today's buildings provide highly controlled, sustainable energy efficient indoor environments. These buildings include very sophisticated mechanical systems created by a team of skilled professionals. A key member of this team is the NEBB Certified Testing, Adjusting and Balancing (TAB) Firm (CF).

This eighth edition represents an update from past editions but remains divided into two distinct parts: standards, and procedures. This *Procedural Standard* has been developed using language defined by "Required" (Minimum Requirements) as it relates to the standards and procedures described in this manual.

This Standard and these procedures are intended as the minimum NEBB requirements that a CF must follow when performing TAB procedures. Contract documents supersede the NEBB requirements when those requirements exceed those stated in this Standard. Conversely, however, this Standard's inclusion of "recommended" testing or recording of parameters are not a requirement for a report to be certified. It is important that this Standard provide procedural direction on testing above and beyond the minimum requirements for report certification so as to be a useful tool in diagnostic and performance related investigations. Recommended items will be clearly delineated within this Standard. Unless so delineated, all testing and reporting requirements of this Standard are considered mandatory under the reporting criteria section. This *Procedural Standard* has been carefully compiled and reviewed by the NEBB TAB Committee.

Part 1. STANDARDS

Part 1 covers Definitions, as well as requirements for Quality Control and Compliance, Instrumentation Requirements, and TAB reports. Revised requirements for TAB instruments and reports are identified. The report requirements allow the CF flexibility in designing their reports by defining sets of information that will be required to complete a NEBB Certified TAB Report.

Part 2. PROCEDURES

Part 2 covers measurement procedures and the testing, adjusting and balancing of both air and hydronic distribution systems.

Part 3. APPENDICES

The Appendices include a Pre-TAB Checklist, and a suggested TAB Specification.

This edition of NEBB *Procedural Standard*, when used by CFs, will assure the building owner or operator a properly balanced environmental system within design and installation limitations.

PART 1.

Standards

Section 1.

DEFINITIONS AND ACRONYMS

Absolute Value: The numerical value without regard to its sign. For example, the absolute value of 3 is 3, and the absolute value of -3 is also 3.

Acceleration: The vector quantity that specifies the time rate of change of velocity.

Accuracy: The capability of an instrument to indicate the true value of a measured quantity.

Adjusting: The varying of system flows by partially closing balancing devices, such as dampers and valves, and varying fan speeds to achieve optimum system operating conditions within design and installation limitations.

AHJ: Authority Having Jurisdiction is the local governing authority having jurisdiction over a designated portion of the project.

Air Change Rate (also referred to as Air Changes per Hour or ACH): The number of times the total air volume of a defined space is replaced in a given unit of time. Ordinarily computed by dividing the total volume of the subject space into the total volume of air supplied to or exhausted from the space per unit of time. (*Supply air volume is used to calculate ACH in rooms requiring a positive pressure. Exhaust air volume is used to calculate ACH in rooms requiring a negative pressure.*)

Air Exchange Rate: Air exchange rate is the rate at which outdoor air replaces indoor air within a given space or room.

AHU: Air Handling Unit

Balancing: The methodical proportioning of air and hydronic flows through the system mains, branches, and terminal devices using acceptable procedures to achieve the specified airflow or hydronic flow within installation, testing and design limitations.

Calibrate (Calibration): The act of comparing an instrument of unknown accuracy with a standard of known accuracy to detect, correlate, report, or correct by adjustment unacceptable variation in the accuracy of the tested instrument.

Conformed Contract Documents: Current and complete documents.

Corrective Action: Repairing, replacing, re-building, calibrating or adjusting of equipment or systems.

Deficiency: Any installation, measurement, or finding outside the tolerances allowed by NEBB *Procedural Standard* or project specifications.

Differential Pressure (ΔP): The difference between two pressures measured with respect to the same reference pressure.

Diffuser: Outlet designed to mix supply air and room air, and to distribute it in varying directions (may or may not have an integral damper).

Diversity: In air or hydronic systems, diversity is the term used to describe the difference in air or water volume between the prime mover (fan or pump) and the terminal elements. An example would be a fan system where the fan is sized for 85% of the total air flow at the terminals. In this example, the diversity would be represented as 85% diversity.

DX: Direct Expansion refrigerant type system.

Embedded Motor: Any motor that is inaccessible without disassembling the equipment it is mounted in. (Examples: cassette ductless units, Fan Powered VAV, VRF fan coil units, direct drive ceiling exhaust fans, etc.)

EOR: Engineer Of Record. The engineer responsible for project plans and specifications.

Environmental Systems: Systems using a combination of mechanical equipment, airflow, water flow and electrical energy to provide heating, ventilating, air conditioning, humidification, and dehumidification for the purpose of human comfort or process control of temperature and humidity.

Equal Area Method: Term used to describe the more common method of duct traversing by averaging velocity readings taken from the center of equal areas of the duct cross-section.

ESP: External Static Pressure.

Face Velocity: The average velocity of air moving perpendicular to the hood face, usually expressed in feet per minute (fpm) or meters per second (m/s).

Fenestration: Any opening in a building structure such as windows, skylights, window walls, doors, louvers, and access panels.

Function: The particular type of data measurement specified in *NEBB Standard for Instrumentation and Calibration*.

GRD: An acronym referring to Grilles, Register and Diffusers (see individual definitions).

Grille: Louvered or perforated face over an opening with no balancing damper integral to the device.

High Efficiency Particulate Air Filter (HEPA): An extended media, dry-type filter in a rigid frame having a minimum particle-collection efficiency of 99.97 percent for 0.3 micron particulate at a rated airflow.

IP: Inch/Pound Term used to describe measurement system used in the United States and elsewhere.

Log Tchebycheff Method or Log-T: An alternate approved method of laying out a duct traverse as opposed to the Equal Area Method.

Memory Stop: An adjustable mechanical device that allows a valve to be closed (for service) and limits the valve to a predetermined position when re-opened.

Micron: A unit of measurement equal to one-millionth of a meter or approximately 0.00003937 inch. (25 microns are approximately 0.001 inch).

NEBB Certified TAB Report: The data presented in a NEBB Certified TAB Report accurately represents system measurements obtained in accordance with the current edition of the *NEBB Procedural Standard for Testing, Adjusting, and Balancing of Environmental Systems*. A NEBB Certified TAB Report does not necessarily guarantee that systems included are balanced to design flows. Any variances from design quantities, which exceed NEBB tolerances or contract document tolerances, are noted in the test-adjust-balance report project summary.

NEBB Certified TAB Firm (CF): A firm that has met and maintains all the requirements of NEBB for firm certification in Testing, Adjusting, and Balancing and is currently certified by NEBB. A CF shall employ at least one NEBB Certified TAB Professional on staff.

NEBB Certified Professional (CP): An individual who has successfully passed the professional level certification examinations and maintains the CP re-certification requirements of NEBB.

NEBB Certified Technician (CT): An employee of the firm who has met the technician level experience requirements of NEBB and has successfully passed the technician level certification examinations. A CT shall be supervised by a NEBB Certified TAB Professional.

NEBB Procedural Standard for Testing, Adjusting and Balancing of Environmental Systems (Procedural Standard): A NEBB publication that outlines responsibilities, instrument standards, report requirements, measurement procedures and job performance expectations for the CF, CP and CT.

NPSH: Net Positive Suction Head.

OA: Outside Air.

Phase: To schedule or order activities so as to be available or complete when, or as, needed.

Point-to-Point Verification: This activity confirms a specific sensor or device is paired and connected to the proper controller.

Potable Water: Water that is satisfactory for drinking, culinary and domestic purposes and that meets the requirements of the Health Authority Having Jurisdiction.

Precision: The ability of an instrument to produce repeatable readings of the same quantity under the same conditions. The precision of an instrument refers to its ability to produce a tightly grouped set of values around the mean value of the measured quantity.

Procedure: A defined approach that outlines the execution of a sequence of work or operations. Procedures are used to produce repeatable and defined results.

QAP: Quality Assurance Program.

RA: Return Air. Sometimes used to designate Relief Air.

Range: The upper and lower limits of an instrument's ability to measure values for which the instrument is calibrated.

Recommended: Testing procedures, measurements, and/or data gathering, whether included in the cer-

tified report or otherwise, that enables further diagnostic review and troubleshooting above and beyond the requirements for report certification.

Register: Combination grille and damper assembly.

Resolution: The smallest change in a measured variable that an instrument can detect; the implementation of actions that correct a tested or observed deficiency.

Required: Designates any data, function or action that must be gathered or performed to qualify as a NEBB certified report, unless such data is impossible to gather or a given function or action cannot be performed. Any information or action that cannot be fulfilled in accordance with this *Procedural Standard* must be clearly explained in the final report summary.

RPM: Revolutions Per Minute.

RTU: Roof Top Unit.

SA: Supply Air.

Shaft Pressurization System: A type of smoke-control system intended to positively pressurize stair and elevator shafts with outdoor air by using fans to keep smoke from contaminating the shafts during an alarm condition.

Shutoff Head: Term used to describe the dynamic measurement of a pump's total dynamic head at no flow. Performed by closing the pump discharge valve only.

SI: International System of Units (*Système international d'unités*), the modern international standard version of the metric system.

Smoke-Control System: An engineered system that uses fans to produce airflow and pressure differences across barriers to limit smoke movement.

Smoke-Control Zone: A space within a building that is enclosed by smoke barriers and is a part of a zoned smoke-control system.

Stairwell Pressurization System: A type of smoke-control system that is intended to positively pressurize stair towers with outdoor air by using fans to keep smoke from contaminating the stair towers during an alarm condition.

Static Head: The pressure due to weight of fluid above the point of measurement. In a closed system, static head is equal on both sides of the pump.

Static Pressure (SP): In an HVAC System, the potential energy a system possesses at the point of measurement to produce and maintain fluid flow against system resistance. Can be positive or negative relative to the appropriate reference pressure.

Static Test: Test or inspection that validates a specified static condition such as pressure testing. Static tests may be specification or code initiated.

Suction Head: The height of fluid surface above or below the centerline of a pump on the suction side.

System Effect: A phenomenon that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system. System Effect cannot be measured directly, but can be estimated.

TDH: Total Dynamic Head. The total equivalent height that a fluid is to be pumped, taking into account friction losses in the pipe.

Terminal Device: A point where the controlled medium enters or leaves the distribution system (air side; grille, register or diffuser) (hydronic side; heat transfer elements such as coils, radiant panels, chill beams, etc.).

Terminal Unit: A device that regulates the amount and/or the temperature of the controlled medium.

Test Procedure: A written protocol that defines methods, personnel, and expectations for tests conducted on components, equipment, assemblies, systems, and interfaces among systems.

Testing: The use of specialized and calibrated instruments to measure parameters such as temperature, pressure, vapor flow, airflow, fluid flow, fluid quantities, rotational speed, electrical characteristics, velocity, sound and vibration level, air and hydronic quantities, and other data in order to determine performance, operation, or function.

Testing, Adjusting and Balancing (TAB): A systematic process or service applied to HVAC systems, and other environmental systems, to achieve and document air and hydronic flow rates.

Total Pressure (TP): The sum of static pressure and velocity pressure at the point of measurement in the system ($TP = SP + VP$). Value may be positive or negative.

TSP: Total Static Pressure.

Troubleshooting: Procedural activities for investigating a specific fault or failure of a system or piece of equipment.

VAV: Variable Air Volume.

Velocity: The vector quantity that specifies the time rate of change of displacement.

Velocity Pressure (VP): The kinetic energy of flow exerted only in the direction of flow. Velocity pressure cannot be measured directly. It is the difference between total pressure and static pressure at the point of measurement.

Zone: A volume of building served by a single ventilation system. For buildings with natural ventilation only, the whole building is considered a zone.

Section 2. NEBB PROGRAMS, QUALITY CONTROL & COMPLIANCE

2.1 NEBB PROGRAMS

NEBB is a not-for-profit organization founded in 1971 to:

- a) Develop standards, procedures and programs for Building Systems Commissioning, Cleanroom Performance Testing, Fume Hood Performance Testing, Retro-Commissioning and Building Enclosure Testing, Sound Level Testing, Testing-Adjusting-Balancing Environmental Systems and Vibration Testing,
- b) Promote advancement of the industry through technical training and development.
- c) Operate programs to certify firms and qualify individuals who meet and maintain NEBB standards.

Additional information on the NEBB Program is available at www.nebb.org.

2.1.1 NEBB DISCIPLINES

NEBB establishes and maintains standards, procedures and specifications for work in its various disciplines, which include:

- a) Building Enclosure Testing (BET)
- b) Building Systems Commissioning (BSC)
- c) Cleanroom Performance Testing (CPT)
- d) Fume Hood Performance Testing (FHT)
- e) Retro-Commissioning (RCx)
- f) Sound Measurement (SM)
- g) Testing, Adjusting and Balancing (TAB) of air and hydronic systems
- h) Vibration Measurement (VM)

Each discipline is anchored by a NEBB *Procedural Standard* manual that provides guidelines for work to be performed. NEBB also has created technical manuals, training materials, programs, and seminars to enhance and support each discipline.

2.1.2 CERTIFICATION OF FIRM

NEBB certifies firms that meet certain criteria, ensuring strict conformance to NEBB's *Procedural Standard*. Among other requirements, NEBB CFs must document a record of responsible performance and own a complete set of instruments as listed in [Table 4.1](#). The firm must employ a NEBB CP for each discipline in which the firm is certified.

2.1.3 CERTIFICATION OF PROFESSIONAL

CPs are responsible for the supervision of all work performed by the CF and its employees. CPs must possess a strong grasp of engineering principles, system design, system equipment and procedures. They must also demonstrate proficiency in execution of the work including problem solving, troubleshooting, field measurements, proper use of instruments and performance of the actual work in the field.

2.1.4 CERTIFICATION OF TECHNICIAN

See the [NEBB website](#)

2.1.5 RECERTIFICATION REQUIREMENTS for NEBB CPs

See the [NEBB website](#)

2.1.6 RECERTIFICATION REQUIREMENTS for NEBB CFs

See the [NEBB website](#)

2.2 QUALITY ASSURANCE PROGRAM (QAP) North America only

The credibility of NEBB is built by maintaining integrity through high standards, quality programs, and demonstrated capabilities of its CFs. As further assurance, NEBB offers a Quality Assurance Program to guarantee that the work will be accomplished in accordance with its standards. The NEBB Certificate of Conformance may be provided if specified or requested, but is not mandatory.

2.2.1 PROGRAM BENEFITS

The QAP affords building owners, architects, engineers and other agents a reliable basis for specifying work within the various disciplines of NEBB. The program promotes proper execution of projects by ensuring compliance with *Procedural Standard*.

2.2.2 NEBB QUALITY ASSURANCE PROGRAM CERTIFICATE

If specified in the contract documents, the CF will make application to the NEBB Office for a Certificate of Conformance Certification. The QAP Conformance Certification is applicable to any project.

2.3 QUALITY CONTROL AND COMPLIANCE

Building owners are entitled to a professional service by every NEBB CF on every project, whether the job is NEBB specified or not. It is the responsibility of the NEBB CF and NEBB CP to establish and maintain procedures and practices that will assure a consistent pattern of high quality work on all projects.

2.3.1 TAB WORK COMPLIANCE

Project scope is guided by the project specifications. Project TAB procedures will be guided by *NEBB TAB Procedural Standard*, recorded in the TAB report and will serve as a record of data acquired and work performed.

Regardless of project specifications, data acquisition will always conform to the NEBB *Procedural Standard* in effect at time contract was issued. If specification requirements exceed the current NEBB *Procedural Standard*, those specifications will take precedence.

2.4 CERTIFIED TAB PROFESSIONAL RESPONSIBILITIES

CPs shall ensure that the project work is performed to NEBB *Procedural Standard* and that a copy of the *Standard* is available if needed.

2.4.1 FURTHER RESPONSIBILITIES

The NEBB TAB CP has project responsibility, which includes authority to represent the NEBB TAB CF. Examples of project responsibility may include labor decisions, negotiating change orders, committing to contract interpretations and implementing changes in job schedules.

The NEBB TAB CP has the responsibility to assure that the systems have been tested, adjusted and balanced in accordance with this *Procedural Standard* and the contract documents to assure the accuracy of all data included in the final TAB report. Factors such as technician training, instrument use, coordination, supervision, work instructions and project communication play a critical role in achieving this requirement.

2.4.2 CT TRAINING

The NEBB CP is responsible to ensure that CT's performing the work are properly trained and possess sufficient skills within the following areas:

2.4.2.1 CT TAB PROCEDURES TRAINING

CTs must be prepared to measure and record data in the manner specified within the *Procedural Standard*, as well as to perform the specific tasks and procedures to acquire the data. This preparation requires CTs to possess knowledge of HVAC system fundamentals and operating characteristics.

2.4.2.2 CT INSTRUMENT USE AND MAINTENANCE

NEBB Certified Professionals and Technicians shall possess knowledge and skill in the proper use and care of instruments required to perform the work. This includes a thorough understanding of the operating principles and use of TAB equipment and instruments. Considerations for the delicate nature of many of the TAB instruments typically used, as well as the adverse effects of dirt, shock, jarring movements and exceeding rated capacities, shall be addressed along with the proper methods for storing and transporting the instruments.

2.4.3 COORDINATION/SUPERVISION

The NEBB Certified Professional is responsible for ensuring either a NEBB CP or NEBB CT is continually present while TAB work is being performed on every NEBB certified project, and directing those technicians in performing the work. The NEBB CP is ultimately responsible for the accuracy of any field measurements and certified reports generated.

2.4.4 PROJECT COMMUNICATION

Before the final report is submitted, the CP may provide reports of progress and problems as encountered to appropriate project personnel. When reporting a problem, the CP may provide input as needed to determine causes and make recommendations.

2.4.5 WORK COMPLETION

The CP determines when the TAB project is complete, and when to submit the Final TAB Report. Generally, the specified TAB project is complete when:

- a) All HVAC systems and components are tested and balanced within specified tolerances.
- OR
- b) Reasonable efforts have been taken to achieve requirements of *Procedural Standard*. In this event the CP will notify the appropriate project personnel of system deficiencies preventing balancing within design tolerances before the final report is submitted. Any variances from design quantities, which differ from NEBB tolerances, shall be noted in the project summary of the Final TAB Report.

2.4.6 COMPILATION AND SUBMISSION OF FINAL TAB REPORTS

A Final TAB Report shall include information and data to provide an accurate quantitative record of system information, measurements and final settings. Reports shall include notes and comments as appropriate to provide the reviewer with additional details including test procedure, system operation and results. Reports shall meet the requirements listed in [Sections 5 and 6](#).

The certification page bears the stamp of the CP/CF. The stamp on the certification page is signed as evidence the CP has personally reviewed and accepted the report.

Section 3. RESPONSIBILITIES

3.1 INTRODUCTION

Many approaches can be taken to execute a Testing, Adjusting and Balancing (TAB) project that meets NEBB standards. The following will outline the responsibilities Design Professionals and Construction Teams have to ensure a successful TAB project.

3.2 DESIGN AND CONSTRUCTION TEAM RESPONSIBILITIES

3.2.1 DESIGN PROFESSIONAL RESPONSIBILITIES

NEBB strongly recommends the TAB contract documents:

- a) Specify equipment and systems to be Tested, Adjusted and Balanced, in accordance with *NEBB Procedural Standard*.
- b) Define who retains the services of the CF and requires that the CF be retained early in the construction process.
- c) Identify the system components within contract documents required for successful balancing (i.e., main, branch and final volume dampers, flow measuring stations, pressure and/or temperature test ports, other applicable balancing devices, etc.).
- d) Specify that the control system firm both commission and document their work prior to TAB work commencing.
- e) Specify that the control system firm provides access to hardware, software and on-site technical support as required at no cost to the TAB CF.
- f) Specify adequate access to all equipment and components required by the TAB process.
- g) Completely define commissioning support responsibilities for the CF.

- h) Align the project balancing tolerances with the tolerances specified by the *NEBB Procedural Standard*.
- i) Specify who is to provide and install any drive changes required.

3.2.2 CONSTRUCTION TEAM RESPONSIBILITIES

NEBB strongly recommends the TAB contract documents specify that the Construction Team will:

- a) Provide the CF with a conformed set of contract documents (drawings, specifications, and approved submittals), including all current approved change orders and contract modifications.
- b) Develop a project schedule with the input of the CF that coordinates the work of other disciplines, providing adequate time in the construction process for successful completion of the TAB work.
- c) Notify the CF of *all* schedule changes.
- d) Ensure that the building enclosure is complete, including structural components, window and door installation, door hardware, ceilings, stairs, elevator/mechanical shafts and roof systems. All plenums and chases must be sealed.
- e) Ensure that all necessary mechanical and HVAC work is complete and is safe to operate. This includes, but is not limited to: duct leakage testing, hydrostatic testing; piping system flushing, filling, venting, and chemical treating. All strainers should be cleaned and the correct screens installed. The duct systems and all related equipment should be cleaned and the specified clean air filters installed. For additional requirements, see Appendix A: *Pre-TAB Checklist within this edition of Procedural Standard*.
- f) Complete the installation of permanent electrical power systems serving the HVAC equipment and systems. Such electrical systems should be properly installed in accordance with all applicable codes to ensure the safety of all construction personnel.

- g) Perform startup of all HVAC equipment and systems in accordance with manufacturers' recommendations.
- h) Complete the installation, programming (including design parameters and graphics), calibration and startup of all building control systems. Verify that the building control system provider has commissioned and documented their work before TAB work begins.
- i) Require that the control system firm provides access to hardware, software and onsite technical support as required at no cost to the CF.
- j) Furnish and install all drive changes as required.
- k) Make corrections reported in the deficiency list in a timely manner and provide written notice when complete.

3.2.3 NEBB CERTIFIED TAB FIRM RESPONSIBILITIES

The CF shall:

- a) Follow the current NEBB *Procedural Standard* when performing the TAB work.
- b) Communicate through proper channels on a regular basis, design, installation, or functional concerns that prevent the CF from performing and completing the TAB work in accordance with current NEBB *Procedural Standard* and design specification.
- c) Perform the specified commissioning support requirements.
- d) Publish a NEBB Certified TAB Report.

Section 4. STANDARDS FOR INSTRUMENTS AND CALIBRATION

4.1 MINIMUM INSTRUMENTATION

A NEBB Certified TAB Firm (CF) will, at minimum, own the instrumentation listed in [Table 4.1](#) included in this edition of the *Procedural Standard*. Respective instruments will be applied in accordance with and maintained to properly perform in accordance with manufacturer recommendations.

4.2 RANGE AND ACCURACY

RANGE AND ACCURACY

A NEBB Certified TAB Firm shall possess instruments (of the firm's choice) for each function and range listed in [Table 4.1](#). Each instrument shall have been specifically designed to meet the criteria (Minimum Accuracy, Range, and Resolution) of the function.

Instrumentation with multiple capabilities shall be accepted for more than one function when submitting documentation for a firm's certification, providing that each separate function meets NEBB requirements.

Information and data regarding accuracy of all submitted instrumentation for the stated functions shall be available from the manufacturer.

All required instrumentation shall be calibrated in accordance with the manufacturer's recommendations by a testing laboratory traceable to the National Institute of Standards and Technology or equivalent institute in countries other than the United States.

Firms with multiple sets of instrumentation shall comply with *either* of the following conditions as a minimum requirement for NEBB certification:

- a) Calibrate all instrumentation used by the firm on TAB projects in accordance with [Table 4.1](#).
OR
- b) Maintain a complete set of calibrated instrumentation used for comparison with regularly used instrumentation. Instruments shall be calibrated in accordance with [Table 4.1](#). Periodic checking of regularly used instrumentation against the calibrated set shall be performed. **Acceptance criteria for the results of the comparisons are the responsibility of the NEBB Certified TAB Professional.**

NEBB TAB CPs must understand the importance of using accurate instrumentation in the field, and shall be prepared to have witnesses verify their work with the Firm's calibrated set of instrumentation. Results of the data verification shall validate the accuracy of the instrumentation used to perform the work.

Table 4.1 Instrumentation List – IP Units

FUNCTIONS/INSTRUMENT TYPE	MINIMUM RANGE	ACCURACY	RESOLUTION	CALIBRATION INTERVAL
Rotation Measurement	0-5000 RPM	$\pm 2\%$ of reading ± 2 RPM	1 RPM	12 Months Date:
Temperature Measurement Air	-40 to 240° F	$\pm 0.5\%$ of reading + 1.4° F	0.2° F	12 Months Date:
Temperature Measurement Immersion	-40 to 240° F	$\pm 0.5\%$ of reading + 1.4° F	0.2° F	12 Months Date:
Temperature Measurement Contact	-40 to 240° F	$\pm 0.5\%$ of reading + 1.4° F	0.2° F	12 Months Date:
Electrical Measurement - CAT III True RMS				12 Months Date:
Volts AC	0 to 600 VAC	$\pm 2\%$ of reading ± 5 digits	1.0 Volt	
Amperes	0 to 100 Amps	$\pm 2\%$ of reading ± 5 digits	0.1 Ampere	
Air Pressure Measurement	0 to 10.00 in w.g.	$\pm 2\%$ of reading ± 0.001 in w.g.	0.001 in w.g. ≤ 1 in w.g. 0.01 in w.g. > 1 in w.g.	12 Months Date:
Air Velocity Measurement Hot Wire Anemometer OR Airfoil with Digital Meter	50 to 3900 fpm	$\pm 5\%$ of reading, not less than ± 7 fpm	1.0 fpm	12 Months Date:
Air Velocity Measurement Rotating Vane	50 to 2500 fpm	$\pm 2\%$ of reading ± 4 fpm	1.0 fpm	12 Months Date:
Humidity Measurement	10 to 90% RH	$\pm 3\%$ RH	1.0%	12 Months Date:
Direct Reading Hood	100 to 2000 cfm	$\pm 5\%$ of reading ± 7 cfm	Digital: 1 cfm Analog: N/A	12 Months Date:
Hydronic Pressure Measurement	-30 in h.g. to 60 PSI 0 to 100 PSI 0 to 200 PSI	$\pm 2\%$ of reading ± 1 PSI $\pm 2\%$ of reading ± 1 PSI $\pm 2\%$ of reading ± 1 PSI	0.5 PSI 1.0 PSI 2.5 PSI	12 Months Date:
Hydronic Differential Pressure Measurement	0 to 100 in w.g. 0 to 200 ft. w.g.	$\pm 2\%$ of reading ± 2 in. w.g. $\pm 2\%$ of reading ± 0.2 ft. w.g.	1.0 in. w.g. 1.0 ft. w.g.	12 Months Date:

Table 4.1 Instrumentation List – SI Units

FUNCTIONS/INSTRUMENT TYPE	MINIMUM RANGE	ACCURACY	RESOLUTION	CALIBRATION INTERVAL
Rotation Measurement	0-5000 RPM	$\pm 2\%$ of reading ± 2 RPM	1 RPM	12 Months Date:
Temperature Measurement Air	AIR: -40 to 115°C	$\pm 0.5\%$ of reading + 0.8°C	0.1°C	12 Months Date:
Temperature Measurement Immersion	IMMERSION: -40 to 115°C	$\pm 0.5\%$ of reading + 0.8°C	0.1°C	12 Months Date:
Temperature Measurement Contact	CONTACT: -40 to 115°C	$\pm 0.5\%$ of reading + 0.8°C	0.1°C	12 Months Date:
Electrical Measurement - CAT III True RMS				12 Months Date:
Volts AC	0 to 600 VAC	$\pm 2\%$ of reading ± 5 digits	1.0 Volt	
Amperes	0 to 100 Amps	$\pm 2\%$ of reading ± 5 digits	0.1 Ampere	
Air Pressure Measurement	0 to 2,500 Pascals	$\pm 2\%$ of reading ± 0.25 Pascals	0.25 Pascals \leq 250 Pascals 2.50 Pascals \leq 250 Pascals	12 Months Date:
Air Velocity Measurement Hot Wire Anemometer OR Airfoil with Digital Meter	0.25 to 20 m/s	$\pm 5\%$ of reading, not less than ± 0.5 m/s	0.005 m/s	12 Months Date:
Air Velocity Measurement Rotating Vane	0.25 to 12.5 m/s	$\pm 2\%$ of reading ± 0.02 m/s	0.005 m/s	12 Months Date:
Humidity Measurement	10 to 90% RH	$\pm 3\%$ RH	1.0%	12 Months Date:
Direct Reading Hood	50 to 1000 L/s	$\pm 5\%$ of reading ± 3 L/s	Digital: 0.5 L/s Analog: N/A	12 Months Date:
Hydronic Pressure Measurement	-760 mm h.g. to 400 kPa 0 to 700 kPa 0 to 1,400 kPa	$\pm 2\%$ of reading ± 7 kPa $\pm 2\%$ of reading ± 7 kPa $\pm 2\%$ of reading ± 7 kPa	3.3 kPa 6.7 kPa 16.7 kPa	12 Months Date:
Hydronic Differential Pressure Measurement	0 to 25 kPa 0 to 600 kPa	$\pm 2\%$ of reading ± 0.5 kPa $\pm 2\%$ of reading ± 0.5 kPa	250 kPa 3.0 kPa	12 Months Date:

Section 5. STANDARDS FOR REPORTS AND FORMS

5.1 REPORTS

The NEBB *Procedural Standard for Testing, Adjusting, and Balancing of Environmental Systems* establishes minimum requirements of a NEBB Certified TAB Report.

NEBB does not require the use of NEBB produced forms. Customized forms are acceptable based on the data acquisition requirements of this section. Contract document data reporting requirements shall take precedence when they exceed minimum requirements of NEBB.

5.2 REPORT FORMS

Listed below are the requirements for each NEBB Certified TAB Report.

5.2.1 REPORT TITLE

Include: The heading: “Certified Test, Adjust and Balance Report” (Project Name/Address; Engineer Name; HVAC Contractor Name; NEBB Certified TAB Firm Name/Address/Certification Number).

5.2.2 REPORT CERTIFICATION¹

The certification page bears the stamp of the NEBB Certified TAB Professional (CP). The stamp on the certification page is signed as evidence the CP has reviewed the report and assumes responsibility for all work, test methods and observed conditions documented within.

Include: Project Name; Certifying NEBB Certified TAB Professional’s Name; Firm Name; Certification Number; Expiration Date; Certifying NEBB Certified TAB Professional’s NEBB Stamp (signed & dated); and the following exact verbiage:

“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 information was gathered. Any variances from design quantities, which exceed NEBB tolerances, are noted in the TAB report project summary.”

¹ This data may be included on the report title page or on a separate certification page.

5.2.3 TABLE OF CONTENTS

The table of contents, with page numbers, serves as a guide to the organization of the TAB report.

5.2.4 REPORT SUMMARY/REMARKS

A NEBB Certified TAB Report includes a required narrative description of system set-up conditions established prior to testing adjusting and balancing. The narrative must explain the rationale for how the system was configured for testing, such as to establish a full load condition, and the steps taken to achieve the desired set-up.

This section shall also include a listing of deficiencies in the summary and identifies the appropriate pages in the report. Part of the CP’s responsibilities is to determine “noteworthy” deficiencies. This section might also be used to discuss possible recommendations such as solutions to system balance issues.

A summary of all *Procedural Standard* items that exceed NEBB and/or Contract Document tolerances or any other items that require discussion or explanation shall be included.

A list of all items which could not be obtained for reasons beyond the control of the CF shall be included.

5.2.5 ALL REPORT PAGES

All tested items included in the NEBB TAB Report shall be clearly identified with a unique designa-

tion. Schematic diagrams, mechanical plans where permissible, or a narrative description may be used. Each data form supplied in a NEBB TAB Report shall include the name of the individual who reported the information, along with the time period the data was collected.

Include: Project name, sequentially numbered pages and remarks section to record pertinent information.

5.2.6 INSTRUMENT CALIBRATION

This is a listing of the instruments that will be used to verify the reported data including instrument type, manufacturer, model number, serial number and calibration date.

5.2.7 ABBREVIATION LIST

Any abbreviations or acronyms used in the report shall be defined in an abbreviation list.

5.2.8 DRAWINGS AND SCHEMATICS

Include: Pertinent contract drawings, schematics, sketches, etc.

5.2.9 AIR AND HYDRONIC FLOW MEASUREMENT REPORT

5.2.9.1 AIR SYSTEM OUTLET REPORT

a) System Designation	Design
b) System Sketch	Actual
c) Area Served	Actual
d) Outlet/Inlet Designation	Actual
e) Outlet/Inlet & Total Design CFM	Design
f) Outlet/Inlet & Total Preliminary CFM	Actual
g) Outlet/Inlet & Total Final CFM	Actual
h) Outlet/Inlet Size where $A_k \neq 1.0$	Actual
i) Outlet/Inlet Area where $A_k \neq 1.0$	Actual
j) A_k Where Effective Area $\neq 1.0$	Actual
k) Velocity Where $A_k \neq 1.0$	Actual

5.2.9.2 TRAVERSE: (Duct, Coil Face, Filter Face & Opening¹)

a) System Designation	Design
b) Unit Designation	Design

c) Reading Location	Actual
d) Reading Designation (Unique ID/mode)	Actual
e) Instrument Used	Actual
f) CFM	Design & Actual
g) Dimension of Traversed Area	Actual
h) Sq. Ft. of Traversed Area ¹	Actual
i) Cross Section Sketch	Actual
j) Velocity Readings in Grid Form	Actual
k) Average Velocity	Actual
l) Centerline Duct SP	Actual
m) Air Temperature	Actual

¹ Include effective area multiplier if opening is equipped with a screen, expanded metal, etc.

5.2.9.3 HYDRONIC SYSTEM BALANCE REPORT

a) System Designation	Design
b) System Sketch	Actual
c) Fluid Type/% Glycol	Design & Actual
d) Differential Pressure	Design & Actual
e) GPM	Design & Actual

5.2.9.4 ULTRASONIC FLOW MEASUREMENT (when provided)

(Recommended alternate flow measurement & method when ΔP measurement is not possible or reliable)

a) System Designation	Design
b) Unit Designation	Design
c) Measurement Location	Actual
d) Measurement Designation (Unique ID/mode)	Actual
e) Instrument Used	Actual
f) Fluid Type/% Glycol	Actual
g) Pipe Material	Actual
h) Pipe Wall Thickness	Actual
i) Pipe Size	Installed
j) Transducer Size	Actual
k) Transducer Spacing	Actual
l) GPM	Design & Actual

5.2.9.5 FLOW BALANCING DEVICES

DEVICE	SYSTEM DESIGNATION	MFR.	MODEL #	GPM	SIZE	OPERATING PRESSURE RANGE	ΔP	DIAL SETTING
Orifice Plate	D	I	I	D/A	I		A	
Venture	D	I	I	D/A	I		A	
Circuit Setter Variable Cv	D	I	I	D/A	I		A	A
Manual Flow Balancing Valve Fixed Cv	D	I	I	D/A	I		D/A	A
Flow Limiting Balancing Valve Self-Adjusting Cv	D	I	I	D/A	I	D/I	A	

D = Design, A = Actual, I = Installed

5.3 REQUIRED REPORT DATA

Modern HVAC equipment is varied and complex. The following test report requirements are listed by component to insure that any type or arrangement of equipment can be accurately and completely tested and reported. The CF shall determine what components a unit includes and insure that final reports include each component's required data.

5.3.1 UNIT & NAMEPLATE DATA (required for all stand-alone equipment - not required for individual components)

- | | |
|---|-----------|
| a) Unit Designation | Design |
| b) Manufacturer | Installed |
| c) Model Number | Installed |
| d) Serial Number | Installed |
| e) Type | Installed |
| f) Service | Design |
| g) Area Served | Design |
| h) Location. | Design |
| i) Unit Cross Sectional Sketch or Static Pressure Profile | Actual |

5.3.2 FAN, MOTOR & DRIVE – ACCESSIBLE (where fan and motor are accessible)

FAN:

- | | |
|----------------------------|-----------------|
| a) Airflow | Design & Actual |
| b) TSP | Design & Actual |
| c) ESP | Design & Actual |
| d) Static Pressure Profile | Actual |
| e) RPM | Design & Actual |
| f) Rotation | Design & Actual |

MOTOR:

- | | |
|-----------------------------|--------------------|
| a) Manufacturer | Installed |
| b) Horsepower | Installed |
| c) Frame | Installed |
| d) Full Load Amps | Installed |
| e) Service Factor | Installed |
| f) Volts | Nameplate & Actual |
| g) Corrected Nameplate Amps | Actual |
| h) Operating Amps | Actual |
| i) Brake Horsepower | Actual |

BELT DRIVE:

- | | |
|--------------------------------------|-----------|
| a) Motor Sheave Manufacturer/PD/bore | Installed |
| b) Fan Sheave Manufacturer/PD/bore | Installed |
| c) C to C Distance | Installed |
| d) Belt Manufacturer/quantity/size | Installed |

5.3.3 FAN, MOTOR & DRIVE – EMBEDDED (where fan and motor are not accessible i.e. FPVAV, VRF, PTAC, etc.)

- | | |
|-------------------------|---------------------|
| a) Airflow ¹ | Design & Actual |
| b) Nameplate Volts | Actual ² |
| c) Nameplate Amps | Actual ² |
| d) Operating Volts | Actual ² |
| e) Operating Amps | Actual ² |

¹ Required for each FPVAV mode of operation; not required for embedded fans unless specified

² Required if nameplate is accessible

5.3.4 FILTERS

- | | |
|-------------|--------------------|
| a) Quantity | Installed |
| b) Size | Installed |
| c) Type | Design & Installed |

5.3.5 HEAT EXCHANGERS

All heat exchanger data in the table above is required for each project except temperatures which may be difficult or impossible to obtain for various reasons: chiller or boiler plants not online, lack of test ports, etc. All temperatures are Type 1. At a minimum, air temperatures are **highly recommended** for all projects as the best way to identify system performance problems.

DEVICE	AIR									WATER					ELECTRICITY			
	EAT				LAT					EWT	LWT	ΔT	ΔP	GPM	Volts	Amps	Stages	Kw
	DB	WB	DB	WB	ΔT	CFM	ΔP	Face Area	Face Vel.									
DX Coil	A	A	A	A	A	D/A	A	A	A									
Chilled Water Coil	A	A	A	A	A	D/A	A	A	A	A	A	A	D/A ³	D/A ³				
Hot Water Coil	A		A		A	D/A	A	A	A	A	A	A	D/A ³	D/A ³				
Gas or Oil Fired	A		A		A	D/A												
Steam coil	A		A		A	D/A	A	A	A									
Electric Strip Heat	A		A		A	D/A									D/A	D/A	D/A	D/A
Heat Wheel ²	A	A	A	A	A	D/A	A	A	A									
Desiccant Wheel ²	A	A	A	A	A	D/A	A	A	A									
Evaporative Media	A	A	A	A	A	D/A				A ¹	A ¹	A ¹		D/A ¹				

D = Design, A = Actual, I = Installed

1 For cooling towers only, 2 Repeat required readings for supply and exhaust paths, 3 Water ΔP not required when balancing device is used to balance and data is already reported on Hydronic Flow Measurement Report

5.3.6 PUMP

- a) Flow Rate Design & Actual
- b) Impeller Installed
- c) Pump Off Pressure Actual
- d) RPM Design & Actual

SHUTOFF:

- a) Suction Pressure Actual
- b) Discharge Pressure Actual
- c) Total Dynamic Head Design & Actual

FINAL SETTING:

- a) Suction Pressure Actual
- b) Discharge Pressure Actual
- c) Total Dynamic Head Design & Actual

5.3.7 MOTORS

- a) Manufacturer Installed
- b) Horsepower Installed
- c) Frame Installed
- d) Full Load Amps Installed

- e) Service Factor Installed
- f) Volts Nameplate & Actual
- g) Nameplate Amps Actual
- h) Corrected Nameplate Amps Actual
- i) Operating Amps Actual
- j) Brake Horsepower Actual
- k) Current Overload Size/Setting Actual

5.3.8 CONTROL DAMPERS: (return air, outside air, relief air, etc.)

- a) Airflow Design and Actual
- b) % Open Setting Actual

5.3.9 CONTROL DAMPERS: (terminal unit primary air)

- a) Maximum Cooling Airflow Design & Actual
- b) Minimum Cooling Airflow Design & Actual
- c) Heating Maximum Airflow Design & Actual
- d) Heating Minimum Airflow Design & Actual
- e) Controller Address Actual
- f) Controller Calibration Factor Actual

5.3.10 FINAL SYSTEM SETTINGS:
*(information needed to restore
balanced condition settings)*

- | | |
|--|--------|
| a) Primary Air System ΔP Setpoint | Actual |
| b) Hydronic System ΔP Setpoint | Actual |
| c) Hydronic System Fill Pressure | Actual |
| d) Glycol % | Actual |
| e) Motor Speed Setting -
Variable or high/med/low | Actual |
| f) % Setting for all devices in controls
hardware or software | Actual |
| g) Final Hertz | Actual |

PART 2. PROCEDURES

Section 6. BASIC TESTING, ADJUSTING & BALANCING MEASUREMENTS

6.1 INTRODUCTION

This section prescribes procedures for basic testing, adjusting and balancing (TAB) measurements that are accurate and repeatable. Basic 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:

- Manometer (Inclined Gauge or Digital)

Air pressure measurements for HVAC TAB procedures are accomplished with a manometer, connecting tubing and an appropriate sensing tip. This manometer may be as basic as an inclined oil manometer or as sophisticated as a multi-function instrument with manometer 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

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 an evaluation of System Effect. The impact of System Effect is to be taken into account during the design phase as installation problems can occur.

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

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

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 fan, the external static pressure actually refers to the difference between two 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 Manometer
- Inclined Oil Gauge Manometer
- Rotating Vane anemometer
- Thermal Anemometer (Hot Wire) (Not to be used for duct traverses.)

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 in order 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.

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 manometer, 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 manufacturer'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 mea-

sured. 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 manometer. Verify the "zero" of the instrument 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 either 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*)
 - Log Tchebycheff (Log-T) method - See the latest edition of the NEBB TAB Manual for Technicians for measuring point layout.
- g) Round ducts 6" and larger are traversed by the Equal Area method. 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 center-line 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 4 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.

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

IP (US) UNITS

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

SI (METRIC) UNITS

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

Where: V = Air velocity - fpm (m/s)

V_p = Velocity pressure - in. w.g. (Pascals)

D = Air density - lb/ft³ (kg/m³)

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

Equation 6-2

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

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

Where: P_B = Absolute static pressure - in. Hg (kPa) (Barometric pressure + Static pressure)

T = Air temperature -°F (°C)

6.4 TEMPERATURE MEASUREMENT PROCEDURES

The following procedures describe the methods to be utilized when making temperature measurements. While the procedures outlined here are prescriptive, instrumentation use 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 more readily available in hydronic systems than air systems. In air systems, a uniform temperature profile and its associated velocity profile, sometimes can be impossible to achieve. For hydronic systems, thorough mixing normally can be attained due to the elbows immediately adjacent to the heat transfer equipment.
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, a sufficient number of temperature readings must be taken during a given time rate and the results integrated over that time.

Same instrumentation: The final issue deals with the use 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:

6.4.3.1 TEMPERATURE MEASUREMENTS – TYPE 1 – PERFORMANCE CHECKS

Type 1 temperature measurements are a recommendation of this *Standard*. They are single point air temperature measurements for the purpose of ensuring that systems are heating or cooling.

6.4.3.2 TEMPERATURE MEASUREMENTS – TYPE 2 – PERFORMANCE VERIFICATION

Type 2 temperature measurements as described below are required only when specified by the Engineer. The purpose of Type 2 temperature measurements is to determine heat flow through energy balance calculations.

Air Temperature – Dry Bulb

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

Example 6.1

A temperature traverse of a 20" x 16" (500mm x 400mm) duct is to be made. A 16- point equal area traverse is performed. In [Table 6.1](#), the measured temperatures (°F/°C) and corresponding velocities (fpm/m/s) are recorded. In [Table 6.1](#) the tempera-

ture and the velocities are not constant. In Table 6.2 the same temperatures are shown but with the idealized condition that each area has the identical velocity/airflow.

Air Temperature Traverses - Wet Bulb

As with dry bulb measurements, where a uniform profile exists, wet bulb temperature measurements may be as simple as a single point reading in the middle of the duct. In systems with suspected poor mixing or temperature stratification, multiple readings must be taken and then averaged.

Where a non-uniform profile exists, an equal area temperature traverse and a corresponding velocity traverse are made and the weighted average used as the resultant temperature. Additionally, when the selected instrumentation is a wick-type psychrometer, the wick, or sock, must remain continuously wetted with distilled water. The temperature of the water is to be the same temperature as the dry bulb air temperature. Wet bulb readings must be taken over time to assure that steady-state conditions exist.

Table 6.1 Variable Temperatures and Airflow Velocities

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

Weighted Average Temperature 97.74° F/36.52° C

Table 6.2 Variable Temperatures and Airflow Velocities

POSITION		A	B	C	D
1	Temperature	100°/38°	90°/32°	90°/32°	90°/32°
	Velocity	1000/5.0	1000/5.0	1000/5.0	1000/5.0
2	Temperature	105°/41°	100°/38°	90°/32°	90°/32°
	Velocity	1100/5.0	1000/5.0	1000/5.0	1000/5.0
3	Temperature	110°/43°	100°/38°	95°/35°	95°/35°
	Velocity	1000/5.0	1000/5.0	1000/5.0	1000/5.0
4	Temperature	110°/43°	100°/38°	90°/32°	90°/32°
	Velocity	1000/5.0	1000/5.0	1000/5.0	1000/5.0

Weighted Average Temperature 96.56° F/35.87° C

6.4.4 HYDRONIC TEMPERATURE MEASUREMENTS

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

6.5 FLOW MEASURING HOOD PROCEDURES

The following procedures describe the methods to be utilized when making air volume measurements with a flow measuring hood. While the procedures outlined here are prescriptive, instrumentation use will always be in accordance with the manufacturer's 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 of 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.

6.5.1.2 SPECIFIC MEASUREMENT TECHNIQUES

The flow measuring hood should be modified for the particular job. The large end of the cone should be sized to fit over the complete diffuser and should have a gasket around the perimeter to prevent air leakage. Some digital instruments have memory, averaging, and printing capabilities. Flow measuring hoods 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's 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. For exhaust/return applications, follow the manufacturer's recommended procedures.

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 imme-

diately 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 [Table 4.1: 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
- Bourdon Tube Pressure Gauge

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:

- The system and instruments shall be free of air and at proper pressures prior to balancing.
- Verify the range of the instrument to be used is appropriate for the system being tested and the type of measurements being taken.
- Verify the system pressures and temperatures do not exceed instrument rating.
- 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?
- 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 [Table 4.1](#).

[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

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:

- The system shall be free of air and the instrument purged of air before use.
- 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 used at all times. 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.
- 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 [Table 4.1. 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, site operations or maintenance staff must take the electrical readings for the NEBB CF. 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 wire is energized. De-energize wire and test for verification.
- g) Clamp meter jaws around the phase wire to be tested after the equipment is energized. (Inrush 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:
 - 1) T1 and T2
 - 2) T1 and T3
 - 3) 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% 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 the average value, calculated similarly to the voltage imbalance procedure, may indicate problems with the motor or power supply.

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

- j) In the preceding equations the power factor and efficiency values must be used to obtain the actual motor brake horsepower (kW). These values are typically difficult to obtain

and a reasonable estimate may be used. The normal range for both power factor (pf) and efficiency (eff) is between 80 and 90%. 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

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

*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.) 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.

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. 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 agent and owner.

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 the majority of 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.

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.

8.2.2 LIMITATIONS

Not all systems are covered in this section, only those most commonly 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) Record unit nameplate data as described in [Section 6](#).
- c) Confirm that all items affecting airflow of a duct system is ready for the TAB work, such as doors and windows closed, ceiling tiles (return air plenums) in place, transfer grilles in place, etc.
- d) Confirm that automatic control devices are complete, properly installed and the control system has been commissioned by others prior to starting the TAB work.
- e) Establish the conditions for design maximum system requirements.
- f) 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.
- g) 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.

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 outside 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 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% 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 in excess of 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.

8.3.7 100% OUTSIDE AIR CONDITION

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 $\pm 10\%$ 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) Set air outlet deflections as specified.
- 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) Adjust the damper, using a branch damper as the first choice and a face damper as the last resort, 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, $\pm 10\%$.
- 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 (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 or as necessary.
- 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 $\pm 10\%$ 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 or as necessary.
- 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) Verify the construction team responsibilities for system installation and startup as discussed in [Section 3](#) are complete.
- b) Record unit nameplate data as described in [Section 6](#).
- 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 air systems are to be balanced before adjusting barometric relief dampers.
- e) Verify that all manual branch and outlet volume dampers are locked 100% open.
- f) Verify correct rotation.
- g) Measure the motor operating amperage.
- h) Measure motor voltage.
- i) Confirm that the voltage and amperage matches the motor rating.
- j) Check for unusual noises indicating mechanical malfunction.
- k) Measure fan rpm and compare to design rpm.
- l) 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.*)
- m) 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.
- n) 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.*)
- o) Determine the AHU's design total static pressure (TSP) and/or external static pres-

sure (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.

- p) 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.
- q) Measure the AHU total air volume. A duct traverse is the most accurate method available. The sum of several traverses may be required.
- r) Adjust fan airflow to meet design requirements, if necessary.
- s) Determine the method for adjusting outlets – proportional or stepwise, and balance the inlets and outlets in accordance with the prescribed procedures.
- t) 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.
- u) At the conclusion of all inlet and outlet balancing, readjust the AHU minimum outside air ventilation rate, if required.
- v) 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 handling 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 are similar to 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: This type of terminal is available in either pressure dependent (PD) or pressure independent (PI) configuration. 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 matches 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 matches 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 of 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 matches 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 HVAC 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 [Section 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 of 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 of 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 DUAL DUCT SYSTEMS

The procedures to TAB variable volume dual duct systems are similar to 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 similar to those required for constant volume dual duct sys-

tems, and are to be adapted as necessary by the CP to conform to the particular 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:
 - 1. Perform a duct traverse.
 - 2. 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:

- f) Set the volume controller to design maximum airflow.
- g) Test the total airflow delivered by the terminal unit using one of the following methods:
 - 1. Perform a duct traverse.
 - 2. Total of air being delivered from the outlets.
- h) Calibrate the controller, by appropriate methods, to the measured airflow.
- i) Balance the outlets using either the proportional or the stepwise method.
- j) Set the volume controller to the design minimum airflow.
- k) 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):

- e) Set the terminal unit to the design maximum cooling set point.
- f) Set the fan speed to design airflow by measuring the outlet total airflow and comparing to design requirements.
- g) 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.
- h) Balance the air outlets using an appropriate method.
- i) Place the terminal unit to the minimum position and adjust the primary airflow to design requirements.
- j) Verify the heating airflow and report.
- k) 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.

8.11.4 DUAL DUCT TERMINAL UNITS (CONSTANT OR VARIABLE VOLUME)

It is not practical to cover all of 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:
 1. Perform a duct traverse.
 2. 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

carefully and completely specify 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 pulley sets, thus requiring pulley 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 pulley 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 crit-

ical). 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 as long as the final package

meets the horsepower 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 of 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 start-up, 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 (ERV) 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 are 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 system. The added effort required by the TAB CF is defining the flow across the exchanger and evaluating its performance.

There are two distinct types of energy recovery units:

8.16.2 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*.

8.16.3 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 procedures 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 in order 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.

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 by the use of calibrated flow measuring devices. Flow

measurement is accomplished by the use of 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 pre-planning is 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, m³/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 measure-

ments, 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 manufac-

turer 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.

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 $\pm 10\%$ 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 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 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 $\pm 10\%$.
- l) Re-measure all terminals and record final values.
- m) Mark or set all memory stops (see [Section 1](#)) on all of 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 (a) through (f) 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, $\pm 10\%$.
- 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 of 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 $\pm 10\%$ 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, $\pm 10\%$.
- j) Re-measure all terminals and record final values.
- k) Mark or set all memory stops (see [Section 1](#)) on all of 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, $\pm 10\%$.
- 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 of 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 pre-set 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 90% of the design terminal flow.

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. Insure 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 set-point 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) Conduct the basic pump testing and flow procedures as outlined previously. If the pump is controlled by a VFD, verify the pump is op-

erating at its rated speed. Caution should be used when conducting the required pump "wide open test" on a system with diversity. Insure that an overload condition cannot be reached.

- d) With the primary system off, conduct the basic pump testing and flow procedures on the secondary system as outlined previously.
- e) The terminals are balanced using either the stepwise or the proportional balancing methods described previously.
- f) 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.
- g) 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.
- h) After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.
- i) 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 dif-

ferential 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, in order 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 is 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 is 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 is specified by the manufacturer. Tolerances of +/-10% may not be suitable for all applications. 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 passive 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.
- e) 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.
- f) Take extra caution to avoid generating a false alarm call to the occupants or Fire Department.
- g) Confirm that the fan rotation is correct.
- h) Measure fan motor amperage and voltage.
- i) Verify that the motor is not overloaded.
- j) Verify that all appropriate stairwell pressurization fans and dampers operate according to the approved sequence of operation.
- k) Measure the pressure(s) from the stairwell to the reference point(s) as specified by the AHJ or the EOR.
- l) Adjust the fan speed, if required, to change the shaft pressurization to meet specified requirements.

- m) 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.
- n) If the stairwell is equipped with a relief damper(s), verify its operation and report discrepancies.
- o) 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.
- e) 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.
- f) Ensure testing will not generate a false call to the fire department.
- g) Confirm that the fan rotation is correct.
- h) Measure fan motor amperage and voltage.
- i) Verify that the motor is not overloaded.
- j) Verify that all appropriate elevator pressurization fans operate. If isolation dampers are present verify proper operation during the pressurization event.
- k) 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.
- l) 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.
- m) If required, adjust the fan speed to change the shaft pressurization to meet specified requirements.
- n) 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 in order 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 air flow 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's important to note that air stratification within HVAC units may inhibit accurate airflow temperature measurement. Mixed air temperatures may vary considerably 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 10-1 (U.S. and SI)

$$T_m = [(X_o T_o) + (X_r T_r)] / 100$$

Equation 10-2 (U.S. and SI)

$$X_o = 100 (T_r - T_m) / (T_r - T_o)$$

Equation 10-3 (U.S. and SI)

$$X_r = 100 (T_m - T_o) / (T_r - T_o)$$

Where: T_m = Temperature of mixed air - °F (°C)

X_o = % of outdoor air

T_o = Temperature of outdoor air - °F (°C)

X_r = % of return air

T_r = Temperature of return air - °F (°C)

PART 3.

APPENDICES

Appendix A.

SAMPLE PRE-TAB CHECKLIST

This sample checklist is provided by the TAB firm to the installing contractor for the contractor's use in verifying system readiness prior to balancing. (This recommended Pre-TAB checklist is available from www.nebb.org.)

Project:

1.HVAC Units & Built-Up Units	Ready		Date
	Yes	No	
a) GENERAL			
Louvers installed			
Manual dampers adjusted and locked			
Automatic dampers operating			
Housing construction complete			
Access doors closed			
Condensate drain piping and pan			
Free from dirt and debris			
b) FILTERS			
Type and size			
Number			
Clean			
Frame - Leakage			
Temporary			
c) COILS (HYDRONIC)			
Size and rows			
Fin spacing and condition			
Obstruction and/or debris			
Airflow and direction			
Piping leakage			
Correct piping connections and flow			
Valves open or set			
Air vents or steam traps			
Provisions made for TAB measurements			

	Ready		Date
	Yes	No	
d) COILS (ELECTRIC)			
Sizes and construction			
Airflow direction			
Duct connections			
Safety switches			
Contractors and disconnect switches			
Electrical service and connections			
Obstruction and/or debris			
e) FANS			
Rotation			
Wheel clearance and balance			
Bearing and motor lubrication			
Drive alignment			
Belt tension			
Drive set screws tight			
Belt guard in place			
Flexible duct connector alignment			
Starters and disconnect switches			
Electrical service and connections			
VFD set up for correct operating frequency			
f) VIBRATION ISOLATION			
Springs and compression			
Base level and free (remove shipping bolts, screws and brackets)			

Project:

2. DUCT SYSTEMS	Ready		Date
	Yes	No	
a) GENERAL			
Manual dampers adjusted and locked			
Access doors closed and tight			
Fire dampers open and accessible			
Terminal units open or set			
Registers and diffusers open and set			
Turning vanes in square elbows			
Provisions made for TAB measurements			
Ductwork sealed as required			
b) ARCHITECTURAL			
Windows installed and closed			
Doors closed as required			
Ceiling plenums installed and sealed			
Access doors closed and tight			
Air shafts and openings as required			
3. PUMPS			
a) MOTORS			
Rotation			
Lubrication			
Alignment			
Set screws tight			
Guards in place			
Starters and disconnect switches			
Electrical service and connections			

	Ready		Date
	Yes	No	
b) PIPING			
Correct flow and connections			
Leakage			
Valves open or set			
Strainer clean			
Air vented			
Flexible connectors			
Cavitation possibilities			
c) BASES			
Vibration isolation			
Grouting			
Leveling			
4. HYDRONIC EQUIPMENT			
a) BOILERS			
Operating controls and devices			
Safety controls and devices			
Lubrication of fans and pumps			
Draft controls and devices			
Piping connections and flow			
Valves open or set			
Water make-up provisions			
Blow-down provisions			
Electrical connections			
b) HEAT EXCHANGERS			
Correct flow and connections			
Valves open or set			
Air vents or steam traps			
Leakage			
Provisions made for TAB measurements			

Project:

	Ready		Date
	Yes	No	
c) COOLING TOWERS AND EVAPORATIVE CONDENSERS			
Correct flow and connections			
Valves open or set			
Leakage			
Provisions made for TAB measurements			
Sump water level			
Spray nozzles			
Fan/pump rotation			
Motor/fan lubrication			
Drives and alignment			
Guards in place			
Starters and disconnect switches			
Electrical connections			
5. Refrigeration Equipment			
Crankcase heaters energized			
Operating and safety controls and devices			
Valves open or set			
Piping connections and flow			
Flexible connectors			
Oil level and lubrication			
Guards in place			
Vibration isolation			
Starters, contactors and disconnect switches			
Electrical connections			

6. Hydronic Piping Systems	Ready		Date
	Yes	No	
Leak tested and flushed			
Fluid levels and make-up			
Relief or safety valve settings			
Compression tanks/air vented			
Steam traps and connections			
Strainers clean			
Valves open or set			
Provisions made for TAB measurements			
7. Control Systems			
Data centers operating			
Outdoor/return dampers set			
Economizer controls set			
Static pressure control set			
Space controls operating			
Complete system operating			
8. Other Checks			
a) Other trade or personnel notified of TAB work requirements			
b) Preliminary data complete			
c) Test report forms prepared			

Appendix B. SAMPLE TAB SPECIFICATION

(This recommended TAB specification is available from www.nebb.org.)

NEBB recommends that these TAB Specifications be referenced as related documents in other appropriate sections of the project specifications as defined in [Section 1](#).

SECTION 230593: TESTING, ADJUSTING AND BALANCING

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification sections, apply to this Section.

This Section includes testing, adjusting and balancing to produce design flows for the following:

1. Air Systems:
 - a. Constant-volume air systems.
 - b. Dual-duct systems.
 - c. Variable-air-volume systems.
 - d. Multizone systems.
 - e. Induction-unit systems.
2. Hydronic Systems
 - a. Constant-flow systems
 - b. Variable-flow systems
 - c. Primary-secondary systems
3. Kitchen hood systems
4. Fume hoods and Bio-Safety cabinet systems
5. Exhaust hood systems
6. Space pressurization
7. Shaft pressurization systems
8. Existing HVAC systems

1.2 DEFINITIONS

Absolute Value: The numerical value without regard to its sign. For example, the absolute value of 3 is 3, and the absolute value of -3 is also 3.

Acceleration: The vector quantity that specifies the time rate of change of velocity.

Accuracy: The capability of an instrument to indicate the true value of a measured quantity.

Adjusting: The varying of system flows by partially closing balancing devices, such as dampers and valves, and varying fan speeds to achieve optimum system operating conditions within design and installation limitations.

AHJ: Authority Having Jurisdiction is the local governing authority having jurisdiction over a designated portion of the project.

Air Change Rate (also referred to as Air Changes per Hour or ACH): The number of times the total air volume of a defined space is replaced in a given unit of time. Ordinarily computed by dividing the total volume of the subject space into the total volume of air supplied to or exhausted from the space per unit of time. (*Supply air volume is used to calculate ACH in rooms requiring a positive pressure. Exhaust air volume is used to calculate ACH in rooms requiring a negative pressure.*)

Air Exchange Rate: Air exchange rate is the rate at which outdoor air replaces indoor air within a given space or room.

AHU: Air Handling Unit

Balancing: The methodical proportioning of air and hydronic flows through the system mains, branches, and terminal devices using acceptable procedures to achieve the specified airflow or hydronic flow within installation, testing and design limitations.

Calibrate (Calibration): The act of comparing an instrument of unknown accuracy with a standard of

known accuracy to detect, correlate, report, or correct by adjustment unacceptable variation in the accuracy of the tested instrument.

Conformed Contract Documents: Current and complete documents.

Corrective Action: Repairing, replacing, re-building, calibrating or adjusting of equipment or systems.

Deficiency: Any installation, measurement, or finding outside the tolerances allowed by *NEBB Procedural Standard* or project specifications.

Differential Pressure (ΔP): The difference between two pressures measured with respect to the same reference pressure.

Diffuser: Outlet designed to mix supply air and room air, and to distribute it in varying directions (may or may not have an integral damper).

Diversity: In air or hydronic systems, diversity is the term used to describe the difference in air or water volume between the prime mover (fan or pump) and the terminal elements. An example would be a fan system where the fan is sized for 85% of the total air flow at the terminals. In this example, the diversity would be represented as 85% diversity.

DX: Direct Expansion refrigerant type system.

Embedded Motor: Any motor that is inaccessible without disassembling the equipment it is mounted in. (Examples: cassette ductless units, Fan Powered VAV, VRF fan coil units, direct drive ceiling exhaust fans, etc.)

EOR: Engineer Of Record. The engineer responsible for project plans and specifications.

Environmental Systems: Systems using a combination of mechanical equipment, airflow, water flow and electrical energy to provide heating, ventilating, air conditioning, humidification, and dehumidifica-

tion for the purpose of human comfort or process control of temperature and humidity.

Equal Area Method: Term used to describe the more common method of duct traversing by averaging velocity readings taken from the center of equal areas of the duct cross-section.

ESP: External Static Pressure.

Face Velocity: The average velocity of air moving perpendicular to the hood face, usually expressed in feet per minute (fpm) or meters per second (m/s).

Fenestration: Any opening in a building structure such as windows, skylights, window walls, doors, louvers, and access panels.

Function: The particular type of data measurement specified in *NEBB Standard for Instrumentation and Calibration*.

GRD: An acronym referring to Grilles, Register and Diffusers (see individual definitions).

Grille: Louvered or perforated face over an opening with no balancing damper integral to the device.

High Efficiency Particulate Air Filter (HEPA): An extended media, dry-type filter in a rigid frame having a minimum particle-collection efficiency of 99.97 percent for 0.3 micron particulate at a rated airflow.

IP: Inch/Pound Term used to describe measurement system used in the United States and elsewhere.

Log Tchebycheff Method or Log-T: An alternate approved method of laying out a duct traverse as opposed to the Equal Area Method.

Memory Stop: An adjustable mechanical device that allows a valve to be closed (for service) and limits the valve to a predetermined position when re-opened.

Micron: A unit of measurement equal to one-millionth of a meter or approximately 0.00003937 inch. (25 microns are approximately 0.001 inch).

NEBB Certified TAB Report: The data presented in a NEBB Certified TAB Report accurately represents system measurements obtained in accordance with the current edition of the *NEBB Procedural Standard for Testing, Adjusting, and Balancing of Environmental Systems*. A NEBB Certified TAB Report does not necessarily guarantee that systems included are balanced to design flows. Any variances from design quantities, which exceed NEBB tolerances or contract document tolerances, are noted in the test-adjust-balance report project summary.

NEBB Certified TAB Firm (CF): A firm that has met and maintains all the requirements of NEBB for firm certification in Testing, Adjusting, and Balancing and is currently certified by NEBB. A CF shall employ at least one NEBB Certified TAB Professional on staff.

NEBB Certified Professional (CP): An individual who has successfully passed the professional level certification examinations and maintains the CP re-certification requirements of NEBB.

NEBB Certified Technician (CT): An employee of the firm who has met the technician level experience requirements of NEBB and has successfully passed the technician level certification examinations. A CT shall be supervised by a NEBB Certified TAB Professional.

NEBB Procedural Standard for Testing, Adjusting and Balancing of Environmental Systems (Procedural Standard): A NEBB publication that outlines responsibilities, instrument standards, report requirements, measurement procedures and job performance expectations for the CF, CP and CT.

NPSH: Net Positive Suction Head.

OA: Outside Air.

Phase: To schedule or order activities so as to be available or complete when, or as, needed.

Point-to-Point Verification: This activity confirms a specific sensor or device is paired and connected to the proper controller.

Potable Water: Water that is satisfactory for drinking, culinary and domestic purposes and that meets the requirements of the Health Authority Having Jurisdiction.

Precision: The ability of an instrument to produce repeatable readings of the same quantity under the same conditions. The precision of an instrument refers to its ability to produce a tightly grouped set of values around the mean value of the measured quantity.

Procedure: A defined approach that outlines the execution of a sequence of work or operations. Procedures are used to produce repeatable and defined results.

QAP: Quality Assurance Program.

RA: Return Air. Sometimes used to designate Relief Air.

Range: The upper and lower limits of an instrument's ability to measure values for which the instrument is calibrated.

Recommended: Testing procedures, measurements, and/or data gathering, whether included in the certified report or otherwise, that enables further diagnostic review and troubleshooting above and beyond the requirements for report certification.

Register: Combination grille and damper assembly.

Resolution: The smallest change in a measured variable that an instrument can detect; the implementation of actions that correct a tested or observed deficiency.

Required: Designates any data, function or action that must be gathered or performed to qualify as a NEBB certified report, unless such data is impossi-

ble to gather or a given function or action cannot be performed. Any information or action that cannot be fulfilled in accordance with this *Procedural Standard* must be clearly explained in the final report summary.

RPM: Revolutions Per Minute.

RTU: Roof Top Unit.

SA: Supply Air.

Shaft Pressurization System: A type of smoke-control system intended to positively pressurize stair and elevator shafts with outdoor air by using fans to keep smoke from contaminating the shafts during an alarm condition.

Shutoff Head: Term used to describe the dynamic measurement of a pump's total dynamic head at no flow. Performed by closing the pump discharge valve only.

SI: International System of Units (*Système international d'unités*), the modern international standard version of the metric system.

Smoke-Control System: An engineered system that uses fans to produce airflow and pressure differences across barriers to limit smoke movement.

Smoke-Control Zone: A space within a building that is enclosed by smoke barriers and is a part of a zoned smoke-control system.

Stairwell Pressurization System: A type of smoke-control system that is intended to positively pressurize stair towers with outdoor air by using fans to keep smoke from contaminating the stair towers during an alarm condition.

Static Head: The pressure due to weight of fluid above the point of measurement. In a closed system, static head is equal on both sides of the pump.

Static Pressure (SP): In an HVAC System, the potential energy a system possesses at the point of measurement to produce and maintain fluid flow against system resistance. Can be positive or negative relative to the appropriate reference pressure.

Static Test: Test or inspection that validates a specified static condition such as pressure testing. Static tests may be specification or code initiated.

Suction Head: The height of fluid surface above or below the centerline of a pump on the suction side.

System Effect: A phenomenon that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system. System Effect cannot be measured directly, but can be estimated.

TDH: Total Dynamic Head. The total equivalent height that a fluid is to be pumped, taking into account friction losses in the pipe.

Terminal Device: A point where the controlled medium enters or leaves the distribution system (air side; grille, register or diffuser) (hydronic side; heat transfer elements such as coils, radiant panels, chill beams, etc.).

Terminal Unit: A device that regulates the amount and/or the temperature of the controlled medium.

Test Procedure: A written protocol that defines methods, personnel, and expectations for tests conducted on components, equipment, assemblies, systems, and interfaces among systems.

Testing: The use of specialized and calibrated instruments to measure parameters such as temperature, pressure, vapor flow, airflow, fluid flow, fluid quantities, rotational speed, electrical characteristics, velocity, sound and vibration level, air and hydronic quantities, and other data in order to determine performance, operation, or function.

Testing, Adjusting and Balancing (TAB): A systematic process or service applied to HVAC systems,

and other environmental systems, to achieve and document air and hydronic flow rates.

Total Pressure (TP): The sum of static pressure and velocity pressure at the point of measurement in the system ($TP = SP + VP$). Value may be positive or negative.

TSP: Total Static Pressure.

Troubleshooting: Procedural activities for investigating a specific fault or failure of a system or piece of equipment.

VAV: Variable Air Volume.

Velocity: The vector quantity that specifies the time rate of change of displacement.

Velocity Pressure (VP): The kinetic energy of flow exerted only in the direction of flow. Velocity pressure cannot be measured directly. It is the difference between total pressure and static pressure at the point of measurement.

Zone: A volume of building served by a single ventilation system. For buildings with natural ventilation only, the whole building is considered a zone.

1.3 TAB FIRM QUALIFICATIONS

The TAB firm shall be NEBB Certified in Testing, Adjusting and Balancing of Air and Hydronic Systems.

1.4 TAB FIRM SUBMITTALS

1.4.1 Qualification Data:

When requested, submit 2 copies of evidence that TAB firm and this Project's TAB team members meet the qualifications specified in [Section 1.3 TAB Firm Qualifications](#).

1.4.2 TAB Agenda:

When requested, submit two copies of the TAB Agenda. Include a complete set of report forms intended for use on the project.

1.4.3 Certified TAB Reports:

Submit a final TAB report in accordance with the current edition of the NEBB *Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems (Procedural Standards)*.

1.5 QUALITY ASSURANCE

1.5.1

The NEBB Certified TAB Firm (CF) shall submit two copies of the firm's NEBB TAB Certification.

1.5.2

When requested, the CF shall furnish the NEBB Certificate of Conformance Certification.

1.5.3 TAB Report Forms:

Prepare report forms in accordance with the requirements from the current edition of the *Procedural Standards*.

1.5.4 Instrumentation Calibration:

Calibration of instruments shall be in accordance with the current edition of the *Procedural Standards*.

1.6 CONSTRUCTION TEAM RESPONSIBILITY TO TAB AGENCY

1.6.1

Provide the NEBB CF with a conformed set of contract documents (drawings, specifications, and approved submittals), including all current approved change orders/contract modifications.

1.6.2

Develop a project schedule with the input of the CF that coordinates the work of other disciplines and provides adequate time in the construction process to allow successful completion of the TAB work.

1.6.3

Notify the NEBB Certified TAB Firm of schedule changes.

1.6.4

Ensure that the building enclosure is complete, including but not limited to, all structural components, windows and doors installed, door hardware com-

plete, ceilings complete, stair, elevator and mechanical shafts complete, roof systems complete, all plenums sealed, etc.

1.6.5

Ensure that all necessary mechanical work is complete. This includes, but is not limited to, duct leakage testing and hydrostatic testing. The piping systems should be flushed, filled, vented, and chemically treated. The duct systems and equipment have been cleaned.

1.6.6

Complete the installation of permanent electrical power systems serving the HVAC equipment and systems. Such systems shall be properly installed in accordance with all applicable codes to ensure the safety of all construction personnel.

1.6.7

Complete the installation of all HVAC equipment and systems to ensure safe operation.

1.6.8

Perform the startup of all HVAC equipment and systems in accordance with the manufacturer's recommendations.

1.6.9

Complete installation, programming (including design parameters and graphics), calibration, and start-up of all building control systems.

1.6.10

Verify that the building control system provider has commissioned and documented their work before the TAB work begins.

1.6.11

Require that the building control system firm provide access to hardware and software, or onsite technical support required to assist the TAB effort. The hardware and software or the onsite technical support shall be provided at no cost to the CF.

1.6.12

Furnish and install all drive changes as required.

PART 2 – PRODUCTS (NOT APPLICABLE)

PART 3 – EXECUTION

3.1 EXAMINATION

Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems' designs that may preclude proper TAB of systems and equipment. *Contract Documents* are defined in the General and Supplementary Conditions of Contract.

3.1.1

Verify that balancing devices, such as test ports, gauge cocks, flow-control devices, balancing valves and fittings, and manual volume dampers, are required by the Contract Documents. Verify that quantities and locations of these balancing devices are accessible and appropriate for effective balancing and for efficient system and equipment operation.

3.1.2

Examine approved submittal data of HVAC systems and equipment.

3.1.3

Examine HVAC system and equipment installations to verify that indicated balancing devices, such as test ports, gauge cocks, flow-control devices, balancing valves and fittings, and manual volume dampers, are installed, and that their locations are accessible and appropriate for effective balancing and for efficient system and equipment operation.

3.1.4

Examine systems for functional deficiencies that cannot be corrected by adjusting and balancing.

3.1.5

Report deficiencies discovered before and during performance of TAB procedures. Record default set points if different from indicated values.

3.2 GENERAL PROCEDURES FOR TESTING AND BALANCING

3.2.1

Perform testing and balancing procedures on each system according to the procedures contained in the current edition of the NEBB *Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems (Procedural Standards)* and this section.

3.2.2

Mark equipment and balancing device settings (including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices) with paint or other suitable permanent identification material to show final settings.

3.3 PROCEDURES FOR TESTING, ADJUSTING, AND BALANCING EXISTING SYSTEMS

Perform TAB of existing systems to the extent indicated by the contract documents and the current edition of the NEBB *Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems (Procedural Standards)*.

3.4 ACCEPTANCE CRITERIA

The systems will be considered balanced in accordance with *Procedural Standards* when the following conditions are satisfied:

3.4.1

All measured airflow and hydronic flow quantities are within $\pm 10\%$ of the design quantities unless there are reasons beyond the control of the CF. Deficiencies shall be noted in the TAB report.

3.4.2

There is at least one direct 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.

3.4.3

There is at least one direct path with fully open balancing valves from the pump discharge balancing

valve (if present) 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.

3.5 REPORTING

Provide appropriate deficiency information to the construction team as TAB work progresses. Deficiency information is sufficient to facilitate contractor's dispatch of appropriate personnel to resolve items noted prior to final TAB work.

3.6 FINAL REPORT

The final report is in accordance with the requirements of the current edition of the *Procedural Standards*.



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