PROCEDURAL STANDARDS FOR TESTING ADJUSTING AND BALANCING OF ENVIRONMENTAL SYSTEMS

2005 – SEVENTH EDITION

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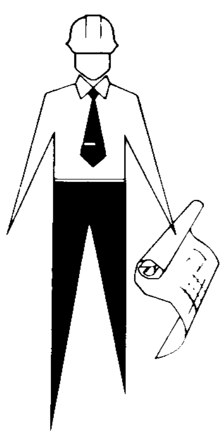

2005 – SEVENTH EDITION

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PROCEDURAL STANDARDS FOR TESTING, ADJUSTING, AND BALANCING OF ENVIRONMENTAL SYSTEMS

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These Procedural Standards were developed using reliable engineering principles and research plus consultation with, and information obtained from, manufacturers, users, testing laboratories and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable. System balancing, which complies with these Procedural Standards, will not necessarily be acceptable, if when examined and tested, it is found to have other features that impair the result intended by these standards. The National Environmental Balancing Bureau assumes no responsibility and has no liability for the application of the principles or techniques contained in these Procedural Standards. Authorities considering adoption of these Procedural Standards should review all Federal, State, local and contract regulations applicable to the specific installation.

FOREWORD

The purpose of the NEBB *Procedural Standards for Testing Adjusting and Balancing of Environmental Systems* is to establish 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 indoor environments. These conditions could not exist without sophisticated mechanical systems created by a team of skilled professionals. A key member of this team is the NEBB Certified Test, Adjust, and Balance (TAB) Firm.

This Seventh Edition represents a departure from past editions and is divided into two distinct Parts: S*tandards* and *Procedures*. These TAB procedural standards have been developed using language defined by **"*Shall, Should, and May*"** as it relates to the standards and procedures described in this manual. It is important to note these particular words throughout this manual and how they pertain to the NEBB standards and procedures.

These standards and procedures are intended as the minimum NEBB requirements that a NEBB Certified TAB Firm shall follow when performing Testing, Adjusting, and Balancing procedures. Contract documents may supercede the NEBB requirements. These TAB Procedural Standards have been carefully compiled and reviewed by the NEBB Technical Committees.

Part 1 STANDARDS

Part 1, STANDARDS, covers the requirements for Quality Control and Compliance, Instrumentation Requirements, and TAB Reports. Revised requirements for TAB instruments and reports are identified. The new report requirements allow the NEBB Certified Firm more flexibility in designing their reports by prescribing sets of information that ***"Shall, Should*** and/or ***May"*** be required to complete a TAB Report.

Part 2 PROCEDURES

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

APPENDICES

The Appendices include an overview of TAB Instrumentation, a Pre–TAB Checklist, and a suggested TAB Specification.

This Seventh Edition of the TAB Procedural Standards, when used by NEBB Certified TAB Firms, will assure the building owner or operator a properly balanced environmental system within design and installation limitations.

Andrew P. Nolfo, P.E.
NEBB Technical Director

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PART 1 - STANDARDS

SECTION 1 DEFINITIONS

These procedural standards have been developed using language defined by "Shall, Should, and May" as it relates to the standards and procedures described in this publication. It is important to note these particular words throughout this publication and how they pertain to NEBB standards and procedures.

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

Adjusting: *Adjusting* is 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: The local governing **A**uthority **H**aving **J**urisdiction over the installation.

Balancing: *Balancing* is 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 testing and design limitations.

Calibrate: The act of comparing an instrument of unknown accuracy with a standard of known accuracy to detect, correlate, report, or eliminate by adjustment any variation in the accuracy of the tested instrument.

Conformed Contract Documents: Current and complete documents.

Contract Document Review: A NEBB Qualified TAB Firm review of the contract plans and specifications is limited to determining the proper placement of balancing devices. A NEBB Qualified TAB Firm is ***not*** responsible for the review of equipment sizing, design load calculations or any other engineering function that is properly the responsibility of the design professional.

Deficiency: *Deficiency* is considered any circumstance that adversely affects the specified balance of a device or system.

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

Environmental Systems: *Environmental Systems* are systems that primarily use 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.

Function: For the purposes of this NEBB Standard, *function* refers to the specific type of data measurement specified in Table 4-1 of Section 4, *Standards for Instrumentation and Calibration.*

May: The word **may** is used to indicate a course of action that is permissible as determined by the NEBB Certified TAB Firm.

Memory Stop: A memory stop is an adjustable mechanical device that allows a valve to be closed (for service), and limits the valve to a predetermined position when re-opened.

NEBB Certified TAB Firm: A *NEBB Certified TAB Firm* is a firm that has met and maintains all the requirements of the National Environmental Balancing Bureau for firm certification in Testing, Adjusting, and Balancing and is currently certified by NEBB. A NEBB Certified TAB Firm shall employ at least one NEBB Qualified TAB Supervisor in a full time management position.

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 Standards 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 Qualified TAB Supervisor: A *NEBB Qualified TAB Supervisor* is a full time employee of the firm in a management position who has successfully passed the supervisor level written and practical qualification examinations and maintains the Supervisor re-qualification requirements of NEBB.

NEBB Qualified TAB Technician: A *NEBB Qualified TAB Technician* is a full time employee of the firm who has met the technician level experience requirements of NEBB and has successfully passed the technician level written and practical qualification examinations. A NEBB Qualified TAB Technician shall be supervised by a NEBB Qualified TAB Supervisor. (Supervision is not intended to infer constant oversight. A NEBB Qualified TAB Technician is capable of performing assigned tasks with periodic supervision.)

Precision: *Precision* is 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 *Procedure* is defined as the approach to and execution of a sequence of work operations to yield a repeatable and defined result.

Range: *Range* is the upper and lower limits of an instrument's ability to measure the value of a quantity for which the instrument is calibrated.

Resolution: *Resolution* is the smallest change in a measured variable that an instrument can detect.

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

Shall: The word **shall** is used to indicate mandatory requirements to be followed strictly in order to conform to the standards and procedures and from which no deviation is permitted. Note: In the event unique circumstances prevent a required action from being fulfilled, a notation shall be included in the TAB report explaining the exception. For example, such notation could be one of the following: *Not Available, Not Applicable, or Not Accessible.* The simple notation "N/A" without definition is not allowed.

Should: The word **should** is used to indicate that a certain course of action is preferred but not necessarily required.

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.

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

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

Standard: A *Standard* is defined as a required qualification, action, or result for TAB work.

Suction Head: The height of fluid surface above 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 it can be estimated.

TAB Technician: A *TAB Technician* is an employee of a TAB firm who assists a NEBB Qualified TAB Supervisor and/or a NEBB Qualified TAB Technician by performing TAB work in the field. (Supervision is not intended to infer constant oversight. A NEBB TAB Technician may be capable of performing assigned tasks without direct, full time supervision.)

Terminal: A point where the controlled medium enters or leaves the distribution system (e.g., a grill or diffuser).

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

Testing: *Testing* is the use of specialized and calibrated instruments to measure temperatures, pressures, rotational speeds, electrical characteristics, velocities, and air and hydronic quantities for an evaluation of flow conditions.

Testing, Adjusting, and Balancing (TAB): TAB is a systematic process or service applied to heating, ventilating and air-conditioning (HVAC) systems and other environmental systems to achieve and document air and hydronic flow rates. The standards and procedures for providing these services are referred to as *"Testing, Adjusting, and Balancing"* and are described in this document.

Total Pressure (TP): *Total pressure* is the sum of the static pressure and the velocity pressure at the point of measurement in the system. **(TP = SP + VP).**

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

SECTION 2 NEBB PROGRAM, QUALITY CONTROL AND COMPLIANCE

2.1 NEBB PROGRAMS

The National Environmental Balancing Bureau (NEBB) is a not-for-profit organization founded in 1971 to:

a) develop standards, procedures and programs for the performance of testing, balancing and commissioning of building systems,
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 with integrity.

Additional information on NEBB Programs 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) Testing-Adjusting-Balancing (TAB) -- Air and Hydronic Systems
b) Sound and Vibration (S&V) Measurement
c) Cleanroom Performance Testing (CPT)
d) Building Systems Commissioning (BSC)

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

2.1.2 FIRM CERTIFICATION

NEBB certifies firms that meet certain criteria, ensuring strict conformance to its high standards and procedures. Among other requirements, NEBB Certified Firms must document a record of responsible performance, own a complete set of instruments required for the sophisticated techniques and procedures necessary to "fine-tune" modern environmental systems, and have a NEBB Qualified Supervisor as a full-time employee.

2.1.3 SUPERVISOR QUALIFICATION

NEBB also establishes professional qualifications for the supervision and performance of work in its various disciplines. NEBB Qualified Supervisors must have extensive experience, and they must pass appropriate, college-level written examinations and demonstrate certain practical working knowledge and proficiency in the use of instruments required for the various disciplines.

2.1.4 TECHNICIAN QUALIFICATION

NEBB also qualifies technicians who must possess certain background and experience as well as pass rigorous written and practical examinations. For example, NEBB Qualified TAB Technician status is maintained by continued employment with a NEBB Certified TAB Firm, and the Technician must perform a minimum number of hours of TAB work each year.

2.1.5 RECERTIFICATION REQUIREMENTS

Through the recertification procedures, the firm must verify that its NEBB Qualified Supervisor is still on staff and that it continues to own a complete set of instruments that are in current calibration. In addition, the firm's NEBB Qualified Supervisor renews his or her qualification. Among other requirements, Supervisors must keep abreast of developments in their discipline by attending and successfully completing continuing education seminars annually.

2.2 QUALITY ASSURANCE PROGRAM - CONFORMANCE CERTIFICATION

The credibility of NEBB is built by maintaining integrity through high standards, quality programs, and demonstrated capabilities of its certified firms. 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 Certification is an integral element of the program. It assures that the NEBB Certified Firm will perform specified services in conformity with the current applicable NEBB Procedural Standards.

2.2.1 PROGRAM ADVANTAGES

The NEBB Quality Assurance Program 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 NEBB standards and procedures.

2.2.2 NEBB QUALITY ASSURANCE PROGRAM CERTIFICATE

The NEBB Certified TAB Firm shall make application to the NEBB Office for a Certificate of Conformance Certification if specified in the contract documents. The NEBB Quality Assurance Program Conformance Certification is also available for any project.

2.3 QUALITY CONTROL AND COMPLIANCE

Building owners are entitled to a professional service by every NEBB Certified Firm on every project, whether the job is NEBB-specified or not. It is the responsibility of the NEBB Certified Firm and its NEBB Qualified Supervisor to establish and maintain procedures and practices that will assure a consistent pattern of high quality work on all projects. This point cannot be overemphasized.

2.3.1 TAB WORK COMPLIANCE

The scope of work shall be performed as specified in the Test, Adjust, and Balance (TAB) specifications or as contractually amended. Each relevant or applicable item as identified in the contract documents by description, or by reference, shall be performed and recorded in the TAB report. Data presented in a TAB report shall provide an accurate quantitative record of system measurements and information.

Regardless of what is specified, in all cases the process by which the data is acquired shall conform to the current edition of the NEBB *Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems*.

References to desired procedures may include statements such as "the work will be performed in accordance to NEBB Standards." When specifications indicate that the TAB work shall be performed in accordance with NEBB standards, the TAB procedures will conform to the current edition of the NEBB *Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems.*

2.4 TAB SUPERVISOR RESPONSIBILITIES

It is the responsibility of the NEBB Qualified TAB Supervisor to control the quality of the TAB work. This means that the NEBB TAB Certified Firm, through its NEBB Qualified TAB Supervisor, shall satisfy the contract obligations set forth in the drawings and applicable specifications.

2.4.1 EXECUTION OF TAB PROCEDURES

The NEBB Qualified TAB Supervisor shall have project responsibility, which includes authority to represent the NEBB Certified TAB Firm. Examples of project responsibility may include labor decisions, negotiating change orders, committing to contract interpretations and implementing changes in job schedules.

The NEBB Qualified TAB Supervisor has the responsibility to assure that the systems have been tested, adjusted, and balanced in accordance with these Procedural Standards 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 TECHNICIAN TRAINING

The NEBB Qualified TAB Supervisor has a responsibility to assure that technicians performing the work are properly trained and possess sufficient skills. Areas that should be stressed are TAB procedures, instrument use and maintenance, coordination and supervision, and project communication.

2.4.3 TAB PROCEDURES TRAINING

NEBB Qualified TAB Technicians must be prepared to completely measure and record data in the manner specified. It is mandatory that NEBB Qualified TAB Technicians possess the ability to perform the specific tasks and procedures required for each project. An understanding of HVAC system fundamentals and operating characteristics is important, and technicians should possess rudimentary knowledge of all related systems and procedural considerations. This may require periodic training to promote knowledge and skill development as well as to facilitate the transfer of knowledge and basic skills in the use of new technology.

2.4.4 INSTRUMENT USE and MAINTENANCE

NEBB Qualified TAB Technicians shall possess knowledge and skill in the proper use and care of instruments required to perform the work. This shall include 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.

2.4.5 COORDINATION / SUPERVISION

The NEBB Qualified TAB Supervisor shall be responsible for directing technicians in performing the work. Instructions may delineate items such as the scope of work, location of Pitot tube traverses, dampers, outlets, equipment, balancing devices, etc. so that field personnel may know exactly what to do and what is required of them.

2.4.6 PROJECT COMMUNICATION

The NEBB Qualified TAB Supervisor shall report on progress made toward work completion, when required, as well as report and address problems if encountered. When a problem exists, the NEBB Qualified TAB Supervisor should notify the appropriate project personnel. The NEBB Qualified TAB Supervisor may provide input as to the cause of the problem and recommend possible solutions.

2.4.7 WORK COMPLETION

The NEBB Qualified TAB Supervisor shall determine when the testing and balancing work has been completed, and when to submit the TAB report. Generally, the specified TAB work is complete when:

a) All HVAC systems and components are tested and balanced within acceptable tolerances;

or

b) Reasonable efforts within the extent of testing, adjusting, and balancing have been performed in an effort to achieve acceptable system performance. The NEBB Qualified TAB Supervisor shall notify the appropriate project personnel of any significant system deficiencies preventing balancing or balancing within tolerances before the final report is submitted. Any variances from design quantities, which differ from NEBB tolerances, shall be noted in the project summary in the TAB report.

2.4.8 COMPILATION AND SUBMISSION OF FINAL TAB REPORTS

Reports shall include information and data to provide an accurate quantitative record of system measurements and information. Reports also shall include notes and comments, as appropriate, to provide the reviewer with additional details related to the test procedure, system operation and results. Reports shall meet the criteria listed in Sections 5 and 6.

The certification page shall bear the stamp of the NEBB Qualified TAB Supervisor. The stamp on the certification page shall be signed as evidence that the NEBB Qualified TAB Supervisor has personally reviewed and accepted the report. *Signature stamps are specifically prohibited.*

SECTION 3 RESPONSIBILITIES

3.1 INTRODUCTION

Many approaches can be taken to deliver a successful TAB project. In order to maximize value and benefits from a system balance, it is important to understand that the design professionals and other construction team members have responsibilities that will affect the outcome of the TAB process.

3.2 DESIGN AND CONSTRUCTION TEAM RESPONSIBILITIES

3.2.1 DESIGN PROFESSIONALS RESPONSIBILITIES

It is recommended that the contract documents shall:

a) Specify the equipment and systems to be tested, adjusted, and balanced, the parameters to be measured and the acceptable tolerances. NEBB standards and procedures define industry best practices to perform the TAB.

b) Define who retains the services of the NEBB Certified TAB Firm and require that the NEBB Certified TAB Firm be retained early in the construction process.

c) Clearly identify on the mechanical plans the system components 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 building and / or HVAC control system firm commission and document their work before the TAB work begins.

e) Specify that the building control system firm provides 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 NEBB Certified TAB Firm.

f) Provide adequate access to all equipment and components required by the TAB process.

g) Completely define commissioning support responsibilities for the NEBB Certified TAB Firm.

3.2.2 CONSTRUCTION TEAM RESPONSIBILITIES

It is recommended that the construction team shall:

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a) Provide the NEBB Certified TAB Firm 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 NEBB Certified TAB Firm, that coordinates the work of other disciplines and provides *adequate* time in the construction process to allow successful completion of the TAB work.

c) Notify the NEBB Certified TAB Firm of ***all*** schedule changes.

d) Ensure that the building enclosure is complete, including but not limited to, all structural components, windows and doors installed, door hardware complete, ceilings complete, stair, elevator and mechanical shafts complete, roof systems complete, all plenums sealed, etc.

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 and hydrostatic testing. The piping systems should be flushed, filled, vented, and chemically treated. 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 the NEBB pre-TAB checklist in the Appendix.

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

g) Perform start up 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 balancing begins

i) 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 NEBB Certified TAB Firm.

j) Furnish and install all drive changes as required.

3.2.3 NEBB CERTIFIED TAB FIRM RESPONSIBILITIES

The NEBB Certified TAB Firm shall:

a) Follow the current NEBB standards and procedures when performing the TAB work.

b) Communicate on a regular basis, through proper channels, items relating to design, installation, or function that prevent the NEBB Certified TAB Firm from achieving completion of the TAB work in accordance with the current edition of the NEBB *Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems.*

c) Perform the specified commissioning support requirements.

d) Publish a NEBB Certified TAB Report of final conditions that accurately reflect the HVAC system(s) final air and hydronic flow conditions.

SECTION 4 STANDARDS FOR INSTRUMENTATION AND CALIBRATION

4.1 MINIMUM INSTRUMENTATION

A NEBB Certified TAB Firm will use a variety of instrumentation to perform the specified TAB procedures on a project. It is the responsibility of the NEBB Certified TAB Firm to provide appropriate instrumentation that meets the minimum requirements of TABLE 4-1 (US or SI) for use on a project. Instrumentation used on a NEBB project shall be in proper operating condition and shall be applied in accordance with the manufacturer's recommendations. TABLE 4-1 (US or SI) lists the minimum instrumentation that a NEBB Certified TAB Firm shall own and maintain.

NEBB does not currently allow certification in only one discipline (i.e. Air *or* Hydronic TAB Certification). However prior to 1999, firms were allowed to be certified in only one discipline and not in the other. A firm certified in one discipline is only required to own instruments appropriate for their category of certification as noted above, ("A" for Air TAB qualification and "H" for Hydronic TAB qualification). NEBB Certified TAB Firms certified in one discipline are encouraged, *but not required*, to achieve certification in the remaining discipline.

4.2 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.

The accuracy and range as reported by the instrument manufacturer shall be verified by a testing laboratory traceable to the National Institute of Standards and Technology or equivalent institute in countries other than the United States. Calibration requirements for each function are specified and shall be met. Some instruments such as U-tube manometers and inclined manometers may not require calibration. However, if a "mechanical / electrical" device is substituted or employed in place of these types of instruments, the indicated calibration requirements noted shall apply.

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. 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 Qualified TAB Supervisor.***

Supervisors 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.

Instruments shall be used in accordance with manufacturer's recommendations. The most suitable instrument, or combination of instruments, should be employed for a particular measurement or reading. For example, a traverse may be accomplished with a Pitot tube and manometer (digital, analog, or incline); it is not acceptable to use a Pitot tube with another device that does not provide the same overall accuracy.

See Section 6 – *Basic TAB Measurements* for a discussion of TAB measurement procedures and instrument use techniques. See Appendix A for an overview of the TAB Instrumentation.

TABLE 4-1 NEBB MINIMUM INSTRUMENTATION REQUIREMENTS (U.S. UNITS)

	Function	Minimum Range	Accuracy	Resolution	Calibration Interval
A, H	Rotation Measurement	0 to 5000 rpm	± 2% of reading	± 5 rpm	12 Months
 A H H	Temperature Measurement Air Immersion Contact	 -40 to 240 ^{o}F -40 to 240 ^{o}F -40 to 240 ^{o}F	 ± 1% of reading ± 1% of reading ± 1% of reading	 0.2 ^{o}F 0.2 ^{o}F 0.2 ^{o}F	 12 Months
A, H	Electrical Measurement Volts AC Amperes	 0 to 600 VAC 0 to 100 Amps	 ± 2% of reading ± 2% of reading	 1.0 Volt 0.1 Ampere	 12 Months
A	Air Pressure Measurement	0 to 10.00 in.w.g.	± 2% of reading	0.01 in.w.g. ≤1in.w.g. 0.1in.w.g. >1in.w.g.	12 Months
A	Air Velocity Measurement (Not for Pitot tube traverses)	50 to 2500 fpm	± 5% of reading	20 fpm	12 Months
A	Humidity Measurement	10 to 90% RH	2% RH	1%	12 Months
A	Direct Reading Hood	100 to 2000 cfm	± 5% of reading, ± 5 cfm	Digital – 1 cfm Analog - Not applicable	12 Months
A	Pitot Tubes (2 required)	18" minimum, adequate length for intended use.	Not applicable	Not applicable	Not required
H	Hydronic Pressure Measurement (Pressure Gauges)	-30" hg. to 60 PSI 0 to 100 PSI 0 to 200 PSI	± 2% of reading ± 2% of reading ± 2% of reading	0.5 PSI 1.0 PSI 2.5 PSI	12 Months
H	Hydronic Differential Pressure Measurement	0 to 100 in.w.g. 0 to 100 ft.w.g.	± 2% of reading ± 2% of reading	1.0 in.w.g. 1.0 ft.w.g.	12 Months

TABLE 4-1 NEBB MINIMUM INSTRUMENTATION REQUIREMENTS (S.I. UNITS)

	Function	Minimum Range	Accuracy	Resolution	Calibration Interval
A, H	Rotation Measurement	0 to 5000 rpm	± 2% of reading	± 5 rpm	12 Months
 A H H	Temperature Measurement Air Immersion Contact	 -40 to 115 °C -40 to 115 °C -40 to 115 °C	 ± 1% of reading ± 1% of reading ± 1% of reading	 0.1 °C 0.1 °C 0.1 °C	 12 Months
A, H	Electrical Measurement Volts AC Amperes	 0 to 600 VAC 0 to 100 Amps	 ± 2% of reading ± 2% of reading	 1 Volt 0.1 Ampere	 12 Months
A	Air Pressure Measurement	0 to 2500 Pascals	± 2% of reading	2.5 Pa ≤250 Pa 25 Pa >250 Pa	12 Months
A	Air Velocity Measurement (Not for pitot traverses)	0.25 to 12.5 m/s	± 5% of reading	0.1 m/s	12 Months
A	Humidity Measurement	10 to 90 %RH	2% RH	1%	12 Months
A	Direct Reading Hood	50 to 1000 L/s	± 5% of reading, ± 2.5 L/s	Digital - 0.5 L/s Analog - Not applicable	12 Months
A	Pitot Tubes (2 required)	45 cm minimum, adequate length for intended use.	Not applicable	Not applicable	Not required
H	Hydronic Pressure Measurement (Pressure Gauges)	-760 mm hg. to 400 kPa 0 to 700 kPa 0 to 1400 kPa	± 2% of reading ± 2% of reading ± 2% of reading	3.3 kPa 6.7 kPa 16.7 kPa	12 Months
H	Hydronic Differential Pressure Measurement	0 to 25 kPa 0 to 300 kPa	± 2% of reading ± 2% of reading	250 Pa 3.0 kPa	12 Months

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.

Calibrations of all instrumentation requiring calibration shall be traceable to current NIST Standards for US firms, or equivalent organizations in other countries.

"**A**" = instrumentation required for Air Certification. "**H**" = equals instrumentation required for Hydronic certification.

SECTION 5 STANDARDS FOR REPORTS AND FORMS

5.1 REPORTS

The NEBB *Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems* establishes minimum requirements of a NEBB Certified TAB Report. The standards have been developed and written using **"Shall, Should, and May"** language. It is important to note these particular words throughout this document and how they pertain to NEBB Procedural Standards.

NEBB does not require the use of NEBB produced forms. Customized forms are acceptable based on the data acquisition requirements of this section. Where contract document data reporting requirements exceed the minimum requirements of NEBB, the NEBB Certified TAB Firm is responsible to meet the requirements of the contract documents.

NEBB Test, Adjust, and Balance Reports shall include the following information:

A. **REPORT TITLE**

B. **REPORT CERTIFICATION**

C. **TABLE OF CONTENTS**

D. **REPORT SUMMARY / REMARKS**

E. **APPROPRIATE FORMS**

F. **INSTRUMENT CALIBRATION**

G. **ABBREVIATIONS**

5.2 REQUIRED FORMS

Listed below are the **requirements** for each NEBB Certified TAB Report in **Shall, Should, and May** language.

5.2.1 REPORT TITLE

Shall Data: The heading: "Certified Test; Adjust; Balance Report"; Project Name / Address; Engineer Name; HVAC Contractor Name; NEBB Certified TAB Firm Name / Address / Certification Number.

May Data: Architect Name; Architect Address / Contact Numbers; Engineer Address / Contact Numbers; HVAC Contractor Address / Contact Numbers.

5.2.2 REPORT CERTIFICATION

The certification page SHALL bear the stamp of the NEBB Qualified TAB Supervisor. The stamp on the certification page SHALL be signed as evidence that the NEBB Supervisor has reviewed and accepted the report. ***Signature stamps are specifically prohibited.***

Shall Data: Project Name; Certifying NEBB Qualified TAB Supervisor's Name; Firm Name; Certification Number; Expiration Date; Certifying NEBB Qualified TAB Supervisor'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 STANDARDS FOR TESTING, ADJUSTING, AND BALANCING OF ENVIRONMENTAL SYSTEMS*. ANY VARIANCES FROM DESIGN QUANTITIES, WHICH EXCEED NEBB TOLERANCES, ARE NOTED IN THE TEST- ADJUST- BALANCE REPORT PROJECT SUMMARY."

(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 shall serve as a guide to the organization of the TAB report.

Shall Data: Page numbers of system and component information in the report.

5.2.4 REPORT SUMMARY / REMARKS

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

This section also includes a listing of deficiencies in the summary and identifies the appropriate pages in the report. "Deficiency" can be subjective when performing TAB work. Part of the NEBB Supervisor's responsibilities is to determine "noteworthy" deficiencies.

Shall Data: Summary of all items that exceed NEBB / Contract Document tolerances or any other items that require discussion / explanation.

5.2.5 ALL REPORT PAGES

All tested items included in the NEBB TAB Report shall be clearly identified with a unique designation. The method of identification may use schematic diagrams, mechanical plans where permissible, or a narrative description. Each data form supplied in a NEBB TAB Report shall include the name of the responsible technician / NEBB Qualified TAB Supervisor who reported the information, and the time period the data was collected.

Shall Data: Project name. All pages shall be numbered consecutively.

May Data: Remarks section to record any information pertinent to the data reported on the data sheet.

5.2.6 INSTRUMENT CALIBRATION

This is a listing of the instruments that will be used to verify the reported data.

Shall Data:

Instrument type Instrument manufacturer Instrument model Number	Instrument serial Number Instrument calibration Date Dates of use

5.2.7 ABBREVIATIONS

This is a list of definitions of the relevant abbreviations used in the report.

Shall Data: A listing of all abbreviations and their definition as used in the report.

5.3 AIR HANDLING UNIT TEST DATA (CENTRAL STATION)

Shall Design / Submittal Data:

Unit designation Manufacturer Model number Total design airflow Total outlet airflow Outside airflow	Fan rpm Fan motor HP (kW) Fan motor rpm Fan motor voltage Fan motor phase Total SP or External SP

Shall Actual / Test Data:

Unit serial number Supply airflow Return airflow Outside airflow Total suction SP Total discharge SP Total SP Fan motor HP (kW) Fan motor rpm Fan motor operating HZ	Fan motor rated voltage Fan motor rated amperage Fan motor service factor Fan motor operating voltages Fan motor operating amperages Motor sheave OD / bore Fan sheave OD / bore Sheave centerline distance Fan rpm Number belts / size

Should Design / Submittal Data:

Unit type / size / arrangement / class External SP	

Should Actual / Test Data:

Fan motor manufacturer Fan motor frame External SP	External discharge SP External suction SP All coil and filter pressure drops (ΔP)

May Design / Submittal Data:

Fan discharge position	

May Actual / Test Data:

Sheave manufacturer Belt manufacturer Supply airflow in economizer mode Fan motor amperage in economizer mode	Fan motor no load amperages Fan motor BHP (kW) Number filters / type / size Adjustable sheave operating diameter

5.4 AIR HANDLING UNIT TEST DATA (PACKAGE / UNITARY BELT DRIVE)

Shall Design / Submittal Data:

Unit designation Manufacturer Model number Total design airflow Total outlet airflow Outside airflow	Fan rpm Fan motor HP (kW) Fan motor rpm Fan motor voltage Fan motor phase Total SP or External SP

Shall Actual / Test Data:

Unit serial number Supply airflow Return airflow Outside airflow External suction SP External discharge SP External SP Fan motor HP (kW) Fan motor rpm Fan motor operating HZ	Fan motor rated voltage Fan motor rated amperage Fan motor service factor Fan motor operating voltages Fan motor operating amperages Motor sheave OD / bore Fan sheave OD / bore Sheave centerline distance Fan rpm Number belts / size

Should Design / Submittal Data:

Unit type / size / arrangement / class	External SP

Should Actual / Test Data:

Fan motor manufacturer	Fan motor frame

May Actual / Test Data:

Sheave manufacturer Belt manufacturer Supply airflow in economizer mode Fan motor amperage in economizer mode	Fan motor no load amperages Fan motor BHP (kW) Number filters / type / size All coil and filter pressure drops (ΔP) Adjustable sheave operating diameter

5.5 AIR HANDLING UNIT TEST DATA (PACKAGE / UNITARY DIRECT DRIVE)

Shall Design / Submittal Data:

Unit designation Manufacturer Model number Total design airflow Total outlet airflow Outside airflow	Fan rpm Fan motor HP (kW) Fan motor voltage Fan motor phase Total SP or External SP

Shall Actual / Test Data:

Unit serial number	Fan motor HP (kW)
Supply airflow	Fan rpm or speed setting
Return airflow	Fan motor rated voltage
Outside airflow	Fan motor rated amperage
External suction SP	Fan motor service factor
External discharge SP	Fan motor operating voltages
External SP	Fan motor operating amperages
	Fan motor operating HZ

May Design / Submittal Data:

Fan motor BHP (kW)	

May Actual / Test Data:

Fan motor manufacturer	Fan motor amperage in economizer mode
Fan motor calculated BHP (kW)	All coil and filter pressure drops (ΔP)
Supply airflow in economizer mode	Number filters / type / size

5.6 FAN TEST DATA (BELT DRIVE)

Shall Design / Submittal Data:

Unit designation	Fan rpm
Type of service	Fan motor HP (kW)
Manufacturer	Fan motor rpm
Model number	Fan motor voltage
Total design airflow	Fan motor phase
Total outlet airflow	Total SP or External SP

Shall Actual / Test Data:

Unit serial number	Fan motor service factor
Total airflow	Fan motor operating voltages
Suction SP	Fan motor operating amperages
Discharge SP	Motor sheave OD / bore
TSP or ESP	Fan sheave OD / bore
Fan motor HP (kW)	Sheave centerline distance
Fan motor rpm	Fan rpm
Fan motor rated voltage	Number belts / size
Fan motor rated amperage	Fan motor operating HZ

Should Design / Submittal Data:

Unit type / size / arrangement / class	External SP

Should Actual / Test Data:

Fan motor manufacturer	

May Actual / Test Data:

Sheave manufacturer	Fan motor no load amperages
Belt manufacturer	Fan motor calculated BHP (kW)
All filter pressure drops (ΔP)	Adjustable sheave operating diameter

5.7 FAN TEST DATA (DIRECT DRIVE)

[Required for fans of 1/6 HP (125 W) and greater]

Shall Design / Submittal Data:

Unit designation Type of service Manufacturer Model number Total design airflow Total outlet airflow	Total SP or External SP Fan speed Fan motor HP (kW) Fan motor voltage Fan motor phase

Shall Actual / Test Data:

Unit serial number Total airflow Suction SP Discharge SP Total SP or External SP Fan motor HP (kW)	Fan rpm or speed setting Fan motor rated voltage Fan motor rated amperage Fan motor operating voltages Fan motor operating amperages Fan motor operating HZ

Should Design / Submittal Data:

Unit type / size / arrangement / class	External SP

Should Actual / Test Data:

Fan motor manufacturer	

May Actual / Test Data:

All filter pressure drops (ΔP)	Fan motor calculated BHP (kW)

5.8 FAN TEST DATA (DIRECT DRIVE)

[Required for fans less than 1/6 HP (125 Watts)]

Shall Design / Submittal Data:

Unit designation Type of service Manufacturer	Model number Total design airflow

Shall Actual / Test Data:

Total airflow	

5.9 AIR OUTLET TEST DATA (ALL)

Shall Design / Submittal Data:

System designation Outlet number Area served Size	Design airflow System total design airflow Code or type

Shall Actual / Test Data:

Final velocity (when Ak ≠1.0) Ak factor (when Ak ≠1.0)	Final airflow

May Actual / Test Data

First test reading	Instrument used for testing

5.10 VARIABLE VOLUME TERM. TEST DATA (PRESSURE DEPENDENT)

Shall Design / Submittal Data:

VAV terminal designation Terminal type Size	Design maximum airflow Minimum design cooling airflow Heating design airflow

Shall Actual / Test Data:

Final maximum airflow Final minimum cooling airflow Final heating airflow	***Include connected Grille, Register, and Diffuser data for each VAV address***

May Actual / Test Data:

First test reading	Instrument used for testing

5.11 VARIABLE VOLUME TERM. TEST DATA (PRESSURE INDEPENDENT)

Shall Design / Submittal Data:

VAV terminal designation Terminal type Size	Design maximum airflow Minimum design cooling airflow Heating design airflow

Shall Actual / Test Data:

Final maximum airflow Final minimum cooling airflow Final heating airflow DDC flow correction / calibration factor(s) (where available) DDC max / min flows (where available)	***Include connected Grille, Register, and Diffuser data for each VAV address***

May Actual / Test Data:

First test reading	Instrument used for testing

5.12 FAN POWERED TERMINAL TEST DATA (PRESSURE DEPENDENT)

Shall Design / Submittal Data:

VAV terminal designation Primary maximum airflow Primary minimum airflow(s)	Terminal type Size Fan airflow

Shall Actual / Test Data:

Final maximum airflow Final minimum cooling airflow Final primary heating airflow Fan airflow	Fan speed (High, Medium, Low, Variable etc.) ***Include connected Grille, Register, and Diffuser data for each VAV address***

May Actual / Test Data:

First test reading	Instrument used for testing

5.13 FAN POWERED TERMINAL TEST DATA (PRESSURE INDEPENDENT)

Shall Design / Submittal Data:

VAV terminal designation Primary maximum airflow Primary minimum airflow(s) Fan airflow	Terminal type Size DDC address

Shall Actual / Test Data:

Final maximum airflow Final minimum cooling airflow Final primary heating airflow Fan airflow Fan speed (High, Medium, Low, Variable etc.)	***Include connected Grille, Register, and Diffuser data for each VAV address*** DDC flow correction / calibration factor(s) (where available) DDC max / min flows (where available)

May Actual / Test Data:

First test reading	Instrument used for testing

5.14 DUCT TRAVERSE TEST DATA

Shall Design / Submittal Data:

System designation Traverse designation Location	Design airflow Duct size, I.D. (width, height, diameter) Duct area

Shall Actual / Test Data:

Average velocity in duct Duct airflow	Static pressure at traverse location. Instrumentation used to measure flow

May Actual / Test Data:

Velocity readings (presented in grid form to represent location in duct) Altitude	Duct air temperature Correction factor

5.15 HYDRONIC PUMP TEST DATA

Shall Design / Submittal Data:

Unit designation Type of service Manufacturer Motor HP (kW) Impeller size	Model number / size Design flow Design head Pump / Motor RPM

Shall Actual / Test Data:

Unit serial number Motor manufacturer Motor HP (kW) Pump / Motor rpm Motor operating voltages Motor rated amperage Motor running load amperages Motor operating HZ	No flow suction pressure No flow discharge pressure No flow head Impeller diameter Final suction pressure Final discharge pressure Total dynamic head Final flow

May Actual / Test Data:

Motor calculated BHP (kW) Calculated water HP (kW)	Calculated pump efficiency Static fill pressure

5.16 HYDRONIC BALANCING VALVE TEST DATA (FIXED OR ADJUSTABLE ORIFICE)

Shall Design / Submittal Data:

Unit designation Service Manufacturer	Model number Size Flow

Shall Actual / Test Data:

Dial setting ΔP	Flow

5.17 HYDRONIC BALANCING VALVE TEST DATA (SELF-ADJUSTING)

Shall Design / Submittal Data:

Unit designation Service Manufacturer Model number	Size Flow Operating pressure range

Shall Actual / Test Data:

ΔP	Flow

5.18 ULTRASONIC FLOW MEASUREMENT TEST DATA

Shall Design / Submittal Data:

Reading designation Service	Location Flow

Shall Actual / Test Data:

Pipe size Transducer size Spacing distance Application	Pipe material Pipe wall thickness Water flow

5.19 COOLING COIL TEST DATA (HYDRONIC)

Shall Design / Submittal Data:

Coil designation System served Coil location	Water flow Airflow

Shall Actual / Test Data:

Final airflow	Water flow

May Design / Submittal Data:

Coil manufacturer Model number Airside face area Entering air DB / WB temperature Leaving air DB / WB temperature Airside sensible MBH (kW) Airside total MBH (kW) Airside ΔP	Airside face velocity Number of rows Number fins per inch (cm) Entering water temperature Leaving water temperature Waterside total MBH (kW) Waterside ΔP

May Actual / Test Data:

Entering air DB / WB temperature Leaving air DB / WB temperature Entering air enthalpy Leaving air enthalpy Calculated airside sensible MBH (kW) Calculated airside total MBH (kW) Airside face velocity	Entering water temperature Leaving water temperature Waterside ΔT Waterside ΔP Calculated waterside total MBH (kW) Airside ΔP

5.20 COOLING COIL TEST DATA (DX)

Shall Design / Submittal Data:

Coil designation System served	Airflow Coil location

Shall Actual / Test Data:

Final airflow	

May Design / Submittal Data:

Entering air DB / WB temperature Leaving air DB / WB temperature Airside total MBH (kW) Coil manufacturer Model number Airside face area	Airside ΔP Airside sensible MBH (kW) Airside face velocity Number of rows Number fins per inch (cm)

May Actual / Test Data:

Entering air DB / WB temperature Leaving air DB / WB temperature Entering air enthalpy Leaving air enthalpy	Calculated airside sensible MBH (kW) Calculated airside total MBH (kW) Airside ΔP Airside face velocity

5.21 HEATING COIL TEST DATA (HYDRONIC)

Shall Design / Submittal Data:

Coil designation System served Coil location	Water flow Airflow

Shall Actual / Test Data:

Final airflow	Final water flow

May Design / Submittal Data:

Entering air DB temperature Leaving air DB temperature Airside total MBH (kW) Airside ΔP Coil manufacturer Model number Airside face area	Entering water temperature Leaving water temperature Waterside total MBH (kW) Waterside ΔP Airside face velocity Number of rows Number fins per inch (cm)

May Actual / Test Data:

Entering air DB temperature Leaving air DB temperature Calculated airside total MBH (kW) Airside ΔP Airside face velocity	Entering water temperature Leaving water temperature Waterside ΔT Waterside ΔP Calculated waterside total MBH (kW)

5.22 HEATING COIL TEST DATA (STEAM)

Shall Design / Submittal Data:

Coil designation System served	Airflow Coil location

Shall Actual / Test Data:

Final airflow	

May Design / Submittal Data:

Entering air DB temperature Leaving air DB temperature Coil manufacturer Model number Airside face area	Airside total MBH (kW) Airside ΔP Airside face velocity Number of rows Number fins per inch (cm)

May Actual / Test Data:

Entering air DB temperature Leaving air DB temperature Airside ΔP	Airside total MBH (kW) Airside face velocity

5.23 HEATING COIL TEST DATA (ELECTRIC)

Shall Design / Submittal Data:

Coil designation System served Coil location	KW Voltage / Phase

Shall Actual / Test Data:

Final airflow Voltages	Amperages

May Design / Submittal Data:

Airside total MBH (kW) Number of Stages	Airside ΔP

May Actual / Test Data:

Entering air DB temperature Leaving air DB temperature Airflow	Calculated airside total MBH Calculated KW Airside ΔP

5.24 CHILLER TEST DATA (WATER COOLED)

Items not included below are outside the scope of TAB responsibilities

Shall Design / Submittal Data:

Unit designation Manufacturer Model number Evaporator water flow	Evaporator ΔP Condenser water flow Condenser water ΔP

Shall Actual / Test Data:

Unit serial number Evaporator water flow Evaporator water ΔP	Condenser water flow Condenser water ΔP

May Actual / Test Data:

Evaporator entering water temperature Evaporator leaving water temperature Evaporator ΔT	Condenser entering water temperature Condenser leaving water temperature Condenser ΔT

5.25 CHILLER TEST DATA (AIR COOLED)

Items not included below are outside the scope of TAB responsibilities

Shall Design / Submittal Data:

Unit designation Manufacturer Model number	Evaporator water ΔP Evaporator water flow

Shall Actual / Test Data:

Unit serial number Evaporator water flow	Evaporator water ΔP

May Actual / Test Data:

Evaporator entering water temperature Evaporator leaving water temperature	Evaporator ΔT

5.26 COMPRESSOR / CONDENSER TEST DATA

Testing of these components is outside the scope of TAB services.

5.27 COOLING TOWER TEST DATA

Shall Design / Submittal Data:

Unit designation Manufacturer	Water flow Model number

Shall Actual / Test Data:

Unit serial number	Water flow

May Design / Submittal Data:

Entering water temperature Leaving water temperature	Water ΔT Water ΔP

May Actual / Test Data:

Entering water temperature Leaving water temperature	Water ΔT Water ΔP

5.28 HOT WATER BOILER TEST DATA

The testing of burner sections, burner / fuel controls, safety controls, and combustion gases are outside the scope of TAB services.

Shall Design / Submittal Data:

Unit designation Manufacturer Model number	Water flow Water ΔP

Shall Actual / Test Data:

Unit serial number Water flow	Water ΔP

May Actual / Test Data:

Entering water temperature Leaving water temperature	Water ΔT

5.29 HEAT EXCHANGER TEST DATA (WATER TO WATER)

Shall Design / Submittal Data:

Unit designation Location Service Manufacturer Model number	Primary water flow Primary water ΔP Secondary water flow Secondary water ΔP

Shall Actual / Test Data:

Unit serial number Primary water flow Primary water ΔP	Secondary water flow Secondary water ΔP

May Design / Submittal Data:

Primary entering water temperature Primary leaving water temperature Primary water ΔT	Secondary entering water temperature Secondary leaving water temperature Secondary water ΔT

May Actual / Test Data:

Primary entering water temperature Primary leaving water temperature Primary water ΔT	Secondary entering water temperature Secondary leaving water temperature Secondary water ΔT

5.30 HEAT EXCHANGER TEST DATA (STEAM TO WATER)

Shall Design / Submittal Data:

Unit designation Location Service Manufacturer	Model number Water flow Water ΔP

Shall Actual / Test Data:

Unit serial number Water flow	Water ΔP

May Design / Submittal Data:

Water entering temperature Water leaving temperature	Water ΔT

May Actual / Test Data:

Water entering temperature Water leaving temperature	Water ΔT

5.31 ENERGY RECOVERY WHEELS

Shall Design / Submittal Data:

Unit designation Location Service Manufacturer Model number	Primary airflow Primary air ΔP Secondary airflow Secondary air ΔP

Shall Actual / Test Data:

Unit serial number Primary airflow Primary air ΔP	Secondary airflow Secondary air ΔP

May Design / Submittal Data:

Primary entering air temperatures Primary leaving air temperatures Primary air ΔT	Secondary entering air temperatures Secondary leaving air temperatures Secondary air ΔT

May Actual / Test Data:

Primary entering air temperatures Primary leaving air temperatures Primary air ΔT	Secondary entering air temperatures Secondary leaving air temperatures Secondary air ΔT

5.32 DUCT AIR LEAKAGE TEST DATA (OPTIONAL)

Duct Leakage testing is outside the scope of the NEBB Procedural Standards. If duct leakage testing is required of the NEBB Certified TAB Firm by the Contract Documents, the work should be performed in accordance with SMACNA Standards.

Design / Submittal Data:

System designation Service Location / zone Altitude Density Leakage class Design static pressure	Pressure class Seal class Airflow volume Surface area Airflow per surface-factor Percent allowable leakage

Actual / Test Data:

Test static pressure Test section air leakage	Test section percent air leakage Test witnesses

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PART 2 - PROCEDURES

SECTION 6 BASIC TAB MEASUREMENTS

6.1 INTRODUCTION

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

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

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

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

6.2 AIR PRESSURE PROCEDURES

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

6.2.1 INSTRUMENTS

The following instruments are typically utilized to perform pressure measurements:

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

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

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

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

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

6.2.2 GENERAL MEASUREMENT TECHNIQUES

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

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

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

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

6.2.3 SPECIFIC MEASUREMENT TECHNIQUES

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

6.3 AIR VELOCITY PROCEDURES

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

6.3.1 INSTRUMENTS

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

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

6.3.2 GENERAL MEASUREMENT TECHNIQUES

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

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

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

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

6.3.3 SPECIFIC MEASUREMENT TECHNIQUES

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

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

b) Determine if the duct is internally lined. This may require the drilling of an exploratory hole to allow the thickness of the liner, if present, to be measured. Measurement of liner thickness is easily done by inserting a Pitot tube into the duct and measuring the thickness on the tube scale.

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

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

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

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

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

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

6.3.4 FACE VELOCITY MEASUREMENTS

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

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

Equation 6-1

ENGLISH (IP) 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/ft^3 (kg/m^3)

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

Equation 6-2

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

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

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

6.4 TEMPERATURE MEASUREMENT PROCEDURES

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

6.4.1 INSTRUMENTS

The following instruments are typically utilized to perform temperature measurements:

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

6.4.2 GENERAL MEASUREMENT TECHNIQUES

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

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

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

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

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

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

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

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

6.4.3 SPECIFIC MEASUREMENT TECHNIQUES

Air Temperatures – Dry Bulb

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

Example 6-1

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

Table 6.1 Variable Temperatures and Airflow Velocities

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

Weighted Average Temperature - 97.74°F / 36.52°C

Table 6.2 Variable Temperatures and Identical Airflow Velocities

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

Weighted Average Temperature – 96.56°F / 35.87°C

Air Temperatures – Wet Bulb

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

Hydronic Temperatures

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

6.5 FLOW MEASURING HOOD PROCEDURES

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

6.5.1 INSTRUMENTS

Flow measuring hoods (various manufacturers)

6.5.2 GENERAL MEASUREMENT TECHNIQUES

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

6.5.3 SPECIFIC MEASUREMENT TECHNIQUES

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

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

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

6.6 ROTATIONAL SPEED MEASUREMENT PROCEDURES

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

6.6.1 INSTRUMENTS

The following instruments are typically utilized to perform rpm measurements:

Chronometric Tachometers
Digital Contact Tachometers
Optical (Photo) Tachometers
Stroboscopes

6.6.2 SAFETY CONSIDERATIONS

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

6.6.3 GENERAL MEASUREMENT TECHNIQUES

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

6.6.4 SPECIFIC MEASUREMENT TECHNIQUES

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

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

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

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

6.7 HYDRONIC PRESSURE PROCEDURES

6.7.1 HYDRONIC PRESSURE MEASUREMENTS

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

6.7.2 INSTRUMENTS

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

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

6.7.3 GENERAL MEASUREMENT TECHNIQUES:

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

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

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

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

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

6.7.4 SPECIFIC MEASUREMENT TECHNIQUES

The following applies to all hydronic systems:

a) The system shall be free of air, and the instrument shall be purged of air before use.

b) Verify the range of the instrument to be used is appropriate for the system being tested and the type of measurements being taken.

c) Verify the system pressures and temperatures do not exceed instrument rating.

d) Verify the instrument is approved for use on the system to be tested. For example, is the instrument approved for use on systems that convey potable water or other fluids for human or animal consumption?

e) Correct readings as required if measurement points are at different elevations, if the instrument hoses are at different elevations, or the pressure gauges are at different elevations.

f) Pressure measurements shall be taken with the appropriate accessories, i.e. P / T probes of proper length and size, isolation valves, pulsation eliminators (snubbers), etc.

6.8 ELECTRICAL MEASUREMENT PROCEDURES

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

6.8.1 INSTRUMENTS

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

6.8.2 SAFETY

EXTREME CARE MUST BE EXERCISED WHEN USING ELECTRICAL TEST INSTRUMENTS.

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

a) Inspect meter before use.

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

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

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

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

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

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

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

6.8.3 GENERAL MEASUREMENT TECHNIQUES:

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

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

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

6.8.4 SPECIFIC MEASUREMENT TECHNIQUES:

Adhere to all safety precautions when taking the following readings:

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

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

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

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

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

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

Equation 6-3

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

Where:

V_i = **Voltage imbalance**
V_d = **Maximum voltage deviation from average**

V_a = Average voltage of three legs

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

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

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

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

Equation 6-4

Single Phase Circuit:

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

Equation 6-5

Three Phase Circuit:

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

Where:

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

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

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

Equation 6-6

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

***Nameplate ratings**

Equation 6-7

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

(* 1 HP = 0.746 kW)

Where:

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

6.8.5 Variable Frequency Drives

Modified electrical measurement procedures are required when a variable frequency drive (VFD) is used. There are two acceptable methods for determining voltage and amperage of a motor operated by a variable frequency drive (VFD). The most accurate method is to use the voltage and amperage provided on the VFD display screen. Note: regardless of whether the motor is single or three phase, most VFD display screens only provide one voltage and amperage reading. Not all VFD's are equipped with display screens. When voltage and amperage readings cannot be taken from the VFD display screen, a true-RMS meter is required.

SECTION 7 PRELIMINARY TAB PROCEDURES

7.1 INTRODUCTION

This section describes the preliminary procedures necessary for the testing, adjusting, and balancing of environmental systems. These procedures are offered as current best practices to achieve the performance requirements specified by the HVAC/R design professional.

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. The term "Balanced to NEBB TAB Procedural Standards" must be referenced to a project's contract documents.

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 Qualified TAB Supervisor 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 Certified TAB Firm's intended scope. To be effective, the agenda should be submitted early in the project schedule to allow for adequate review by the architect / engineer / owner.

After the project paperwork is set up, notify the appropriate project personnel of any concerns that may require clarification or additional information that is required to achieve system balance.

A *sample Pre-TAB checklist*, found in Appendix B of this document, may be appropriate to issue to the contracting team. This checklist should be modified for each project to accurately reflect the equipment on the project.

SECTION 8 AIR SYSTEM TAB PROCEDURES

8.1 INTRODUCTION

Testing, adjusting, and balancing of HVAC systems can best be accomplished by following systematic procedures. The NEBB TAB procedures presented in this section are recommended current best practices for balancing HVAC systems. The procedures in this section address the majority of systems commonly installed. It is the responsibility of the NEBB Certified TAB Firm to determine appropriate procedures for systems not covered in this section.

8.2 PRELIMINARY SYSTEM PROCEDURES

8.2.1 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. The NEBB Certified TAB Firm should normally set-up a system to its maximum capacity, or 'full load' condition, prior to the TAB process. It is this condition that presents the greatest challenge to a system's capacity to meet its design airflow requirements.

8.2.2 Not all system types are addressed in this section. Confer with the engineer of record to establish the proper set-up conditions for specific systems.

8.2.3 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 every item affecting the airflow of a duct system is ready for the TAB work, such as doors and windows being closed, ceiling tiles (return air plenums) in place, etc.

d) Confirm that the automatic control devices will not adversely affect TAB operations. The control systems shall be installed and 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 should be identified at this time.

8.3 ESTABLISHING FAN TOTAL AIRFLOW

8.3.1 The most accurate and accepted field test of airflow is a Pitot tube traverse of the duct. Procedures for conducting a Pitot tube traverse are found in Section 6. In situations where a Pitot tube 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 Pitot tube traverses and should be used with caution.

8.3.2 Additionally, if a Pitot tube traverse is available, a comparison of the total outlet airflow measurement with the Pitot tube 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 Pitot tube 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 is outside the scope of TAB work.

8.3.3 Fan curves can be used when other required data can be obtained, such as SP, rpm and bhp (W). Experience has shown, however, that often not all of the field readings will fall into place on the fan and design system curves due to S*ystem Effect* and measurement errors

8.3.4 If the fan volume is not within plus or minus 10 percent 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 rpm limit 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 often are required. Unless clearly specified in the contract documents, the responsibility for these items is outside the scope of the NEBB Certified TAB Firm.

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

8.3.6 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 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 when ambient conditions may adversely affect system operation.

8.4 BASIC AIR SYSTEM BALANCING PROCEDURES

Balancing air systems may be accomplished in various ways. Two acceptable methods for balancing systems are presented. These methods are appropriate for supply, return and exhaust systems.

Regardless of the method, the objectives remain the same and the system will be considered balanced in accordance with NEBB procedural standards when the following conditions are satisfied:

a) **All measured airflow quantities are within ± 10 percent of the design airflow quantities unless there are reasons beyond the control of the NEBB Certified TAB firm.** ***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)

This technique is initially described for a basic constant volume supply system ***without branch ducts***. It 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.

d) Calculate the percentage of actual airflow to design airflow.

e) Adjust the fan to approximately 110% of design airflow, if possible.

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 serving the GRD with the next (second) lowest percentage of design until both GRD's are the same percentage of design. These GRD's are now in balance.

j) Adjust the damper serving the GRD with the next (third) lowest percentage of design until all three GRD's are at the same percentage of design, and in balance.

k) Continue this procedure until all remaining GRD's have been adjusted to be in balance at approximately the same percentage of design airflow.

l) If necessary, adjust the fan speed to set all GRD's at design airflow, ± 10%.

m) Re-measure all GRD's and record final values.

n) Mark all GRD's with felt markers, spray paint, or in some other manner that is permanent, so that adjustment may be restored if necessary.

Where a basic constant volume supply system ***has branch ducts,*** the procedure is:

o) Follow above steps a) through f) for the GRD's on each branch.

p) Compute the ratio of measured branch flow to design branch flow.

q) The damper serving the branch at the lowest percentage of design flow is not adjusted in this procedure.

r) 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.

s) 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.

t) Continue this procedure until all remaining branches have been adjusted to be in balance at approximately the same percentage of design airflow.

u) If necessary, adjust the fan speed to set all branches at design airflow, ± 10%.

v) Perform the proportioning techniques specified in above steps a) through m) for the diffusers on each branch.

w) Re-measure all GRD's and record final airflow values.

x) Mark all dampers, with felt markers, spray paint, or other permanent technique, so that adjustment may be restored if necessary.

8.4.2 STEPWISE METHOD

This technique is initially described for a basic constant volume supply system ***without branch ducts.*** It 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.

d) Calculate the percentage of actual airflow to design airflow.

e) Adjust the fan to approximately 110% of design airflow if possible.

f) Measure the airflow at all GRD's.

g) Starting at the fan, as the GRD's closest to the fan will typically be the highest, adjust the GRD volume dampers to a value approximately 10% below design airflow requirements.

h) As the adjustment proceeds to the end of the system, the remaining GRD airflow values will increase.

i) Repeat the adjustment passes through the system until all GRD's are within ± 10% of design airflow requirements and at least one GRD volume damper is wide open.

j) If necessary, adjust the fan speed to set all GRD's at design airflow, ± 10%.

k) Re-measure all diffusers and record final airflow values.

l) Mark all dampers, with felt markers, spray paint, or other permanent technique, so that adjustment may be restored if necessary.

Where a basic constant volume supply system ***has branch ducts,*** the procedure is:

m) Follow above steps a) through e) for the GRD’s on each branch.

n) Compute the ratio of measured branch flow to design branch flow.

o) 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.

p) As the adjustment proceeds to the end of the system, the remaining branch airflow values will increase.

q) If necessary, adjust the fan speed to set all branches at design airflow, ± 10%.

r) Balance the GRD's on each branch as described in steps e) through i) above

s) Re-measure all GRD's and record final values.

t) Mark all dampers with felt markers, spray paint, or other 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 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 branch and outlet volume dampers are locked 100% open.

f) Measure the motor operating amperage.

g) Measure motor voltage.

h) Confirm that the voltage and amperage matches the motor rating.

i) Verify correct rotation.

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 should be set to an appropriate position as a starting point (caution should be used if freezing conditions are expected).

m) The OA damper for air handling units using mechanical cooling should be adjusted to a position estimated to equal the design minimum airflow.

n) The OA damper for units using only ventilation air for cooling should be positioned 100% open, with RA dampers closed.

o) Determine if the AHU is rated for 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 static pressure measurement point can be immediately adjacent to the unit. The discharge static pressure should 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 by the most accurate method available. The method used is at the discretion and judgment of the NEBB Qualified TAB Supervisor based on the configuration of the unit and its ductwork.

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 should be checked with 100 percent outside air if this alternative is included in the system design. Appropriate damper adjustments should be made if necessary.

u) At the conclusion of all inlet and outlet balancing, re-adjust 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, *Standards for Reports and Forms).*

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 NEBB Qualified TAB Supervisor. Building pressure can vary if the return / exhaust air fan volume does not respond adequately to changes in the supply air fan volume. Three common methods used are building static control, open loop control and closed loop control. These methods are 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 set-up and balancing process.

There are many variations of unit fan and damper arrangements supplied by manufacturers, which the NEBB Qualified TAB Supervisor 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

Follow the procedures specified previously for a *Basic Constant Volume Supply System* 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) Measure building static pressure and compare to specified requirements.

c) Adjust the powered exhaust fan flow rate if necessary to achieve the required building static pressure.

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 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 NEBB Qualified TAB Supervisor. Building pressure will vary substantially if the return / exhaust air fan volume does not respond adequately to changes in the outside air ventilation rate introduced by the supply air fan. Three common methods used are building static control, open loop control and closed loop control. These methods are discussed later in this section.
Follow the procedures specified previously for a basic constant volume supply system with the following modifications:

a) Set the return / exhaust dampers for the maximum load 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 maximum load condition, set the return / exhaust dampers to both extremes, i.e. *full return - minimum exhaust mode* and then *minimum return - full exhaust mode.*

d) In each condition, verify that the system is operating in compliance with specified requirements.

e) Measure building static pressure and compare to specified requirements.

f) If necessary, perform any necessary adjustments of existing equipment to achieve specified parameters.

g) Final System measurements: At the conclusion of all inlet and outlet balancing, re-adjust the AHU minimum outside air ventilation rate, if required.

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

8.6 MULTIZONE SYSTEMS

Follow the procedures specified previously for a basic constant volume supply system 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 should be left open 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 postured prior to balancing. If the air handling unit (AHU) has a fixed outside air damper it should be set to the appropriate position as a starting point. (Caution should be used if ambient conditions present a risk of damage to the equipment or facility).

d) The OA damper for air handing units using mechanical cooling should be adjusted to a position estimated to equal the design minimum airflow.

e) The OA damper for units using only ventilation air for cooling should be positioned 100% open, with RA dampers closed.
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.

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 NEBB Qualified TAB Supervisor should 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).*

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 static pressure at one of the nozzles and comparing it 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.

Normally the flow of water in induction unit coils is automatically controlled to adjust room temperature. 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. 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 (ratio) method or stepwise method as described previously for balancing diffusers or registers.

8.8 VARIABLE VOLUME SYSTEM OVERVIEW

TAB procedures for a VAV system are similar to those for constant volume systems. The main 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 VAV box airflow requirements and adjust the system in response.

8.8.1 DIVERSITY

Diversity is a design concept in a VAV system that allows a system of terminal units to be served by a fan that is rated for a fraction (usually 80%) of the total system terminal unit capacity. VAV systems with diversity are frequently encountered in TAB work.

8.8.2 TERMINAL UNITS (VAV BOXES)

VAV systems incorporate terminal units (VAV boxes) 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 or pressure independent.*

Pressure dependent terminal unit: A pressure dependent terminal unit is not equipped to measure and maintain primary air discharge 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 function. Listed below are 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 ONLY UNITS WITH REHEAT

This is a cooling only 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 primary airflow across the heating elements falls below a certain value. This is to prevent damage to the unit or the heating coils.

8.8.5 FAN POWERED VAV TERMINAL UNITS

Fan powered VAV terminal units are VAV boxes that contain individual supply air fans.

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. 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 above a threshold value the parallel fan is shut off by the terminal unit controls. When full cooling is no longer needed, the primary air begins to decrease. At a predetermined setpoint, 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 specific sequence specified. Most parallel VAV boxes are pressure independent and include a primary air velocity sensor and controller. Heating coils may be provided at the return inlet or at the VAV box discharge.

Series Fan Terminal unit: This type of terminal is usually available in PI configuration. 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. Improper adjustment of the terminal unit may allow primary air to short circuit into the return air plenum.

8.8.6 DUAL DUCT TERMINAL UNITS

A dual duct VAV terminal unit consists of a plenum box with two primary air inlets, dampers or air valves with actuators, and an air discharge. When the VAV box 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 mixing box 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 NEBB Qualified TAB Supervisor reviews the manufacturer’s operating sequence for the type of dual duct box being balanced.

8.8.7 CONSTANT VOLUME (VAV) TERMINAL UNITS

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

8.8.8 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, but a few are constant volume.

Study the manufacturer's data before attempting to do the TAB work, because many operating sequences are available. 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 VAV 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 at, for example, 60% or 250% of nominal design requirements. This is to be expected, and should be reported as such, while including the system conditions in the project summary.

To eliminate possible misunderstandings later, an agenda with the proposed balancing procedures should be submitted and approved by the system designer or authorized persons before the TAB work is started. This practice is recommended for all jobs, but it is critical on jobs with these particular systems.

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 VAV box 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) Measure the motor amperage.

g) Measure motor voltage.

h) Confirm that the voltage and amperage matches the motor rating.

i) Verify correct rotation.

j) Measure fan RPM and compare to design RPM.

k) Posture the system OA and RA dampers for maximum demand.

l) Verify that adequate supply duct static pressure is available to allow balancing of VAV boxes.

m) Posture all VAV boxes in the maximum demand position.

n) If manual volume dampers are present at the inlet to each box, adjust the dampers to achieve the design airflow at each VAV box being balanced.

o) Balance the outlets on each terminal unit using either of the two recommended balancing procedures.

p) If the existing terminal unit controls allow a minimum airflow, adjust each VAV box 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.

q) Identify the VAV 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 VAV box should be no less than the sum of the VAV box manufacturer recommended minimum inlet static pressure plus the static pressure or resistance of the ductwork and the terminals on the discharge side of the VAV box. Adjust system static pressure to the minimum value necessary to maintain design airflow at this terminal unit(s). This setpoint information should be provided to the appropriate project personnel.

r) Measure the AHU total air volume by the most accurate method available. The method used is at the discretion and judgment of the NEBB Qualified TAB Supervisor based on the configuration of the unit and its ductwork.

s) If necessary, adjust fan airflow to meet design requirements.

t) Determine if the AHU is rated for 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.

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 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 outside air ventilation rate, if required.

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

8.9.2 PRESSURE DEPENDENT VAV PROCEDURES WITH DIVERSITY

The NEBB Certified TAB Firm should 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 NEBB Qualified TAB Supervisor 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 or VAV box 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) Measure the motor amperage.

g) Measure motor voltage.

h) Confirm that the voltage and amperage matches the motor rating.

i) Verify correct rotation.

j) Measure fan RPM and compare to design RPM.

k) Posture the system OA and RA dampers for maximum demand.

l) Verify that adequate supply duct static pressure is available to allow balancing of VAV boxes.

m) 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.

n) If manual volume dampers are present at the inlet to each box, adjust the dampers to achieve the design airflow at each VAV box being balanced.

o) Balance the outlets on each terminal unit using either of the two recommended balancing procedures.

p) Set the non-peak VAV boxes to a full flow condition, and close as many peak boxes as necessary to match the design flow of the non peak boxes.

q) Balance the outlets on each terminal unit using either of the two recommended balancing procedures.

r) If the existing terminal unit controls allow a minimum airflow, adjust each VAV box 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 existing supply fan airflow and static pressure. Measure the static pressure at this unit. The entering static pressure at this VAV box should be no less than the sum of the VAV box manufacturer recommended minimum inlet static pressure plus the static pressure or resistance of the ductwork and the terminals on the discharge side of the VAV box. Adjust system static pressure to the minimum value necessary to maintain design airflow at this terminal unit(s). This setpoint information should be provided to the appropriate project personnel.

t) Measure the AHU total air volume by the most accurate method available. The method used is at the discretion and judgment of the NEBB Qualified TAB Supervisor based on the configuration of the unit and its ductwork.

u) If necessary, adjust fan airflow to meet design requirements.

v) Determine if the AHU is rated for 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.

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, if required.

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

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 VAV boxes 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 VAV box 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 VAV box 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 VAV box 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) Measure the motor amperage.

g) Measure motor voltage.

h) Confirm that the voltage and amperage matches the motor rating.

i) Verify correct rotation.

j) Measure fan RPM and compare to design RPM.

k) Posture the system OA and RA dampers for maximum demand.

l) Verify that adequate supply duct static pressure is available to allow balancing of VAV boxes.

m) Calibrate the volume controllers on each VAV terminal unit using the manufacturer's recommended procedures.

n) Balance the outlets on each terminal unit using either of the two recommended balancing procedures.

o) Identify the VAV 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 VAV box should be no less than the sum of the VAV box manufacturer recommended minimum inlet static pressure plus the static pressure or resistance of the ductwork and the terminals on the discharge side of the VAV box. Adjust system static pressure to the minimum value necessary to maintain design airflow at this terminal unit(s). This setpoint information should be provided to the appropriate project personnel.

p) Measure the AHU total air volume by the most accurate method available. The method used is at the discretion and judgment of the NEBB Qualified TAB Supervisor based on the configuration of the unit and its ductwork.

q) If necessary, adjust fan airflow to meet design requirements.

r) Determine if the AHU is rated for 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.

s) 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.

t) If testing with partially loaded filters is specified, measure pressure drop across air filters and adjust a temporary blockage to meet specified requirements.

u) 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.

v) At the conclusion of all system balancing, adjust and verify the AHU minimum outside air ventilation rate, if required.

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

8.9.4 PRESSURE INDEPENDENT VAV PROCEDURES WITH DIVERSITY

Follow the procedures for pressure independent VAV systems without diversity. When the VAV box balancing procedures are complete, the total system airflow is measured by adjusting a combination of VAV boxes to maximum and minimum airflows to match the design fan airflow. Fan performance is then measured by methods previously described.

Complete the reporting requirements as previously specified.

8.9.5 COMBINATION SYSTEMS

Some system applications may incorporate pressure independent VAV boxes and pressure dependent VAV boxes 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 VAV boxes, 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 NEBB Qualified TAB Supervisor should 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 VAV box 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) Measure motor voltage.

i) Confirm that the voltage and amperage matches the motor rating.

j) Verify correct rotation.

k) Measure fan RPM and compare to design RPM.

l) Posture the system OA and RA dampers for maximum demand.

m) Determine if the AHU is rated for 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.

n) If testing with partially loaded filters is specified, measure pressure drop across air filters and adjust a temporary blockage to meet specified requirements.

o) 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.

p) Measure the AHU total air volume by the most accurate method available. The method used is at the discretion and judgment of the NEBB Qualified TAB Supervisor based on the configuration of the unit and its ductwork.

q) If necessary, adjust fan airflow to meet design requirements.

r) Balance the dual duct boxes using procedures described in the following Paragraph 8.11.4. The NEBB Qualified TAB Supervisor should use these procedures as a guide, and modify the procedures as required by the individual projects.

s) 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.

t) Final System measurements: At the conclusion of all system balancing, adjust and verify the AHU minimum outside air ventilation rate, if required.

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

8.10.2 VARIABLE VOLUME DUAL DUCT SYSTEMS

These systems share many features of a dual duct constant volume system and with minor variations the procedures to TAB these systems are the same.

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 systems, and should be adapted as necessary by the NEBB Qualified TAB Supervisor to suit the particular system being balanced.

8.11 VARIABLE VOLUME TERMINAL UNIT PROCEDURES

8.11.1 COOLING ONLY TERMINAL UNITS

Pressure Dependent:

a) Set the VAV box to maximum airflow.

b) Test the total airflow delivered by the VAV box using one of the following methods:
1. Total of air being delivered from the outlets.
2. Inlet velocity sensor

c) Adjust the VAV box total airflow with available devices.

d) Adjust the outlets using either the proportional or the stepwise method.

e) Adjust the VAV box minimum airflow with available devices.

Pressure Independent:

a) Set the volume controller to design maximum airflow.

b) Test the total airflow delivered by the VAV box using one of the following methods:
1. Total of air being delivered from the outlets.
2. Inlet velocity sensor

c) Calibrate the controller, by appropriate methods, to the measured airflow.

d) Balance the outlets using either the proportional or the stepwise method.

e) Set the volume controller to the design minimum airflow.

f) Calibrate the controller for the required minimum if applicable.

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

8.11.3 FAN TERMINAL VAV UNITS

Parallel Type (Pressure Independent or Dependent):

a) The primary airflows are balanced as discussed previously for a cooling only terminal unit.

b) Set the controls to operate the fan with the primary air valve at minimum flow.

c) Adjust the fan airflow to design airflow by adjusting the fan speed or dampers, whichever is provided.

d) Verify heating airflow and report.

Series Type (Pressure Independent):

a) Set the VAV box to the design maximum cooling set point

b) Set the fan speed to design airflow by measuring the outlet total airflow and comparing to design requirements.

c) Adjust the primary damper to obtain a neutral condition at the return inlet. When the inlet is neutral, the fan airflow is equal to primary airflow.

d) Balance the air outlets using an appropriate method.

e) Place the VAV box to the minimum position and adjust the primary airflow (L/s) to design requirements.

f) Verify the heating airflow and report.

g) On series VAV box 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 that some VAV control systems may require the minimum airflow set point to be calibrated before the maximum airflow set point first. Confirm with the control system supplier.

It should be noted that design primary airflow may not always equal design fan airflow. In these situations an appropriate calibration procedure should be developed.

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 NEBB Certified TAB Firm 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 total airflow delivered by the box using one of the following methods:
   1. Total of air being delivered from the outlets.
   2. Inlet velocity sensor.

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 should 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 NEBB Qualified TAB Supervisor should communicate to the design and construction teams the importance of the construction requirements regarding leakage. 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. Pitot traverses of grease exhaust ducts are not recommended. If a Pitot tube traverse of the exhaust duct is necessary, the access to the duct shall be provided by others. When the testing is complete, repairs to the duct and fire retardant enclosure shall be provided by others and shall be 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 LABORATORY FUME HOODS

NEVER ENTER OR WORK IN A CLEAN SPACE OR BIOLOGICAL LABORATORY WITHOUT PERMISSION, AND ONLY AFTER APPROPRIATE SAFETY AWARENESS TRAINING.

8.15.1 FUME HOOD PERFORMANCE

Containment of contaminants within the fume hood is based on the principle that a flow of air entering at the face, passing through the enclosure, and exiting into the exhaust system will prevent the escape of airborne contaminants from the hood into the room. The degree to which this is accomplished depends on the design of the hood, its installation, and its operation.

Air currents external to a hood easily disturb the hood's air pattern and may cause flow of contaminants into the breathing zone of the researcher. Cross currents are generated by movements of the researcher, people walking past the hood, thermal convection, supply air movement, and a rapid operation of room doors and windows. Terminal supply air velocity in the vicinity of the hood should be limited to 35 fpm (0.175 m/s). It is very important to avoid the location of the hoods near doors and active aisles.

Performance criteria for fume hoods are flow control / face velocity and spillage. Flow control (regulation of flow over the face opening of a hood) is obtained by adjusting the horizontal slots in the back baffle. One slot is at the bottom of the back baffle to draw air across the working surface; another is at the top to exhaust the canopy; and the third is frequently midway on the baffle. These adjustable openings permit regulation of exhaust distribution for specific operations.

Spillage (leakage outward through the face opening) of contamination from hoods into the laboratory can be caused by drafts in the room; eddy currents generated at hood opening edges, surface projections or depressions; thermal heads; and high turbulence operations (blenders, mixers) within the hood.

8.15.2 FUME HOOD PERFORMANCE TESTING

When conducting TAB procedures for fume hoods the NEBB Certified TAB Firm shall either:

1. Consult with the engineer of record to determine the specific criteria for acceptance of the fume hood performance tests (generally applicable to new construction).

or

2. Consult with the supervisory personnel for the laboratory where the fume hoods to be tested are located to determine the specific criteria for acceptance of the performance tests (generally applicable to existing facilities).

Fume hood performance testing should be performed when the lab is operating under the following conditions:

a) Room operating under normal conditions.

b) All air systems balanced.

c) Pressure gradients to adjoining spaces at proper values.

d) Laboratory exhaust fume hood fans are operating satisfactorily.

8.15.3 FACE VELOCITY MEASUREMENT PROCEDURES

The intent of this test is to determine the actual average face velocity of the hood as it is typically used. The following procedures are the minimum recommended steps to achieve satisfactory fume hood performance, if any specific information regarding the face velocity measurement techniques for a fume hood is not available.

a) Verify that the room conditions are satisfactory.

b) Select the calibrated instrument for taking measurements.

c) Set the fume hood sash to the specified operating height.

d) A maximum 1.0 square foot (300 mm x 300 mm) grid pattern shall be formed by equally dividing the hood opening dimensions. Velocity readings shall be taken with a calibrated instrument at the center of the grid spaces. The instrument shall be mounted in a ring stand, or other appropriate device, in the plane of the hood sash and perpendicular to the opening. The technician shall not hold the instrument while taking a velocity reading. The technician shall assume a position away from the face of the hood to avoid influencing velocity measurements.

e) Face velocities shall be integrated over a period of at least five seconds. If an anemometer is used that measures instantaneous point velocities, a minimum of four readings shall be taken at each point.

f) The average of the velocity measurements shall be calculated, and the highest and lowest readings shall be noted.

g) If a Pitot tube traverse is taken in the exhaust duct prior to measuring face velocities, it may be necessary to allow approximately 10% to 15% for cabinet leakage, or a value as determined by the fume hood manufacturer.

h) Mark the hood sash opening and/or damper setting when final adjustments are made on fume hoods.

8.15.4 VISUAL METHOD PROCEDURES (IF REQUIRED)

The intent of this optional test is to render a visual observation of the hood performance as it is typically used. Smoke can be provided by means of a plastic bottle that contains an ampoule of liquid Titanium Tetrachloride. Other sources of persistent, neutral buoyancy aerosols could provide the same visualization of airflow.

a) A suitable source of smoke shall be in the center of the sash opening on the work surface 6" (150 mm) inside the rear edge of the sash. Note: Some smoke sources generate a jet of smoke that produces an unacceptably high directional component that may overcome the hoods exhaust air pattern leading to an erroneous conclusion.

b) Observe the air pattern from the side of the hood face. A release of smoke from the hood that is steady and visible is an indication of failure.

c) Airflow patterns and time for hood clearance shall be observed and noted.

d) Mark sash opening and / or damper setting when final adjustments are made on fume hoods.

8.16 BIOSAFETY CABINETS

Fume hoods and Bio Safety cabinets are similar in purpose as they provide a safe working environment for laboratory personnel. Due to the variety of configurations of Bio Safety cabinets, field performance testing shall be in strict accordance with manufacturer's recommendations.

8.17 INDUSTRIAL EXHAUST HOODS AND EQUIPMENT

8.17.1 AIR AND FUME EXHAUST SYSTEMS

The current edition of the American Conference of Industrial Hygienists *Industrial Ventilation, A Manual of Recommended Practice* should be consulted for proper testing techniques. Industrial exhaust air systems with hoods fall into two categories. One group, similar in many respects to laboratory fume hoods, is used over vats such as dip tanks and plating tanks. Exhaust hoods are often placed at one end above the tank and make up air hoods are placed at the opposite end. This permits vapors to be swept from the tank surface but still leaves the top open for overhead handling equipment. Often an exhaust duct will be connected directly to a piece of equipment with no external hood. Other times, hoods may be used just to remove heat from equipment. Heat recovery systems also are being used more frequently. In these situations, makeup air becomes critical and air density must be corrected in calculations.

The balancing procedure is basically the same as any other exhaust air system. A Pitot tube traverse of the exhaust air duct is the preferred method where possible. 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 should 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.

8.17.2 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 should 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.

8.18 BUILDING STATIC PRESSURE CONTROL METHODS

There are three commonly applied methods of controlling building static pressure, described in the following paragraphs.

8.18.1 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).

8.18.2 OPEN LOOP CONTROL

Open loop, (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 NEBB Qualified TAB Supervisor. 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.

8.18.3 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.

8.19 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.

Testing of the stairwell system should be conducted, for new construction, with the cooperation of the construction team. It is recommended that a preliminary test be completed before scheduling the AHJ to witness a final test.

The NEBB Qualified TAB Supervisor shall review with the AHJ and / or the engineer of record the minimum pressure differentials to be achieved, and 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 should 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 wishes to test 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 usually may be started by applying canned smoke or a magnet to a smoke detector.

f) All shaft pressurization systems shall be operational at time of testing. Additionally, all other HVAC systems shall be properly postured for a fire and smoke control event.

g) Testing *shall not* generate a false call to the fire department.

h) Confirm that the fan rotation is correct.

i) Measure fan motor amperage and voltage.

j) Verify that the motor is not overloaded.

k) Verify that all appropriate stairwell pressurization fans and dampers operate according to the approved sequence of operation.

l) Measure the pressure(s) from the stairwell to the reference point(s) as required by the AHJ or the engineer of record. A pressure differential of 0.05 in.w.g. (12.5 Pa) from the stair shaft to the reference point is generally considered to be the minimum acceptable pressure difference.

m) Adjust the fan speed, if required, to change the shaft pressurization to meet specified requirements.

n) Verify that the maximum door opening force does not exceed 30 pounds (13.6 kg) or a locally specified value. Use of a belt tension checker or other appropriate device is generally advised to test door-opening forces.

o) If the stairwell is equipped with a relief damper(s), verify its operation and measure the airflow exiting the stairwell through the damper. Compare the measured airflow to design requirements, and report discrepancies.

p) Report the actual test conditions and results to the AHJ and engineer of record.

8.20 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 engineer of record.

Testing of the elevator pressurization system should be conducted, for new construction, with the cooperation of the construction team. The presence of the elevator contractor is ***required*** due to the complexity of elevator systems. It is recommended to satisfactorily complete a preliminary test before scheduling the AHJ to witness a final test.

The NEBB Qualified TAB Supervisor shall review with the AHJ and / or the engineer of record the minimum pressure differentials to be achieved, and 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 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. A smoke control event usually may be started by applying canned smoke or a magnet to a smoke detector.

f) All shaft pressurization systems shall be operational at the time of testing. Additionally, all other HVAC systems shall be properly postured for a fire and smoke control event.

g) Testing *shall not* generate a false call to the fire department.

h) Confirm that the fan rotation is correct.

i) Measure fan motor amperage and voltage.

j) Verify that the motor is not overloaded.

k) Verify that all appropriate elevator pressurization fans operate. If isolation dampers are present verify proper operation during the pressurization event.

l) Verify that all elevator cars in the tested shaft return to the recall floor, and remain there with the doors open for the duration of the test.

m) Measure the pressure(s) from the elevator shaft to the reference point(s) as required by the AHJ. A pressure differential of 0.05 in.w.g. (12.5 Pa) from the elevator shaft to the reference point is generally considered to be the minimum acceptable pressure difference.

n) Adjust the fan speed, if required, to change the shaft pressurization to meet specified requirements.

o) Report the actual test conditions and results to the AHJ and engineer of record.

SECTION 9 HYDRONIC SYSTEM TAB PROCEDURES

9.1 INTRODUCTION

Testing, adjusting, and balancing (TAB) of HVAC systems can best be accomplished by following systematic procedures. The NEBB TAB procedures presented in this section are recommended current best practices for balancing HVAC systems. The procedures in this section address the majority of systems commonly installed. It is the responsibility of the NEBB Certified TAB Firm to determine appropriate procedures for systems not covered in this section.

9.2 PRELIMINARY SYSTEM PROCEDURES

Each type of HVAC system is designed to meet a set of performance parameters. This usually includes maximum heating capacity and maximum cooling capacity. The NEBB Certified TAB Firm should normally set-up a system in its maximum capacity, or "full load" condition prior to the TAB process. It is this condition that presents the greatest challenge to a system's ability to meet its design hydronic flow.

Not all system types are addressed in this section. Consult with the system designer to establish the proper set-up conditions for specific systems.

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, filled, vented, chemical treatment complete, air vents installed and operating, startup strainer screens removed and replaced with final strainer screens, etc.

c) Confirm that the automatic control devices will not adversely affect TAB operations.

d) Establish the conditions for design maximum system requirements.

e) 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 shall be determined by review of the system(s) to be tested. There are five basic methods available for measuring the flow quantity in a piping system:

1. with flow meters or flow fittings,
2. with calibrated balancing valves,
3. using pump curves
4. using the equipment pressure loss, or
5. by the heat transfer method

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. This balance approach is very accurate because it eliminates compounding errors introduced by the temperature difference or equipment pressure drop procedures. Balance by flow measurement allows the pump to be matched to the actual system requirements. Proper instrumentation and good preplanning is needed.

9.3.2 CALIBRATED FLOW MEASURING DEVICES

The NEBB Certified TAB Firm shall 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. Calibrated flow measuring devices are the preferred method of flow measurement.

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

9.3.3 CALIBRATED BALANCING VALVES

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

Self-Adjusting Valves

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

The NEBB Certified TAB Firm shall verify the valve flow rating from the data tag, and verify by differential pressure measurements, if available, that the pressure drop across the valve is within the control range of the valve.

Adjustable Orifice Valves

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

Fixed Orifice Valves

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

9.3.4 PUMP CURVE METHOD

Actual system flow can be determined with the use of a certified pump curve. If a certified curve is not available, pump flow may be approximately quantified 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 differential head. The shut-off head value is compared to pump curve data to determine the size of the pump impeller. 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. If available, verify the pump curve data with data from flow meters and/or calibrated balancing valves.

9.3.5 EQUIPMENT PRESSURE LOSS METHOD

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

When the design criteria of the equipment and the pressure loss are known, the flow rate may be calculated by using the following equation:

Equation 9.1 $Flow_2 = Flow_1 \times P_2 / P_1$

Where:

- $Flow_2$ = **calculated flow**
- $Flow_1$ = **rated flow**
- P_2 = **measured differential pressure**
- P_1 = **rated differential pressure**

9.3.6 HEAT TRANSFER METHOD

Approximate flow rates may be established at heating and cooling terminal units by using both air and hydronic measured heat transfer data and the following equations. Each equation determines the total heat transfer rate of the terminal unit at the time of testing, and then the flow rate is calculated based upon the fluid heat transfer rate (water temperature difference).

<u>For Standard Air (sensible heat):</u>

	(US)	(SI)
Equation 9.2	$Q = 1.08 \times cfm \times \Delta t$	$Q = 1.23 \times L/s \times \Delta t$

Where:

- **Q = Heat flow in Btuh (Watts)**
- **cfm = Cubic feet per minute**
- **L/s = Liters per second**
- **Δt = Temperature difference - °F (°C)**

For water:

	(US)	(SI)
Equation 9.3	**$Q = 500 \times gpm \times \Delta t$**	**$Q(W) = 4190 \times L/s \times \Delta t$**
		$Q\ (kW) = 4190 \times m^3/s \times \Delta t$

Where:

Q = Heat flow in Btuh (Watts or kilowatts)
gpm = Gallons per minute
L/s = Liters per second
m^3/s = Cubic meters per second
Δt = Temperature difference -°F (°C)

Note that in Equation 9.3, the value of 500 (4190) is a constant that is used specifically for water. This constant will change when the system medium is other than water, such as a glycol mixture, steam, or refrigerant.

WARNING: This method can be used to verify that some flow is actually occurring at the measurement location. It is important to note that the temperature difference method will most likely result in significant uncertainty in the actual flow rates. This is an unavoidable consequence of the compounding of measurement errors in the field.

9.4 BASIC HYDRONIC SYSTEM PROCEDURES

Balancing hydronic systems may be accomplished in various ways. Two acceptable methods for balancing systems are presented. These methods are appropriate for all hydronic systems.

Regardless of the method, the objectives remain the same and the system will be considered balanced in accordance with NEBB procedural standards when:

a) All measured hydronic flow quantities are within ± 10 percent of the design hydronic flow quantities unless there are reasons beyond the control of the NEBB Certified TAB Firm. Deficiencies shall be noted in the TAB report summary.

b) 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)

The *Proportional Balancing Method* initially is described 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 unit.

g) The balancing valve serving the terminal unit at the lowest percentage of design flow is not adjusted in this procedure.

h) Adjust the balancing valve serving the terminal unit with the next (second) lowest percentage of design until both terminal units are the same percentage of design. These terminal units are now in balance.

i) Adjust the balancing valve serving the terminal unit with the next (third) lowest percentage of design until all three terminal units are at the same percentage of design, and in balance.

j) Continue this procedure until all remaining terminals have been adjusted to be in balance at approximately the same percentage of design flow.

k) If necessary, adjust the pump volume to set all terminals at design flow ±10%.

l) Re-measure all terminal units and record final values.

m) Mark or set all memory stops on all of the balancing valves so that the adjustment may be restored if necessary.

Where a hydronic system ***has branch circuits with branch balancing valves***, the *proportional balancing* procedure is:

n) Follow above steps a) through f) for the terminals on each branch.

o) Compute the ratio of measured branch flow to design branch flow.

p) The balancing valve serving the branch at the lowest percentage of design flow is not adjusted in this procedure.

q) 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.

r) 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.

s) Continue this procedure until all remaining branches have been adjusted to be in balance at approximately the same percentage of design flow.

t) If necessary, adjust the pump volume to set all branches at design flow, ±10%.

u) Perform the proportioning techniques specified in above steps a) through m) for the terminal units on each branch.

v) Re-measure all terminal units and record final values.

w) 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

The *Stepwise Method* initially is described 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 if possible.

e) Measure the flow at all balancing valves.

f) Starting at the pump, as the terminal units 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 unit flow values will increase.

h) Repeat the adjustment passes through the system until all terminal units are within ±10% of design flow requirements and at least one balancing valve is wide open.

i) If necessary, adjust the pump volume to set all terminal units at design flow, ±10%.

j) Re-measure all terminal units and record final values.

k) Mark or set all memory stops (see Section 1, *Definitions*) on all of the balancing valves so that the adjustment may be restored if necessary.

Where a hydronic system ***has branch circuits with branch balancing valves***, the *Stepwise* procedure is:

l) Follow above steps a) through e) above for the terminal units on each branch.

m) Compute the ratio of measured branch flow to design branch flow.

n) 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.

o) As the adjustment proceeds to the end of the system the remaining branch flow values will increase.

p) If necessary, adjust the pump volume to set all branches at design flow, +/- 10%.

q) Balance the terminal units on each branch as described in above steps e) through i) above.

r) Re-measure all terminal units and record final values.

s) 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.

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, as discussed in Section 3, *Responsibilities,* are complete.

b) Verify that all manual valves are open or preset as required, and all temperature control (automatic) valves are in a normal or desired position.

c) Verify that all automatically controlled devices in the piping or duct systems will not adversely affect the balancing procedures.

d) With the pump(s) off, observe and record system static pressure at the pump(s).

e) Place the systems into operation, check that all air has been vented from the piping systems and allow flow conditions to stabilize.

f) Verify that the system compression tank(s) and automatic water fill valve are operating and set properly.

g) 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.

h) If flow meters or calibrated balancing valves are installed, which would allow the flow rate of the pump circuit(s) to be measured, perform the necessary work and record the data.

i) 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. ***Do not fully close any valves in the discharge piping of a positive displacement pump. Severe damage may occur.***

j) 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.

k) 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.

l) If the measured total head is greater than the design total head, the water flow will be lower than designed.

m) 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 percent of design.

n) Record the suction and discharge pressures and the water flow.

o) 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.).

p) Take a complete set of pressure drop measurements through all equipment and compare this with submittal data readings. Determine which circuits have high or low water flow. Low circuits may be air bound. Check and vent air if present in low flow circuits and retake readings.

q) Compare actual total system flow with design requirements.

r) Use the proportional balancing method or the stepwise method described previously to adjust the flow rates through the equipment.

s) 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.

t) After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.

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

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 percent of the design coil 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 as discussed in Section 3, *Responsibilities,* are complete.

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 terminal units 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.

d) The terminal units 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) The value of the variable flow control setpoint shall be measured and recorded. The control contractor shall be provided with this information.

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 (see Section 5, *Standards for Reports and Forms).*

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

The NEBB Certified TAB Firm should determine if the variable flow system has a diversity factor. The diversity factor is an arithmetic ratio of the pumps rated hydronic flow capacity divided by a summation of all terminal unit's 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 NEBB Qualified TAB Supervisor 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 as discussed in Section 3, *Responsibilities,* are complete.

b) Place the primary system in a simulated full load condition.

c) Conduct the basic pump testing and flow procedures on the primary system as outlined previously.

d) Place the secondary system in a simulated full load condition. If diversity is present in the system, temporary isolation of portions of the system piping and terminal units may be required.

e) Conduct the basic pump testing and flow procedures on the secondary system as outlined previously.

f) The terminal units are balanced using either the stepwise or the proportional balancing methods described previously.

g) When diversity is present in the system, upon completion of balancing procedures with a portion of the system isolated, the isolated units are then opened and an equal capacity of units closed. Units isolated for the initial balancing procedure are then balanced to design flow rates.

h) After all final adjustments are made, perform a final check of the pressures and the flow of all pumps and equipment. Re-measure the voltage and amperage of pump motors and record the data.

i) After all TAB work has been completed, set all memory stops and mark or score all balancing devices at final set points.

j) Record final system data, prepare the report forms, and submit as required (see Section 5, *Standards for Reports and Forms).*

<u>Primary / Secondary / Tertiary systems are balanced in a similar manner.</u>

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 as discussed in Section 3, *Responsibilities,* are complete.

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) 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.

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 (see Section 5, *Standards for Reports and Forms).*

9.6.2 CHILLED WATER SYSTEMS

a) Verify that the construction team responsibilities for system installation and startup, as discussed in Section 3, *Responsibilities,* are complete.

b) With pump(s) off, observe and record the system static pressure at the pump(s).

c) Energize the pumping system.

d) Conduct the basic pump testing and flow procedures as outlined previously.

e) Determine the water flow through the evaporator, and condenser if present, using flow meters, calibrated balancing valves, or pressure / temperature ports. If the measured differential pressure must be 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 (see Section 5, *Standards for Reports and Forms).*

9.6.3 HEAT EXCHANGERS AND BOILER SYSTEMS

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

a) Verify that the construction team responsibilities for system installation and startup as discussed in Section 3, *Responsibilities,* are complete.

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 (see Section 5, *Standards for Reports and Forms).*

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, as discussed in Section 3, *Responsibilities,* are complete.

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 Subsection 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 (see Section 5, *Standards for Reports and Forms).*

SECTION 10 OUTDOOR AIR VENTILATION PROCEDURES

10.1 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 make determinations as to the appropriate amount of outdoor air that should be introduced into a building's HVAC system. Most systems are designed to operate with a scheduled minimum amount of outdoor air whenever the building is occupied. 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 may be difficult. The quantities of outdoor air shall be obtained by making a Pitot tube 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.

10.2 MEASUREMENT OPTIONS

10.2.1 DIRECT MEASUREMENT METHOD

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

10.2.2 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. Quite often, the mixed air temperature is very difficult to measure accurately. With regard to this method, it is important to note that air stratification within HVAC units may inhibit accurate airflow temperature measurement, which may prevent its use. Mixed air temperatures may vary considerably depending on where the readings are taken. If it is determined that air stratification is present, it will be necessary to take several temperature readings by performing a weighted average temperature *traverse*. This can be a time consuming process and a quick reading digital thermometer may speed up the process. 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)

APPENDICES

APPENDIX A OVERVIEW OF TAB INSTRUMENTATION, TABLE 4-1

TABLE 4-1, *NEBB MINIMUM INSTRUMENTATION REQUIREMENTS* in Section 4, *Standards for Instrumentation and Calibration,* explicitly states the instrumentation requirements of NEBB. This edition of the NEBB *Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems* has modified the previous requirements in several ways. The most important change is that instrumentation with multiple capabilities is now acceptable for more than one required function, providing that each individual function meets NEBB Standards. Some instruments with multiple capabilities might only meet NEBB requirements for one or more, but not all, of its test capabilities. The intent of this change is to acknowledge that modern digital instrumentation is sophisticated enough to provide accurate, reliable data for more than one functional category.

Accuracy tolerances for the instrumentation have been adjusted, generally to tighter tolerances as a result of the advent of digital technologies. For example, the accuracy of the temperature measurements has been changed from “Within ½ Scale Division” to "1% of the reading". Likewise, the accuracy of electrical instrumentation has been changed from "3% of full scale" to "2% of the reading". Also, the accuracy of the hydronic differential pressure measurement has been relaxed to "2% of the reading" to accommodate the realities of the most commonly used instrumentation.

The concept of Resolution has been introduced to the table in an effort to further specify the expected quality of the instrumentation.

Calibration intervals have been adjusted in this NEBB TAB Standard to every 12 months. It is important to understand that it is the responsibility of the NEBB Certified TAB Firm to comply with the instrumentation calibration requirements of NEBB. This can be accomplished by compliance with either of the two specified methods discussed in Section 4.

The first column of Table 4-1 contains the letters "A" and "H". These designations only apply to the few remaining NEBB Certified TAB Firms that are certified in only one discipline, *air or hydronic* (A = Air and H = Hydronic). These firms are only required to possess the instrumentation designated with an "A", or an "H" to maintain their certification.

Previous editions of the NEBB TAB Standards identified air temperature measurements, immersion temperature measurements, and contact temperature measurements, as separate functions. This edition of the NEBB Standard recognizes all temperature measurements as one function. As an example, several electronic thermometers are supplied with a variety of temperature probes, which allow the instrument to sense temperatures appropriately.

It is not the intent of this standard to prevent NEBB Certified TAB Firms from using *several instruments* to meet the requirements of a function.

For example, the definition of the temperature function does not mean that NEBB Certified TAB Firms must possess only one instrument to achieve all three parameters (air, immersion, contact). It is *still acceptable* to use more than one instrument to achieve the specified requirements. This distinction is true for all functional categories. NEBB requires that NEBB Certified TAB Firms possess the necessary instrumentation to collect the data at the specified accuracy, resolution, and range. If a NEBB Certified TAB Firm chooses to use more than one instrument to satisfy a function and / or a range, that choice is acceptable.

Table 4-1 lists requirements for digital flow hoods and analog flow hoods. NEBB Certified TAB Firms are ***not*** required to own both types. The listing is necessary to adequately describe the accuracy and resolution requirements for each type of flow measuring hood.

The requirement for a DC volt-meter has been deleted.

The number of required hydronic pressure ranges has been reduced to three.

The change in required minimum ranges for hydronic differential pressure measurement was necessary to ensure that NEBB Certified TAB Firms have the necessary instrumentation to perform measurements on modern hydronic equipment.

APPENDIX B SAMPLE PRE-TAB CHECKLIST

This is a sample checklist to be 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			
Contactors 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			
f) VIBRATION ISOLATION			
Springs and compression			
Base level and free			

Project: ____________________

2. Duct Systems	Ready Yes	Ready No	Date
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			

b) PIPING	Ready Yes	Ready No	Date
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			

	Ready		Date
	Yes	No	
6. Hydronic Piping Systems			
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 C 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 1.6

SECTION 15950 - 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 (TAB) 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

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

Adjusting: *Adjusting* is 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.

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AHJ: The local governing **A**uthority **H**aving **J**urisdiction over the installation.

Balancing: *Balancing* is 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 testing and design limitations.

Calibrate: The act of comparing an instrument of unknown accuracy with a standard of known accuracy to detect, correlate, report, or eliminate by adjustment any variation in the accuracy of the tested instrument.

Conformed Contract Documents: Current and complete documents.

Deficiency: *Deficiency* is considered any circumstance that adversely affects the specified balance of a device or system.

Environmental Systems: *Environmental Systems* are systems that primarily use 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.

May: The word **may** is used to indicate a course of action that is permissible as determined by the NEBB Firm.

NEBB Certified TAB Firm: A *NEBB Certified TAB Firm* is a firm that has met and maintains all the requirements of the National Environmental Balancing Bureau for firm certification in Testing, Adjusting, and Balancing and is currently certified by NEBB. A NEBB Certified TAB Firm shall employ at least one NEBB Qualified TAB Supervisor in a full time management position.

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 Standards 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 Qualified TAB Supervisor: A *NEBB Qualified TAB Supervisor* is a full time employee of the firm in a management position who has successfully passed the supervisor level written and practical qualification examinations and maintains the Supervisor re-qualification requirements of NEBB.

NEBB Qualified TAB Technician: A *NEBB Qualified TAB Technician* is a full time employee of the firm who has met the technician level experience requirements of NEBB and has successfully passed the technician level written and practical qualification examinations. A NEBB Qualified TAB Technician shall be supervised by a NEBB Qualified TAB Supervisor. (Supervision is not intended to infer constant oversight. A NEBB Qualified TAB Technician is capable of performing assigned tasks with periodic supervision.)

Precision: *Precision* is 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 *Procedure* is defined as a specific set of tasks to be accomplished to achieve the defined result.

Range: *Range* is the upper and lower limits of an instrument's ability to measure the value of a quantity for which the instrument is calibrated.
Resolution: *Resolution* is the smallest change in a measured variable that an instrument can detect.

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

Shall: The word **shall** is used to indicate mandatory requirements strictly to be followed in order to conform to the standard and procedures and from which no deviation is permitted. Note: In the event unique circumstances prevent a required action from being fulfilled, a notation shall be included in the TAB report explaining the exception. For example, such notation could be one of the following: *Not Available, Not Applicable, or Not Accessible.* The simple notation "N/A" is not allowed.

Should: The word **should** is used to indicate that a certain course of action is preferred but not necessarily required.

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.

Stair 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.

System Effect: A phenomenon that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.

TAB Technician: A *TAB Technician* is an employee of a NEBB Certified TAB firm who assists a NEBB Qualified TAB Supervisor and / or a NEBB Qualified TAB Technician by performing TAB work in the field. (Supervision is not intended to infer constant oversight. A TAB Technician may be capable of performing assigned tasks without direct, full time supervision.)

Terminal: A point where the controlled medium, such as fluid or energy, enters or leaves the distribution system

Testing: *Testing* is the use of specialized and calibrated instruments to measure temperatures, pressures, rotational speeds, electrical characteristics, velocities, and air and hydronic quantities for an evaluation of flow conditions.

Testing, Adjusting, and Balancing (TAB): TAB is a systematic process or service applied to heating, ventilating and air-conditioning (HVAC) systems and other environmental systems to achieve and document air and hydronic flow rates. The standards and procedures for providing these services are referred to as *"Testing, Adjusting, and Balancing"* and are described in this document.

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 Sub-section 1.3 *TAB Firm Qualifications.*

1.4.2 TAB Agenda: When requested, submit 2 copies of the TAB Agenda. Include a complete set of report forms intended for use on this 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*.

1.5 QUALITY ASSURANCE

1.5.1 The NEBB Certified TAB Firm shall submit 2 copies of the firm's NEBB TAB Certification.

1.5.2 When requested, the NEBB Certified TAB Firm 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 NEBB *Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems.*

1.5.4 Instrumentation Calibration: Calibration of instruments shall be in accordance with the current edition of the NEBB *Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems.*

1.6 CONSTRUCTION TEAM RESPONSIBILITY TO TAB AGENCY

1.6.1 Provide the NEBB Certified TAB Firm 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 NEBB Certified TAB Firm 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 complete, 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. For additional requirements see the NEBB Pre-TAB checklist in Appendix B.

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 start up 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 startup 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 NEBB Certified TAB Firm.

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* 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*.

3.4 ACCEPTANCE CRITERIA

The systems will be considered balanced in accordance with NEBB *Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems* when the following conditions are satisfied:

3.4.1 All measured airflow and hydronic flow quantities are within ± 10 percent of the design quantities unless there are reasons beyond the control of the NEBB Certified TAB Firm. 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 shall be 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 shall be in accordance with the requirements of the current edition of the NEBB *Procedural Standard for the Testing, Adjusting, and Balancing of Environmental System*.

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