



# TEST & BALANCE PROCEDURES



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# **AABC Test and Balance Procedures**

**Associated Air Balance Council**

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## **FOREWORD**

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The *AABC Test and Balance Procedures* were written and compiled by members of the AABC Technical Committee, in an effort to standardize procedures for testing and balancing HVAC Systems. These procedures are considered to be the minimum requirements for testing and balancing.

This book is intended to serve as a companion piece to the *AABC National Standards*, which are essentially performance standards for the test and balance industry. The procedures in this book explain the various steps that need to be taken during the test and balance process in order to meet the AABC National Standards.

The procedures serve several purposes. They serve as a reference for test and balance technicians to ensure that proper procedures are followed; they serve as standards for the industry, to ensure that all test and balance firms have a clear understanding regarding the scope of services required; and they allow engineers to verify whether the testing agency has actually followed AABC standards.

The *AABC Test and Balance Procedures* represent a major initiative by the Associated Air Balance Council to ensure that quality services are provided to the customer.

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## **ACKNOWLEDGEMENTS**

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The members of the AABC Technical Committee are Steve Young, Chairman, *The Phoenix Agency, Inc.*; William K. Thomas, P.E., *Thomas-Young Associates, Inc.*; Theodore Cohen, P.E., *Air Conditioning Test & Balance Co., Inc.*; Gaylon R. Richardson, *Engineered Air Balance Co., Inc.*; Dennis W. Fox, *Precision Air Balance Co., Inc.*; and George G. Ebert, III, *Fluid Dynamics, Inc.* We would like to thank these individuals for all of their work and contributions to the development and compilation of this publication.

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## Introduction

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The *AABC Procedures* are organized logically, from the most basic measurements to complicated system testing and balancing. Section one describes the prerequisites necessary to the actual beginning of the field test and balance work. Section two presents the basic measurement procedures, which are the Basic Measurements required by all component and system procedures. The Component Procedures in section three identify the procedural methods for testing the various HVAC system components. Section four, Air Systems, and section five, Hydronic Systems, incorporate component testing into the procedures required to accomplish successful system balancing.

AABC standards require all AABC members to follow these procedures. Design engineers can expect that each procedure that is specified and applicable to their projects will be performed and included in the final test and balance report. It should not be expected, however, that these procedures will be followed by non-AABC agencies or contractors. Therefore, if non-AABC agencies are included in the job qualifications, it will be necessary for the specifier to require AABC procedures in the contract documents. When non-AABC agencies are included in the specifications, the specifier should also require submittal of job-specific procedures and balancing agendas for prebalance review by the design engineer. This will assure the design engineer that the testing and balancing agency understands the scope required to accomplish the work and meet the design intent.

As long as new designs and innovative products continue to be introduced, these procedures will never be complete. Because of the dynamic nature in the industry, AABC recognizes the need for continuing review and updating of these procedures by appointing a standing committee to maintain the procedures. All are encouraged to submit comments and suggestions to the Procedures Committee at AABC Headquarters.

Striving for the highest standards and a steadfast commitment to the industry, AABC is confident that these procedures, when properly applied, will help to produce quality installations that meet the design objectives.

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## TABLE OF CONTENTS

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### Chapter 1: AABC PREREQUISITES FOR BALANCING

- 1.1 Contractors' Responsibilities Prior to Balancing
- 1.2 Test and Balance Agency Responsibilities

### Chapter 2: BASIC MEASUREMENTS

- 2.1 Instrumentation Requirements and Calibration Data
- 2.2 Electrical Power Measurements
- 2.3 Rotational Speed Measurements
- 2.4 Static Pressure Profile
- 2.5 Pitot Tube Traverse
- 2.6 Anemometer Coil Traverse
- 2.7 Drive Adjustments for Testing and Balancing
- 2.8 Basic Temperature Testing Measurements
- 2.9 Sound Level Measurements
- 2.10 Vibration Level Measurements
- 2.11 Velocity Measurements at Grilles, Registers, Diffusers, & Openings
- 2.12 Air Capture Hood Flow Rate Measurements

### Chapter 3: HVAC COMPONENT TESTING AND BALANCING PROCEDURES

- 3.1 Fan Test and Balance
- 3.2 Air-Handling Unit (AHU) Test and Balance
- 3.3 Constant Minimum Outside Air Test and Balance
- 3.4 Mixing Damper Leakage Testing
- 3.5 Coil Capacity Testing
- 3.6 Electric Heating Coil Measurements
- 3.7 Airflow Station Measurements
- 3.8 Static Pressure Flow Device Measurements
- 3.9 Unit Heater Measurements
- 3.10 Fan Coil and Unit Ventilator Measurements
- 3.11 Induction Unit Measurements
- 3.12 Laboratory Hood Measurements
- 3.13 Kitchen Hood Measurements
- 3.14 Air-Cooled Condenser Measurements
- 3.15 Air-to-Air Heat Recovery Unit Measurements
- 3.16 Water-to-Water Heat Exchanger Measurements
- 3.17 Fire Damper Operation Verification
- 3.18 Pump Capacity Measurements
- 3.19 Water Flow Station Measurements

---

## TABLE OF CONTENTS

---

- 3.20 Chiller Capacity Measurements
- 3.21 Cooling Tower Performance Measurements
- 3.22 Boiler Capacity Measurements
- 3.23 Radiation Heat Measurements
- 3.24 Steam Humidifiers and Trap Measurements
- 3.25 VAV and Constant Volume Box Test and Balance

### Chapter 4: AIR SYSTEMS TESTING AND BALANCING PROCEDURES

- 4.1 Single-Zone Systems
- 4.2 Multi-Zone Systems
- 4.3 Return Air/Outside Air/Relief Air Systems
- 4.4 Constant Primary/Variable Secondary Bypass Systems
- 4.5 Single-Duct, Variable Primary/Variable Secondary, Pressure-Dependent Systems
- 4.6 Constant-Volume, Dual-Duct Systems with Single-Volume Regulators
- 4.7 Constant-Volume, Dual-Duct Systems with Two-Volume Regulators
- 4.8 Single-Duct, Variable Primary/Variable Secondary, Pressure-Independent Systems
- 4.9 Single-Fan, Dual-Duct, Variable Primary/Variable Secondary, Pressure-Independent Systems
- 4.10 Variable Primary/Variable Secondary, System-Powered Bladder or Spring-Regulator Terminal Systems
- 4.11 High-Pressure Induction Systems
- 4.12 Return or Exhaust Low-Pressure Air Systems
- 4.13 Return/Relief Fan Setup for CV or VAV Systems
- 4.14 Outside Air-Intake Setup

### Chapter 5: HYDRONIC SYSTEMS

- 5.1 Primary Constant Flow Systems
- 5.2 Primary/Secondary Constant Flow Systems
- 5.3 Constant Flow Primary/Variable Flow Secondary Systems
- 5.4 Constant Flow Primary/Constant Flow Secondary/Constant Flow Tertiary Systems
- 5.5 Constant Flow Primary/Variable Flow Secondary/Constant Flow Tertiary Systems
- 5.6 Condenser Water Economizer Systems

### Chapter 6: REPORT CONTENTS

- 6.1 Report Contents Procedure

# **Chapter 1: AABC PREREQUISITES FOR BALANCING**

Associated Air Balance Council

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## **1.1 Contractors' Responsibilities Prior to Balancing**

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1.1-1 The contractor is responsible for the following:

- a. Confirming the complete operational readiness of the building, including sealed walls, doors, and ceilings to allow the balancing to be performed and required pressures to be set and maintained.
- b. Allowing access to all components requiring testing, balancing, and servicing. This includes permanently installed ladders and catwalks.
- c. Maintaining a construction schedule that allows the test and balance (TAB) firm to complete contract work prior to occupancy.
- d. Verifying the installation's conformity to the design drawings and specifications.
- e. Providing the TAB agency with a complete set of design and as-built construction drawings and an approved set of equipment submittals.
- f. Promptly correcting deficiencies of materials and work that may delay completion of the TAB work.
- g. Providing operation and maintenance manuals. Manual contents are defined as the manufacturers' data on the HVAC equipment installed and must include the following:
  1. The manufacturers' method for adjusting and setting components for correct operation under actual load conditions;
  2. The manufacturers' recommended tolerance for maximum and minimum operating conditions;
  3. The recommended correction, or  $A_x$  factors, to allow adjustment of flow, rpm, etc.;
  4. A list of spare parts, identification numbers, and diagrams of their proper locations; and
  5. Pressure drops for air and hydronic flows through the component or unit at design flow rate.

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## 1.1 Contractors' Responsibilities Prior to Balancing (continued)

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- h. Starting up all HVAC systems, according to the following conditions:
1. Proper lubrication of rotating or sliding parts is verified.
  2. Motors, fans, and all HVAC equipment have the correct rotation.
  3. Installation of the correct drive (package) is checked.
  4. Belt tension is appropriate for the type of drive.
  5. Vibration isolators and bases are properly installed and are the correct type.
  6. Smoke and fire damper operation (left in full open position) is correct.
  7. Volume and control dampers (left in a neutral or wide open position) function properly.
  8. Verification that duct-leakage test has been performed and ducts are sealed to the minimum tolerance specified.
  9. Verification that all registers, grilles, and diffusers are of the correct type, are properly installed, and are in the open position.
  10. Verification that all terminal boxes are the correct type and are properly installed according to the manufacturer's recommendations.
  11. Verification that motors, starters, and variable speed controllers with overload safety devices are the correct size and are operating properly.
  12. Verification that automatic controls are installed correctly and include all components specified, including interlocks, freeze stats, damper controllers, minimum positioning switches, control valves, actuators, and sensors.
  13. Verification that hydronic pumps and related components are properly installed and operate correctly.
  14. Verification that strainers are clean and that the system is vented and free of air. And verification that expansion tanks are properly installed and working.

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## **1.1 Contractors' Responsibilities Prior to Balancing (continued)**

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15. Verification that coils are piped correctly and are clean.
  16. The motor, amps, volts, and rpm, are compared with nameplate data and are adjusted within a motor-rated hp or amperes.
  17. Verification that fan and pump hp and rpm are within design.
  18. Verification that DDC systems (if any) are complete and operational.
  19. Verification of the correct type, quantity, and cleanliness of installed filters.
- i. Providing the balancing agency with a complete set of drawings, specifications, approved equipment submittal, a project schedule, and a list of changes made from the design before arriving on site to balance the project.

### 1.1-2 Operations during testing and balancing:

- a. The contractor/owner operates and maintains all systems requiring balancing during the balancing period.
- b. The contractor/owner is responsible for the power and fuel consumption needed to complete the project.
- c. The control contractor is responsible for ensuring that the control system responds to the testing and balancing requirements.
- d. The contractor/owner furnishes and installs drives and motors as required to accomplish design requirements.

### 1.1-3 Start-up Report:

The contractor/owner provides a copy of a detailed start-up report, including initial tabulated data required for the start-up of systems, to the test and balance agency for reference in the balancing work.

### 1.1-4 Joint effort of contractors:

- a. Upon completion of balancing, the TAB agency provides flows, pressures, and temperatures to the control contractor for final calibration of the automatic control system. The control contractor provides access to computerized data and equipment and/or provides operating personnel.

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### **1.1 Contractors' Responsibilities Prior to Balancing (continued)**

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- b. After balancing, the TAB agency provides waterflows, etc. to the chiller, cooling tower, and boiler contractors for final setup and performance verification.
- c. After submitting the balancing report, the TAB agency's contract is completed. If more testing and balancing is required, then this is extra work which requires a change order and additional compensation.

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## 1.2 Test and Balance Agency Responsibilities

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1.2-1 The Balancing Agency is responsible for the following:

- a. Inspects the system after notification that the system is complete, started, and operational to determine if the system is actually ready for testing.
- b. Field verifies  $A_x$  factors.
- c. Adjusts VAV boxes' minimum and maximum flows.
- d. Makes all field adjustments required for balancing.
- e. Adjusts installed drives for required rpm and CFM.
- f. Prepares a final report and documentation of balanced conditions.
- g. Documents any deficiencies that prevent the system from being properly balanced and any conditions caused by a deficiency and gives them to the responsible representative for correction. Deficiencies include, but are not limited to the following:
  1. Automatic controls are not complete or calibrated.
  2. Dampers are missing or not initially set open.
  3. The system is not operating.
  4. Filters are dirty.
  5. Strainers are not cleaned.
  6. Air is not vented from the hydronic systems.
  7. Components are missing or not working.
  8. Devices requiring balancing are not accessible.
  9. Electrical work is not complete. (TAB technicians do not attempt to turn on or connect any electrical devices).
  10. Vibration is excessive.
  11. The ductwork leaks excessively.
  12. The building's ceiling and openings are not closed.
  13. The coils shut off for any reason (TAB technicians do not open valves).

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## 1.2 Test and Balance Agency Responsibilities

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14. Main or branch steam valves are closed (TAB technicians do not open valves).

- h. TAB technician reports deficient items discovered during the work and rechecks the items once after notification that they have been corrected. If the TAB work is completed and the deficiency is not corrected, then the deficiency shall be included in the report. Any additional trips required for retesting of a corrected deficiency is considered additional work.
- i. Testing and balancing is performed during normal working hours. Any work other than normal or standard working hours will be listed in the TAB contract with the scheduled times attached. Work performed outside of normal working hours are billed at premium rates.
- j. The method of balancing described herein is the Proportional Method of balancing. The other method commonly used is the Sequential Method, which starts at the fan or pump (hydronics) and progresses to the end of the system. Either method is acceptable in these procedures, as long as the method is accurate and repeatable. Both methods require a duct traverse for accurate flow measurements.

1.2-2 The TAB agency is not responsible for the following:

- a. Installed performance versus design or required performance.
- b. Indoor Air Quality (IAQ).
- c. Delayed occupancy because the project was not scheduled with sufficient time for the balancing work.

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## **Chapter 2: BASIC MEASUREMENTS**

Associated Air Balance Council

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### **2.1 Instrumentation Requirements and Calibration Data**

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2.1-1 This procedure applies to the following:

- a. Air Balancing
- b. Hydronic Balancing
- c. Sound Measurements
- d. Vibration Measurements

2.1-2 This procedure does not apply to the following:

Test Laboratory instrumentation

2.1-3 Air Balance Instrumentation:

a. Manometers

1. Liquid

- 0 to 10" inclined and vertical scale
- 0 to 1" inclined ( Scale = .005")
- Calibration: none, keep fluid and manometer clean

2. Digital

- Accuracy:  $\pm 2\%$
- Calibration: once per year or sooner if damaged

b. Air Differential Pressure Gauges

- Magnehelic® Linkage Type
- 0 to 0.5" WC
- 0 to 1.0" WC
- 0 to 2.0" W.C.
- 0 to 4.0" W.C.

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## 2.1 Instrumentation Requirements and Calibration Data (continued)

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- 0 to 8.0" W.C.
  - Accuracy:  $\pm 10\%$  of full scale
  - Calibration: Once a year or sooner if damaged, check before using on daily test.
- c. Pitot tubes with a correction factor of 1
- 18" Tube with ellipsoidal nose
  - 24" Tube with ellipsoidal nose
  - 36" Tube
  - 48" Tube
  - 60" Tube
  - Accuracy: Standard instrument, within  $\pm 2.5\%$  when used with a manometer
  - Calibration: None, keep clean and replace if damaged
- d. Anemometer—rotating vane and digital read out
- Accuracy:  $\pm 3\%$  above 200 fpm
  - Calibration: Once a year or sooner if damaged
- e. Tachometer—direct reading digital or dial read out; contact, photo, or strobe type
- Accuracy:  $\pm 2\%$  of the full scale used
  - Calibration: Once a year or sooner if damaged
- f. Power meters—clamp on type, including volt-amperage, power-factor, and kw Meters
- Accuracy:  $\pm 3\%$  of full scale used
  - Calibration: Once a year or sooner if damaged
- g. Thermometer—used for both air and hydronic balance
- Glass Stem Accuracy: within 1 scale division mark. Refer to Basic Temperature Testing Measurements procedure
  - Dial Pocket Accuracy: same as above

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## 2.1 Instrumentation Requirements and Calibration Data (continued)

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- Digital Accuracy: same as above
  - Recording Accuracy: within 0.2 Fahrenheit for data logging and 0.5 for chart recording
- h. Air capture hood—digital or analog instruments. Hoods have tops of various sizes for different outlets and inlets.
- Accuracy:  $\pm 5\%$  of full scale
  - Calibration: Once a year or sooner if damaged. Calibration may be field verified by a duct traverse on a single outlet
- i. Smoke Set—including smoke gun, candles, and smoke generator
- Accuracy: None required
  - Calibration: None required

### 2.1-4 Hydronic Balance Instrumentation

- a. Hydronic Differential Pressure Test Gauges Type - Analog or Digital:
- 0 to 50" W.C.
  - 0 to 100" W.C.
  - 0 to 100' W.C. or greater
  - Accuracy:  $\pm 1\%$  of full scale
  - Calibrated: Once a year or sooner if damaged
- b. Bourdon Tube Gauges:
- -30" HG to 30 PSI
  - 0 to 60 PSI
  - 0 to 150 PSI
  - 0 to 300 PSI
  - Accuracy:  $\pm 3\%$  of full scale
  - Calibration: Once a year or sooner if damaged

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## 2.1 Instrumentation Requirements and Calibration Data (continued)

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c. Psychometers:

- Sling degrees F
- Powered degrees F
- Accuracy: within 1 scale division for liquid thermometers and  $\pm 0.2^\circ$  F of full scale for digital
- Calibration: One time for liquid filled thermometers and once a year for digital thermometers

d. Flow meters direct readout in GPM, FPS, or PSI. In WC, feet head all, depending on meter type and/or sensor used.

- Accuracy: within 3 % of range.
- Calibration: Once a year or sooner if damaged

2.1-5 Sound Measurement:

Sound Pressure meter with an Octave Band Analyzer that meets IEC 651 TYPE1 AND ANSI S1.4 1983, TYPE1. Include calibrator, compatible microphone, wind screen, and dB(A) scale.

- Accuracy:  $\pm 1$  % of octave band tested
- Calibration: Verify with calibrator before testing each project

2.1-6 Vibration Measurement:

Vibration Meter – 0.1 to 10 ips/1 to 100 mils/10 to 1,000 Hz

- Accuracy:  $\pm 2\%$  of scale used
- Calibration: Verify with a master vibration source. Calibrate once a year and factory calibrate as required

2.1-7 Optional Instruments:

a. Air Balance:

- Electronic temperature and barometric pressure-corrected manometer
- Digital/Analog Micro-Manometer

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## 2.1 Instrumentation Requirements and Calibration Data (continued)

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- Photo Tachometer
- Duct-Leakage Test Kit
- Accuracy: within  $\pm 2$  % of range used.
- Calibration: Once a year as applicable.

b. Hydronic Balance:

- Digital, non-intrusive clamp on ultrasonic flow meter or equivalent.
- Accuracy: shall be  $\pm 2$  % of full scale used
- Calibration: Set meter at zero before testing and verify with venturi flow meter once a year. Factory calibrate as required.

2.1-8 Calibration:

Follow manufacturer's procedures for calibrating instruments, and trace calibration to the National Bureau of Standards.

- Perform calibration once a year, as noted above, or as directed by manufacturer's data.
- Verify accuracy and maintain a log of measurements every six months for each instrument. This verification can be performed in a test and balance agency's lab or another approved test procedure.
- Display calibration verification tags on all instrumentation and keep them up to date.

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## 2.2 Electrical Power Measurements

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2.2-1 This procedure applies to the following:

- a. Motor electrical test
- b. Power supply system test
- c. Electric/electronic air filtering units test
- d. Electric resistance heating coils test
- e. Variable frequency drive test

2.2-2 This procedure does not apply to the following:

- a. Small fan units without accessible disconnect switches or starters
- b. Any electrical system without a safe means for testing

2.2-3 Operation:

Before the test and balance technician starts the procedure, all electrically operated systems and/or equipment shall be on-line and operating with the proper size overload heaters installed in the starter.

2.2-4 Inspection:

Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies and proceed when they are corrected.

2.2-5 Instrumentation:

- a. Use instrumentation appropriate for the measurement
- b. Frequency speed controllers should have the power readings taken at the controller's source (line side); this location includes controller and motor inefficiencies.
- c. Measurement accuracy: within  $\pm 3\%$

2.2-6 Procedures:

- a. Electrical data measurements include the following:
  - 1. Amperage readings on each phase

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## 2.2 Electrical Power Measurements (continued)

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2. Voltage readings on each phase
  3. Balanced and unbalanced kw readings, when applicable
  4. Power factor, when applicable
  5. Phase indication, when applicable
  6. Additional data as required to verify performance
- b. Take motor kw measurements to verify horsepower before recommending the changing of motors.
  - c. Comply with proper safety procedures, including the use of electrical gloves when taking power readings on high-voltage equipment.
  - d. Record electrical test readings on approved forms that correspond to the equipment being tested.
  - e. Alternate procedure for variable frequency drives:
    1. If a test is required between the controller and motor, then confirm that the controller speed is set to 100 %. Verify factors, load, and operating efficiencies, which can vary widely, with the controller and motor manufacturers.
    2. If load or amperage readings are desired at different motor speeds, then verify correction factors of controller and motor. Do not exceed critical fan speeds.

### 2.2-7 Reports:

- a. Perform electrical power tests on motors before and after fan speed adjustments.
- b. Record power data on approved forms upon completion of balancing.
- c. Include nameplate data in the motor report with the following minimum data:
  1. Manufacturer
  2. Number of speeds (if more than one)
  3. Horsepower (hp)
  4. Revolutions per minute (rpm)

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## 2.2 Electrical Power Measurements (continued)

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5. Amperage (amps)
  6. Voltage (V)
  7. Phase
  8. Service factor
  9. Frame number
- d. Include starter overload size, manufacturers and rating in the report.
  - e. For electric heating coils, measure the kilowatts (kw) directly or measure the amperage, voltage, phase, and power factor and calculate the kw.

### 2.2-8 Compliance:

- a. Upon completion of balancing, measure and record the final power consumption of the equipment.
- b. List unsafe or improper wiring and devices observed.
- c. Assume the frequency is 60 Hz, unless noted otherwise.
- d. Record the phase.
- e. Record the voltage.
- f. Record the kw measurements as required on the forms.
- g. Verify and record that the motor amperage is within the nameplate rating.
- h. Verify and record the starter overload heater manufacturer size and rating for nameplate amps.

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## 2.3 Rotational Speed Measurements

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2.3-1 This procedure applies to the following:

- a. Motor speed test
- b. Fan speed test
- c. Pump speed test
- d. Two-speed motor test
- e. Variable speed drive test

2.3-2 This procedure does not apply to the following:

- a. Direct drive motors without testing access
- b. In-line fans without safe means of testing

2.3-3 Operation:

- a. Verify that rotating equipment is on-line.
- b. Confirm that access to equipment shafts is available for testing.

2.3-4 Inspection:

Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.

2.3-5 Procedures:

- a. Select the type of instrument required for the test.
- b. Remove the belt guards on each unit with the unit off.
- c. Turn the unit on and, with adequate clearance, measure rpm.
- d. Take final rpm measurements with the unit at balanced conditions.
- e. Measure rpm at each speed mode of operation.
- f. Take motor rpm measurements to verify the motor load. Rpm changes with load on the motor, which affects the fan or pump rpm.

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### 2.3 Rotational Speed Measurements (continued)

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- g. Adjust drives and belts as required while the belt guard is off. It is the responsibility of others to replace motors and drives. The TAB agency's responsibility is adjustment.
- h. Verify that vibration isolators are properly installed.
- i. Verify that the drive alignment is correct.
- j. Verify that belt tension is correct.
- k. Reinstall the belt guard with the unit off.
- l. Comply with proper safety procedures, including preventing loose clothing or hair from being caught in the rotating components.
- m. Record all rotational test measurements on approved forms that correspond with the equipment tested.
- n. Use a photo tachometer or strobe when access will not allow a direct reading tachometer to be used.

#### 2.3-6 Instrumentation:

- a. Verify that instrumentation is of the accuracy indicated in section 2.1.
- b. Refer to section 2.1 for acceptable test equipment.

#### 2.3-7 Reports:

- a. Perform the speed test (rpm) before and after the speed adjustments. Test both driver and driven speeds.
- b. Record final speed (rpm) data and all modes of operating speeds upon completion of balancing.

#### 2.3-8 Compliance:

- a. Adjust speed (rpm) on equipment to obtain design flow or specified conditions within the limits of the components.
- b. Record deficiencies.
- c. Record final data in the report.

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## 2.4 Static Pressure Profile

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2.4-1 This procedure applies to the following:

- a. Supply air fans
- b. Return air fans
- c. Exhaust air fans
- d. Relief air fans
- e. Make-up air fans

2.4-2 This procedure does not apply to the following:

- a. Fan coils and unit ventilators that serve one room
- b. Water systems

2.4-3 Operation:

The contract representative should notify the balancing agency that the systems are ready and that the equipment is in operation before the start of testing and balancing.

2.4-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies and proceed when they are corrected.
- b. Inspect and confirm that all devices are installed according to contract specifications and manufacturer's documents. The system should be completely installed before beginning procedures.

2.4-5 Procedures:

- a. Take the fan suction pressure at the eye of the fan wheel inlet or fan inlet plenum. Do not include inlet vanes.
- b. Take the fan discharge pressure at the discharge of the fan outlet. If the fan has an outlet damper as part of the fan, do not include the damper. Fan pressure data, along with the fan rpm, motor brake horsepower, and fan curve can be used to determine the fan performance and system effect.

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## 2.4 Static Pressure Profile (continued)

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- c. Measure the external static pressure in the unit supply outlet duct and at the unit return air inlet duct. The external unit pressure equals the supply outlet duct pressure minus the return inlet duct pressure.
- d. Measure the pressure losses across each related device in the unit, i.e., filters, heating coils, cooling coils, damper sections, etc.
- e. For static controlled systems, measure and record the static pressure at the control static pressure sensor location.
- f. Compare and review static pressure measurements against the manufacturer's submittal data for differences that could affect the system performance.

### 2.4-6 Instrumentation:

- a. Inclined or digital manometer or Magnehelic® gauge
- b. Connect the Pitot tube or static probe to the manometer with tubing and take these measurements.

### 2.4-7 Report:

- a. Measure the total fan static and external static pressure to evaluate the system.
- b. Include the following data in the balancing report:
  - 1. Total fan static pressure
  - 2. Unit external static pressure
  - 3. Pressure loss across filters, all coils, and any additional component in unit that creates a pressure drop
  - 4. A diagram of all data on a drawing of the unit

### 2.4-8 Compliance:

A pressure profile drawing with pressure data is required to comply with this procedure.

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## 2.5 Pitot Tube Traverse

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2.5-1 This procedure applies to the following:

- a. All supply air-ducted systems
- b. All return air-ducted systems
- c. All exhaust air-ducted systems
- d. Outside air-intake ducts

2.5-2 This procedure does not apply to the following:

- a. Small fan coil units without ductwork
- b. Roof type exhaust fans without ductwork
- c. Propeller fans without ductwork

2.5-3 Operation

The fan system must be in operation before the test and balance technician begins the traverse procedure.

2.5-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Confirm that the duct traverse meets the following criteria:
  - 1. The test accuracy, including instrumentation, must be within  $\pm 5\%$ .
  - 2. The results must be repeatable at the traverse location.
  - 3. Set airflow within the design limits and/or system limits.

2.5-5 Instrumentation:

- a. A Pitot tube of proper length to traverse duct
- b. A manometer that can measure the velocity pressure range of the traverse accurately.

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## 2.5 Pitot Tube Traverse (continued)

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### 2.5-6 Procedures:

- a. To accomplish repeatable traverse measurements, take the measurements in a specific, measured pattern. There are two acceptable methods:
  1. The equal area method
  2. The log *Tchebycheff* method
- b. Use tables in the *AABC National Standards* for setup requirements for either method.
- c. Locate a traverse position in a straight section of duct.
- d. Duct size must not change in a traversed section.
- e. Face the Pitot tube into the airstream and parallel to the airstream before taking measurements.
- f. Convert velocity pressure to fpm velocity before averaging.
- g. Take traverse measurements at actual conditions and actual cubic feet per minute (ACFM). Correct ACFM to standard CFM (SCFM) when specified.
- h. Verify that velocity measurements are acceptable. *AMCA Publication 203-90* states that a traverse plane is suitable for flow measurements if more than 75 % of the velocity pressure readings are greater than 1/10 of the maximum velocity measurement.

### 2.5-7 Report:

- a. Include space for all measurements and recorded data for correcting actual conditions to standard conditions.
- b. Refer to the Report Contents procedure.

### 2.5-8 Compliance:

- a. Determine all ducted equipment airflow CFM by the Pitot tube traverse method.
- b. Refer to the Anemometer Coil Traverse procedure for an alternative traverse method when duct traverses are not possible.

---

## 2.6 Anemometer Coil Traverse

---

2.6-1 This procedure applies to the following:

- a. Large fan systems and fan systems where the measured coil is a full airflow coil in a series of coils
- b. Any single coil that is accessible for measurements

2.6-2 This procedure does not apply to the following:

- a. Small fan coil units with ductwork
- b. Systems where the procedure may be hazardous

2.6-3 Operation:

- a. Coils must be accessible, and fan inlet must be covered with a safety screen.
- b. The fan should be on in the normal mode during the test.
- c. Coil bypass dampers should be closed.
- d. Any openings that allow air to bypass the coil should be sealed closed.

2.6-4 Inspection:

Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies and proceed when they are corrected.

2.6-5 Procedures:

- a. Include the following information from the field in calculation documentation, as the ASHRAE RP451 method requires.
  1. Face area of the coil in square feet
  2. Size of the tubes in the coil in inches
  3. Spacing of the tubes in inches
  4. Number of fins per inch on tubes
  5. Number of rows of tubes



---

## 2.6 Anemometer Coil Traverse (continued)

---

h. Average velocity fpm squared                    x            - 8.68316E-8

i. Final factor = base + 0.652 plus sum of other corrections (c through h)

6. Take coil velocity on grid lines in fpm; add and divide by the number of readings to obtain the average fpm.

7. Total area of coil x final factor x average fpm = actual CFM.

8. Actual CFM x density correction = standard CFM

2.6-6    A project example:

a. The only coil you consider is the one you can measure. Only coils in parallel count for flow measurements. When coils are stacked in a series only be concerned with the one coil face with which you can take measurements and use that coils characteristics for factor correction. For example, there is a preheat, a cooling coil, and a reheat coil stacked so there is no space between them. Your only concern is the reheat coil if it is the same as other coils in face size. All the air must flow through the measured coil(s).

1. Coil size 144" X 48" four coils form a bank = 192 Square feet

2. Base factor +0.6520452

3. Corrections to base factor:

4. Number of rows        8        x        +0.0009719    =    +0.0077752

5. Number of fins/inch    8        x        - 0.0067451    =    - 0.053960

6. Tube space "            1.5      x        +0.0473699    =    +0.0710548

7. Tube diameter " +0.625    x        - 0.0911169    =    - 0.0569480

8. Average velocity fpm 600    x        +0.0001762    =    +0.1056978

9. Average velocity squared 360000 X - 0.000000086316 = +0.0312594

10. Correction        =        +0.0424

11. Add to base        +0.6520452

12. Total correction factor = +0.6944270

13. CFM        = 192 X 600 X 0.6944270 = 79998 ACFM

---

## 2.6 Anemometer Coil Traverse (continued)

---

### 2.6-7 Instrumentation:

The instrument used by the ASHRAE research project was an Airflow Developments Limited EDRA-6 Electronic Direct Reading Anemometer. An Airflow Developments limited LCA-6000 Electronic Direct Reading Anemometer works equally as well. The factors used here are based on a four-inch rotating vane head.

### 2.6-8 Limitations:

- a. This alternative method for determining airflow through a large air-handling system is accurate and meets the traverse quality of determining airflow measurements. Perform it exactly as noted.
- b. This method is recommended for any system where duct traverse is impossible and there is sufficient space to take coil measurements. Smaller system coil traverse is possible as long as the rotating vane head is flat on the coil. The ERDA-6 or the DVA model heads can be screwed on a rod and traverse through holes properly spaced in the unit casing at the coils. All the above factor data must be obtained for calculation of the airflow.
- c. When there are two different full-size coils back to back, only take data from the one measured.
- d. Like a duct traverse, airflow must be uniform or the traverse may not be accurate.

### 2.6-9 Report:

- a. Calculate the report with the research numbers included in this procedure. Use the formula in this procedure to calculate the final factors as soon as the traverse fpm is inserted with the coil data specified above.
- b. Correct the actual CFM from the above calculations for SCFM, and include it in the report, if required.
- c. Refer to the Report Contents procedure for additional requirements.

---

## **2.6 Anemometer Coil Traverse (continued)**

---

2.6-10 Compliance:

- a. Use the research numbers shown and the four-inch head electronic anemometer described to measure airflow through the coil.
- b. Calculate the results, as described in this procedure. Apply results to the actual coil area with correction factors to obtain the actual CFM and then correct for density to obtain SCFM, or standard air, if required.

---

## **2.7 Drive Adjustments for Testing and Balancing**

---

2.7-1 This procedure applies to the following:

All equipment that is belt driven.

2.7-2 This procedure does not apply to the following:

Non-belt driven equipment

2.7-3 Operation:

Before beginning or inspecting for balancing, the contract representative notifies the balancing agency that systems are ready, and equipment is in operation.

2.7-4 Inspection:

Inspect and confirm that all devices are installed according to contract specifications and manufacturer's recommendations.

2.7-5 Procedures:

- a. Verify drive and initial operating condition:
  1. Check alignment of drives and motor.
  2. Check drive and belts and adjust if necessary.
  3. Check belt tension and wear.
- b. It is the mechanical contractors' responsibility to install and make initial drive settings for all HVAC equipment.
- c. Adjust all drives, as required, to obtain design CFM for the system without overloading the installed motors.
- d. If the drives cannot be adjusted to obtain the required airflow, then provide the contractor with the required drive information and list the information on a deficiency report.
- e. If the motor horsepower is insufficient, then notify the design engineer and provide the field data to evaluate the deficiency.

---

## **2.7 Drive Adjustments for Testing and Balancing (continued)**

---

### **2.7-6 Report:**

List all drive data in the balancing report on the fan data sheet. Refer to the Report Contents procedure.

### **2.7-7 Compliance:**

- a. Drives of the correct type are used.
- b. Drives are properly aligned.
- c. Obtain the rpm required for the design CFM or list recommended requirements and data for the design engineer's review.

---

## 2.8 Basic Temperature Testing Measurements

---

2.8-1 This procedure applies to the following:

- a. Airstream temperature measurements
- b. Waterstream temperature measurements
- c. Ambient air temperature measurements

2.8-2 This procedure does not apply to the following:

Refrigeration Measurements

2.8-3 Operation:

Verify that equipment is in operation before starting inspection for balancing according to the Prerequisites for Balancing.

2.8-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies and proceed when they are corrected.
- b. Inspect and confirm that all balancing devices are installed according to contract specifications and manufacturer's submittal.
- c. List any deficiencies that prevent proper testing and balancing.

2.8-5 Procedures:

- a. Determine the type of measurements to be made and select a thermometer appropriate for the test.
  1. Airstream: Scale = 0.5° F with 0.2° F accuracy for range 30° F to 120° F
  2. Airstream: Scale = 1° F with 0.5° F accuracy for range 120° F plus
  3. Waterstream: Scale = 0.1° F with 0.2° F accuracy for testing chilled and condenser water
  4. Waterstream: Scale = 1° F with 0.2° F accuracy to test hot water greater than 120° F

---

## 2.8 Basic Temperature Testing Measurements (continued)

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5. Ambient Air: Scale = 1° F with 0.5° F accuracy for field sling psychrometer to determine temperature and comfort of relative humidity
6. Ambient Air: Scale = 0.2° F with 0.2° F accuracy for cooling tower wet bulb testing or critical temperature and humidity controlled areas
7. Performance and Witness Test: Scale = 0.1° F with 0.2° F accuracy
  - b. Use thermometers with current calibration records and compare them to each other for a matched set at the time of the test.
  - c. Immerse thermometers to the point required for accurate measurements according to the manufacturer's directions.
  - d. The test location for a single point measurement should be at the average fluid temperature (air or water). If the average temperature cannot be taken at one location, then take multiple points in a traverse fashion and record the average. Test wells in pipes, must protrude into the pipe to allow for accurate measurement (approximately 50 % of the pipe diameter). Add heat transfer fluid to wells for accurate temperature measurements.
  - e. Avoid effects of radiation, i.e., avoid measuring next to an electric heating coil element.
  - f. Allow time for the thermometer to reach equilibrium with the fluid (air or water) being measured. Take periodic readings without removing the thermometer from the fluid until the temperature remains essentially constant more than a 30-second time period. When using a 0.1° F thermometer and conducting a field performance or witness test, once the thermometer has reached equilibrium, record three readings at five-second intervals and use the average as the station reading.
  - g. In HVAC applications, avoid surface temperature measurements unless no other method is available. The surface temperature will not be the true fluid temperature, and this method has a great deal of error. If a surface temperature is used, give great care to cleaning the pipe so there is good contact with the thermometer and the pipe. Insulate over the thermometer and pipe to reduce the ambient air effect on the temperature readings. This method is best suited to determine the temperature drop between a supply pipe and a return pipe on coils or fin tube radiation.

---

## 2.8 Basic Temperature Testing Measurements (continued)

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- h. Take wet bulb temperatures in airstreams and in ambient air using an appropriate thermometer with a cotton wick installed over the sensing portion of the thermometer. The wick should have extra length to help retain moisture during the measurement period, and may be extended to a water reservoir for a prolonged measurement. The wick should be wetted with distilled water for performance or witness testing. Clean fresh water is adequate for most field testing as the error, if any, is not significant. The airflow over the wick shall be approximately 1,000 fpm for wet bulb testing.

### 2.8-6 Limitations:

- a. Radiation effects
- b. Time for thermometer to reach equilibrium
- c. Proper location
- d. Separated alcohol or mercury in glass thermometers
- e. Broken wires or weak batteries in digital thermometers
- f. Accuracy of surface temperatures
- g. Hazards of mercury thermometers

### 2.8-7 Instrument types:

- a. Dial bimetal
- b. Glass stem:
  - 1. Mercury filled
  - 2. Alcohol filled
- c. Electronic/digital:
  - 1. Thermocouple
  - 2. Thermistor
  - 3. RTD

---

## **2.8 Basic Temperature Testing Measurements (continued)**

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### 2.8-8 Report:

- a. Record all temperature measurements on report forms according to the Report Contents procedure.
- b. Include enthalpy values with wet bulb readings.
- c. Show all temperature measurements in degree Fahrenheit. If metric is required, show degree Fahrenheit in parenthesis after degree Celsius.
- d. Calculate capacities as required by equipment procedure and report on equipment test form. Refer to Report Contents procedure.

### 2.8-9 Compliance:

- a. Instruments of proper range and scale are used.
- b. Instruments in calibration are used.
- c. Proper location for measurements are used.
- d. *Measurements are accurate.*
- e. All measurements are properly recorded.

---

## 2.9 Sound Level Measurements

---

2.9-1 This procedure applies to the following:

- a. Office buildings
- b. Industrial complexes
- c. Medical facilities
- d. Schools
- e. Where specified

2.9-2 This procedure does not apply to the following:

- a. Homes
- b. Warehouses
- c. Where not specified
- d. Solutions to sound problems

2.9-3 Operation:

Verify that fan systems are on-line and running before the technician starts the procedure.

2.9-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. All other test and balance procedures should be completed and the system should be set at design values, unless the testing is for diagnostic purposes.

2.9-5 Instrumentation:

- a. Calibrate the sound meter prior to taking measurements. Use the calibrator provided with the equipment.
- b. Use a sound meter that includes an octave band analyzer and a dB(A) scale.

---

## 2.9 Sound Level Measurements (continued)

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- c. Use a microphone suitable for the type of noise levels measured that is compatible with the meter. Provide a windshield for outside or in-duct measurement.
- d. Verify that noise levels conform as specified. If not specified, then use the levels shown in ASHRAE handbooks or the Kahoe Field Manual as guide lines for data evaluation.
- e. Use a sound meter that meets IEC 651 type 1 and ANSI S1.4, 1983 type 1.
  - 1. It should be equipped with a calibrator, compatible microphone, windscreen, octave band analyzer, and dB(A)-weighted scale.

### 2.9-6 Procedures:

- a. Record a set of background measurements in dB(A) and eight unweighted octave bands (63 Hz to 8,000 Hz) with HVAC system or fan in question off. Background readings shall be taken according to the specifications.
- b. Take sound readings in dB(A) and eight unweighted octave bands (63 Hz to 8,000 Hz) with the equipment on. Take readings no closer than three feet from a wall or from the operating equipment and approximately five feet above the finished floor, and only in areas specified. If areas are not specified, then take readings in rooms adjacent to the mechanical rooms and in any area where the system or air distribution creates noticeable sound levels.
- c. Noise levels cannot be averaged by adding and dividing by number of measurements. See the ASHRAE Handbook of Fundamentals for sound calculations.
- d. When taking sound measurements, make certain no unrelated personnel is in the room or space. Voices and activity will interfere with the actual noise level readings.

### 2.9-7 Report:

- a. Record complete test data on the octave band and dB(A)-approved sound test forms.
- b. Record the background test on the same form and note conditions at the time of the test.

---

## 2.9 Sound Level Measurements

---

- c. Compare test data with noise criteria curves and note if levels are acceptable.
- d. Note possible causes of any observed excessive noise levels.

### 2.9-8 Compliance:

- a. Calibrate sound test equipment before taking measurements.
- b. Where possible, trace the excessive noise level octave band to the source of the noise and comment in the report.
- c. Test sound levels at the quietest background noise period. Note any cause of unpreventable sound that will affect the test outcome.

---

## 2.10 Vibration Level Measurements

---

2.10-1 This procedure applies to the following:

- a. Pumps
- b. Fans
- c. Compressors
- d. Equipment bases

2.10-2 This procedure does not apply to the following:

- a. Pumps under 2 hp
- b. Fans under 2 hp
- c. Compressors under 2 hp
- d. Dynamic balancing
- e. Solutions to vibration problems

2.10-3 Operation:

Systems should be on-line and running before the technician starts the procedure.

2.10-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. There must be access to bearings, shaft, and motors before the test can continue. Access shall be made by others.

2.10-5 Instrumentation:

- a. Verify that the vibration meter calibration date is current before taking readings.
- b. The vibration meter used should be appropriate for measuring mils of deflection, velocity in inches per second, and frequencies in cycles per second or minute.

---

## 2.10 Vibration Level Measurements (continued)

---

- c. The accelerometer must have a clean, flat surface and be mounted properly for accurate readings. See the manufacturer's instructions.
- d. The accelerometer must be suitable for the type of vibration levels measured and must be compatible with the meter. Provide magnetic holders for the accelerometer-transducer.
- e. Vibration limits should follow specifications, or, if not specified, should follow the "Machinery Vibration Severity" chart. Acceptable levels of vibration normally are "Smooth" to "Good."

### 2.10-6 Procedures:

- a. Measure background readings with all components, or the unit in question, turned off. Take background readings for each equipment room or as required by the specifications.
- b. Take vibration measurements in mils of deflection and velocity in inches per second at the running rpm. Compare readings to the severity chart and determine if component is within specifications.
- c. With unit running, set up the vibration meter in a safe, secure location. Connect the transducer to the meter with proper cables. Hold the magnetic tip of the transducer on top of the bearing and measure the unit in mils of deflection. Record the measurement, then move the transducer to the side of the bearing, and record in mils of deflection. Record an axial reading in mils of deflection by holding the nonmagnetic, pointed transducer tip on the end of the shaft.
- d. Change the vibration meter to velocity (inches per second) measurements. Repeat and record the above measurements. For velocity measurements, also record the CPM or the rpm dial. Record each measurement.
- e. Read each bearing on motor, fan, and/or pump. Take axial readings where applicable. Track vibration in mils of deflection from the rotating component through the casing to the base and record. (Refer to vibration forms.) Note if vibration isolators are effective or not, and if they are installed properly.

### 2.10-7 Report:

- a. Record complete test data on approved test forms. Refer to the Report Contents Procedure.

---

## **2.10 Vibration Level Measurements (continued)**

---

- b. Include horizontal-vertical-axial measurements for all tests, where applicable.
- c. Include deflection and velocity measurements for all tests.
- d. Include the Machinery Vibration Severity Chart with conditions plotted with the report.
- e. Include recommendations as necessary and applicable.

### **2.10-8 Compliance:**

- a. The testing meets the requirements of this procedure.
- b. The vibration instrumentation is calibrated and of the proper type for the test application.
- c. The equipment performance meets the minimum requirements of the project specification.

---

## **2.11 Velocity Measurements at Grilles, Registers, Diffusers, & Openings**

---

2.11-1 This procedure applies to the following:

- a. Supply, return, and exhaust Grilles, Registers and Diffusers
- b. Intake louvers
- c. Open ducts

2.11-2 This procedure does not apply to the following:

- a. Coils
- b. Fume hoods
- c. Other velocity measurements

2.11-3 Operation:

The fan system shall be operating before beginning this procedure.

2.11-4 Inspection:

- a. Inspect the system to confirm that it is operating properly, and that the air distribution is properly installed.
- b. Verify that the volume dampers and deflection have been set wide-open and in the neutral position.
- c. Grille will be used hereafter to mean Register, Diffuser, or Grilles

2.11-5 Procedures:

- a. Measure the grille velocity according to the instrument manufacturer's directions. Take readings on an equal grid pattern and average to determine the grille velocity. Use six-inch centers (or less) on any dimension more than eight inches. For dimensions eight inches or less, only one reading is required. For example, a 12 x 8-inch grille requires two readings; a 12 x 10-inch grille requires four readings. Nominal grille size is used for the grid determination. For velocity instruments that measure less than 1.5 inches in diameter, double the number of readings.
- b. Using the traverse procedure, perform a Pitot tube duct traverse of the air-flow serving a grille to determine the volume of airflow through the grille.

---

## 2.11 Velocity Measurements at Grilles, Registers, Diffusers & Openings (continued)

---

- c. Use the traversed CFM, the measured grille velocity, and the inside (core) area of the grille to determine the  $A_x$  factor and the correction factor to be used. Use this factor on grilles of the same style and similar size, if other traverses produce similar results.
- d. The air distribution manufacturer's  $A_x$  factor for the instrument, and the grille can be used only after it proves to be within 10 % of the field test by Items "b" and "c" above.
- e. When measuring the velocity, the instrument must remain at the center grid point until the reading is obtained. "Averaging" by moving the instrument across the grille is not acceptable.
- f. Once the  $A_x$  factor is determined, calculate the grille CFM from the measured velocity.

### 2.11-6 Instrumentation:

- a. Any type of velocity-measuring instrument can be used, however, thermal anemometers are not encouraged, as they are extremely position sensitive.
- b. Pitot tube and manometer are necessary for  $A_x$  factor development.

### 2.11-7 Report:

- a. Record the area served, air device number, size,  $A_x$ , design and test velocity and design and test CFM. Refer to Report Contents procedure.
- b. Record traverse used to determine  $A_x$  factor along with calculations validating the results.

### 2.11-8 Compliance:

- a. Compliance is met when this procedure has been completed, and when the report contents meet with the design, barring any limitations of the system.
- b. Any deficiencies or system limitations should be resolved or noted in the report.

---

## 2.12 Air Capture Hood Flow Rate Measurements

---

2.12-1 This procedure applies to the following:

- a. Air distribution with either positive or negative flow
- b. Openings of suitable size and within flow range and instrument limits

2.12-2 This procedure does not apply to the following:

Uses not recommended by the manufacturer

2.12-3 Operation:

The fan system shall be in operation before beginning this procedure.

2.12-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies and proceed when they are corrected.
- b. Verify that the balancing dampers are set wide-open and in the neutral position.

2.12-5 Procedure:

- a. Set up the capture hood according to the manufacturer's instructions.
- b. Place the hood over the air distribution opening; adjust meter to proper scale, if required; and measure flow rate. Some instruments are position sensitive, and must be zeroed for the position of measurement.
- c. Determine if CFM must be corrected because of hood back pressure effect or density correction. If so, correct CFM and record.
- d. Verify back pressure factors indicated by the manufacturer and used in this procedure by comparing to a Pitot tube traverse. Select a corrected air device, and perform a Pitot tube traverse according to traverse procedures. Compare the traverse results to the corrected result to verify accuracy. If the two-volume measurements do not match within 10 %, then select another corrected air device and perform another Pitot tube traverse. Repeat until consistent correction factors are verified or a reliable field-developed correction factor curve is obtained.

---

## **2.12 Air Capture Hood Flow Rate Measurements (continued)**

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### 2.12-6 Instrumentation:

- a. Manufactured air capture hood
- b. Pitot tube and manometer to verify back pressure correction factors and field calibration checks
- c. Verify instruments are calibrated to the same traverse and read within 5% of each other.

### 2.12-7 Report:

- a. Record area served, air device number, size, design CFM, and test CFM.
- b. Record traverse used to verify back pressure correction factor.

### 2.12-8 Compliance:

- a. Compliance is met when this procedure has been completed, and when the report contents meet the design, barring any limitations of the system.
- b. Any deficiencies or system limitations must be resolved or noted in the report.

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## **Chapter 3: HVAC COMPONENT TESTING AND BALANCING PROCEDURES**

Associated Air Balance Council

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### **3.1 Fan Test and Balance**

---

3.1-1 This procedure applies to the following:

- a. Built-up fan systems
- b. Single fans with ductwork
- c. Exhaust fans with ductwork
- d. Return/relief fans with ductwork

3.1-2 This procedure does not apply to the following:

- a. Small direct-drive fans
- b. Roof-type exhaust fans without ductwork
- c. Propeller fans without ductwork

3.1-3 Operation:

- a. Fan systems must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed, calibrated, and fully operational.

3.1-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list the deficiencies, and proceed when they are corrected.
- b. Verify that the drives are aligned properly and are of the correct size and type. Do not balance a unit with drives out of dynamic balance or of the wrong size and type.
- c. Refer to the Prerequisite for Balancing.
- d. Verify that the fan wheel is the type and size specified.
- e. Verify that the back-draft dampers are installed properly and are open when the fan is on.

---

### 3.1 Fan Test and Balance (continued)

---

#### 3.1-5 Procedures:

- a. Check the fan for proper operating conditions with motor below full-load amperage.
- b. Measure and proportionally balance air distribution if the total is within  $\pm 20\%$  of design. If not, then investigate and make adjustments as necessary.
- c. Locate a traverse position in a straight section of duct. Refer to the Pitot Tube Traverse procedure.
- d. Traverse to determine fan airflow. Flow should be 100 to 110 % of design, assuming 0 % air leakage. If leakage is excessive, then note it as a deficiency.
- e. Adjust fan speed to obtain 100 to 110 % of design airflow (CFM). Measure the power requirements before and after adjustments.
- f. Record final air distribution flow rate.
- g. Upon completion of balancing, record the following minimum data on Report forms. Refer to the Report Contents procedure.
  1. Fan design data
  2. Airflow CFM from duct or coil traverse, corrected to SCFM, if required. Traverse duct according to the Pitot Tube Traverse, procedure.
  3. Power measurements, according to the Electrical Power Measurement procedure
  4. Test kw (if applicable)
  5. All nameplate data
  6. Test motor rpm and fan rpm
  7. Design motor and fan rpm
  8. Drive sizes, belt type, size, and number
  9. Center-to-center distance and motor-base travel
  10. Static pressure profile according to the Static Pressure Profile procedure
  11. Design fan static pressures

---

### **3.1 Fan Test and Balance (continued)**

---

- h. Verify that the controls associated with the fan are operating properly and that sensors have been calibrated.
- i. Set and verify that dampers associated with the fan are operating properly in all specified modes.
- j. Observe the fan operation for excessive noise and vibration. Report excessive noise or vibration to an appropriate representative.
- k. When sound and vibration test are specified follow the:
  - 1. Sound Testing and Noise Level Measurements procedure
  - 2. Vibration Testing and Level Measurements procedure

#### **3.1-6 Report:**

- a. List items not corrected on the deficiency report form and submit it with the report.
- b. Record all test data on an approved fan data sheet.

#### **3.1-7 Compliance:**

- a. To comply with this procedure, complete all of the above steps and record all data on the report forms.
- b. All deficiencies that affect the TAB work should have been resolved by the installing contractors or should be included in the deficiency report.

---

## **3.2 Air-Handling Unit (AHU) Test and Balance**

---

3.2-1 This procedure applies to the following:

- a. Built-up fan systems with ductwork
- b. Multi-zone units with ductwork
- c. VAV air-handling units with ductwork
- d. Rooftop units with ductwork

3.2-2 This procedure does not apply to the following:

- a. Small direct-drive fan-coil units
- b. Unit ventilators or units without ductwork
- c. Unit heaters without ductwork

3.2-3 Operation:

- a. AHU systems must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed, calibrated, and fully operational.

3.2-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list the deficiencies, and proceed when they are corrected.
- b. Verify that the drives are installed properly and are of the correct size and type. Verify that the inlet vanes are working.
- c. Refer to the Prerequisites for Balancing.
- d. Verify that the fan wheels are on a single shaft. If they are on a split shaft, then verify that the shafts are properly connected to the drive end.
- e. Verify that the filters are clean and of the correct size and type.
- f. Verify that the coils are piped correctly.

---

## 3.2 Air-Handling Unit (AHU) Test and Balance (continued)

---

### 3.2-5 Procedures

- a. Check the fan for proper operating conditions and that the motor is below full-load amperage.
- b. Measure and proportionally balance air distribution if the total is within 20 % of design. If not, investigate and make adjustments as necessary.
- c. Locate a traverse position in a straight section of duct. Refer to the Pitot Tube Traverse procedure.
- d. Traverse to determine fan airflow. Flow should be 100 to 110 % of design. This assumes 0 % air leakage.
- e. Adjust fan speed to obtain 100 to 110 % of design air flow (CFM).
- f. Measure power requirements before and after adjustments.
- g. Test multi-zone dampers for leakage from the hot deck when on full cooling by measuring the zone duct temperature. Refer to the Mixing Damper Leakage-Test procedure. Zone temperature should be the same as the temperature leaving the cooling coil. If there is a bypass damper instead of a hot deck, then verify that the bypass damper does not leak in excess of specified limits. Reverse the process for testing the cold deck dampers.
- h. Set the outside air minimum by Pitot tube duct traverse. Refer to the Constant Minimum Outside Air Test and Balance procedure.
- i. Upon completion of balancing, record the following minimum data on report forms. Refer to the Report Contents procedure.
  1. Unit design data
  2. Airflow CFM from duct or coil traverse, corrected to SCFM, if required. Traverse duct according to the Pitot Tube Traverse procedure
  3. Power measurements, according to the Electrical Power Measurement procedure
  4. Test kw (if applicable)
  5. All nameplate data
  6. Test Motor rpm and fan rpm
  7. Design motor and fan rpm

---

### **3.2 Air-Handling Unit (AHU) Test and Balance (continued)**

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8. Drive sizes, belt type, size, and number
  9. Center-to-center distance and motor-base travel
  10. Static pressure profile according to the Static Pressure Profile procedure
  11. Design unit static pressures
  12. Temperatures across coils according to the Coil Capacity Testing procedure
- j. Verify that the controls associated with the unit operate properly and that the sensors are calibrated.
  - k. Set and verify that the dampers associated with the unit operate properly in all specified modes.
  - l. Observe the unit's operation for excessive noise and vibration. Report excessive noise or vibration to the appropriate representative.
  - m. When sound and vibration test are specified follow the:
    1. Sound Testing and Noise Level Measurements procedure
    2. Vibration Testing and Level Measurements procedure

#### **3.2-6 Report:**

- a. List items not corrected on the deficiency report form and submit it with the report.
- b. Record all test data on an approved AHU data sheet.

#### **3.2-7 Compliance:**

- a. To comply with this procedure, complete all of the above steps and record all data on the report forms.
- b. All deficiencies that affect the TAB work should have been resolved by the installing contractors or should be included in the deficiency report.

---

### **3.3 Constant Minimum Outside Air Test and Balance**

---

3.3-1 This procedure applies to the following:

- a. Heating, ventilating, air-conditioning, and DX (refrigeration) systems and related components that supply outside air directly to other units or to occupied spaces
- b. Minimum air quantities for IAQ requirements
- c. Make-up air for exhaust and pressurization

3.3-2 This procedure does not apply to the following:

Variable outside air systems

3.3-3 Operation:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.

3.3-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list the deficiencies, and proceed when they are corrected.
- b. Verify that the drives are installed properly and are of the correct size and type.
- c. Refer to the Prerequisites for Balancing.
- d. Verify that the fan wheels are on a single shaft. If they are on a split shaft, then verify that the shafts are properly connected to the drive end.
- e. Verify that the filters are clean and of the correct size and type.
- f. Verify that the coils are piped correctly.

3.3-5 Procedures:

- a. Set and test the outside air minimum required by the specifications.
- b. Balance the systems that distribute outside air directly to the space to the quantities specified.

---

### 3.3 Constant Minimum Outside Air Test and Balance (continued)

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- c. On systems that distribute outside air directly to other air-handling units, verify that the outside air is properly mixed with the return air so the mixed-air temperature is uniform entering the coil. If the air temperature is not uniform, then include as a deficiency.
- d. Verify that the outside air quality remains constant under all modes of operation.
- e. Test and set the outside air and verify that the minimum CFM stays constant. Verify that the outside system air operates when occupied and when the exhaust system is on.
- f. Measuring and setting outside air:
  - 1. The preferred method of measuring outside air is by duct traverse. Refer to the Pitot Tube Traverse procedure.
  - 2. The mixed air temperature method only applies if the temperature differentials are a minimum of 20° F to allow accurate measurements.
  - 3. An air capture hood is an acceptable method for measuring small outside air requirements, such as a unit ventilator or fan coil unit.
  - 4. Velocities at intakes are acceptable when an appropriate  $A_x$  factor can be field determined by Pitot tube traverse.

#### 3.3-6 Report:

Record all test data on the proper test data sheet. Refer to the Report Contents procedure.

#### 3.3-7 Compliance:

- a. This procedure is complied with when the specifications are met and the specification for the above minimum conditions are listed.
- b. Outside air make up for building exhaust is also a consideration required in balancing the outside air, and should be reported if not included in the minimum outside air requirement.

---

## 3.4 Mixing Damper Leakage Testing

---

3.4-1 This procedure applies to the following:

All HVAC systems with mixing dampers

3.4-2 This procedure does not apply to the following:

Other damper configurations

3.4-3 Operation:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.

3.4-4 Procedures:

- a. Dampers must be the tight, shut-off type.
- b. Set the mixed-temperature thermostat to activate one damper to fully-open position and the other to fully-closed position.
- c. Measure the temperature in the hot deck (or bypass), the cold deck, and the-mixed airstream.
- d. Calculate percent leakage and record all temperatures and percentages on report forms.
- e. Report any percentage above the specified tolerance as a deficiency. If no tolerance is specified, then report any leakage above 5 %.
- f. Use the same procedure above to retest each damper after leaking dampers are reset and tight, replaced, or repaired.

3.4-5 Report:

Record test and correction data on the proper data sheet.

3.4-6 Compliance:

Compliance is met when all mixing dampers allow the mixed air temperature to be less than the allowed leakage when calling for full cool or full heat.

---

## 3.5 Coil Capacity Testing

---

3.5-1 This procedure applies to the following:

- a. Chilled water
- b. Hot water
- c. Direct expansion (DX)
- d. Steam heating

3.5-2 This procedure does not apply to the following:

Other device configurations

3.5-3 Operation:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.

3.5-4 Inspection:

Inspect the system to determine if it is operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.

3.5-5 Procedures:

- a. Measure airflow through the coil by Pitot tube traverse. Use the anemometer coil traverse if the Pitot tube traverse is not possible.
- b. Set the water flow with the flow meter or another method.
- c. Measure and record the water pressure drop across the coil and compare to the design. Only rely upon pressure drop for flow determination if other means are impossible to obtain.
- d. Measure entering and leaving air dry bulb temperatures on all coils, then measure entering and leaving air wet bulb temperatures on all cooling coils. If single point temperature measurement does not produce the average temperature, then take multiple temperatures on a grid pattern (traverse style) and use the average temperature.
- e. On water coils, measure the entering and leaving water temperatures at the same time as the air temperatures.

---

### 3.5 Coil Capacity Testing (continued)

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- f. Calculate the total coil capacity of the air side and record the BTU/hr.
- g. For water coils, calculate the gpm by heat balance and compare to the flow meter reading. Flows should match within  $\pm 10\%$ .
- h. For steam coils, measure and record the entering steam pressure.
- i. For low temperature chilled water using Glycol, record the Glycol-mixture percentage for use in heat transfer calculations.

#### 3.5-6 Condition of coils:

- a. If coils are dirty, then the capacity may be reduced.
- b. Bent or eroded fins reduce capacity.
- c. Air binding prevents proper water flow and reduced capacity.
- d. Airflow must not bypass the coil unless specifically designed to do so.
- e. Excessive airflow (coil face velocity) can cause condensate water carry over on cooling coils, increase resistance to airflow, and cause possible water damage.

#### 3.5.7 Actual capacity vs. design capacity

- a. Actual capacity is the capacity measured in this procedure.
- b. Actual and design capacity match if actual-load conditions equal design-load conditions.
- c. More than likely "b" will not occur, therefore, a part-load condition will exist. Part-load data can be obtained from the manufacturer or simulated from computer programs on coils. The test conditions should be converted to design conditions to determine if the coil will meet the design capacity. Use coil conversion charts and tables to convert the test conditions to design conditions, and indicate in the report.

#### 3.5-8 Report:

Record test and capacity data on the proper data sheet.

---

### **3.5 Coil Capacity Testing (continued)**

---

#### 3.5.9 Compliance:

- a. Compliance is met when this procedure is completed and the coil test capacity meets the design capacity with the airflow and water flow within design limits.
- b. CFM and BTU capacities are as specified.
- c. Part-load data matches field measurements under part-load conditions.

---

## 3.6 Electric Heating Coil Measurements

---

3.6-1 This procedure applies to the following:

- a. AHU heating coils
- b. Reheat coils
- c. Unit heater coils
- d. Fan coil units

3.6-2 This procedure does not apply to the following:

Other device configurations (i.e., motors)

3.6-3 Operation:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.
- c. Airflow through the heater must be within design tolerance.

3.6-4 Inspection:

Inspect the system to determine if it is operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.

3.6-5 Procedures:

- a. Measure the amperage on each leg of power input with the heater fully energized through the control device.
- b. Measure the voltage on each leg of power.
- c. Calculate kw input and record amperage, voltage, phase, and kw.
- d. Verify that no stratification exists downstream of the coil that would supply different temperature air to different areas.
- e. As an alternative method, the entering and leaving dry bulb temperature can be measured as in the air-side procedure of the Coil Capacity Testing procedure. When measuring the air temperature, take care not to include radiant heat from the coil or unmixed air directly downstream of the coil, for these lead to erroneous results.

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### **3.6 Electric Heating Coil Measurements (continued)**

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- f. Verify stages of heat energy, as required, and record the number of stages in the report.
- g. Verify that the safety devices are installed. If not, this is a deficiency that must be resolved or listed in the report.

#### **3.6-6 Condition of Coils:**

- a. If the coils are dirty, then a fire may occur or capacity may be reduced.
- b. Reduced voltage reduces capacity.
- c. Airflow must not bypass the coil or stratification may occur.

#### **3.6-7 Report:**

Record test and capacity data on a proper data sheet.

#### **3.6-8 Compliance:**

Compliance is met when all kw, coil stages, phase, voltage, and controls are tested according to this procedure and are within the limits of the system.

---

## **3.7 Airflow Station Measurements**

---

3.7-1 This procedure applies to the following:

All HVAC system airflow stations

3.7-2 This procedure does not apply to the following:

Other device configurations

3.7-3 Operation:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.

3.7-4 Inspection:

- a. Inspect the system to determine if it is operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Inspect the system to verify that the airflow station is clean and ready for testing.
- c. Verify that the airflow station is installed according to the manufacturer's recommendations, if not, then note as a deficiency, and proceed with the test to verify performance unless directed not to proceed.

3.7-5 Procedures:

- a. Set system in a steady-state condition.
- b. Record station data, including effective area.
- c. Measure the station differential pressure and calculate the CFM according to the manufacturer's instructions.
- d. Perform a Pitot tube traverse of the duct served by the airflow station and calculate the actual CFM.
- e. Calculate the difference in measurement between the Pitot tube traverse and the station reading. Note any deviation greater than 10 % as a deficiency.
- f. If the station has a read out, verify that it is properly calibrated.
- g. If the station air flow rate varies by design, then verify flows at maximum and minimum conditions and report both tests.

---

### **3.7 Airflow Station Measurements (continued)**

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- h. Upon completion of the measurements, record the following minimum data on report forms. Refer to the Report Contents procedure.
  - 1. Unit manufacturer's submittal data and actual data of the airflow station
  - 2. Effective area
  - 3. Differential test pressure
  - 4. Calculated CFM
  - 5. Pitot tube traverse CFM and deviation, if any
  - 6. Station read out quantity, if applicable
  - 7. Convert all data to standard air, if required

#### **3.7-6 Report:**

- a. Include all test data on an approved airflow station data sheet.
- b. Include requirements from the Report Contents procedure.
- c. List any uncorrected deficiencies in the report.

#### **3.7-7 Compliance:**

- a. Compliance with this procedure requires completion of all of the above steps with the results recorded on approved forms.
- b. Instruments must be accurate and suitable for this type of test. Refer to instrumentation requirements.

---

### **3.8 Static Pressure Flow Device Measurements**

---

3.8-1 This procedure applies to the following:

All HVAC systems airflow measurements

3.8-2 This procedure does not apply to the following:

Other device configurations

3.8-3 Operation:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.

3.8-4 Inspection:

Inspect the system to determine if it is operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.

3.8-5 Procedures:

- a. The static pressure airflow measurements include the following:
  1. A duct traverse, and
  2. Static-pressure, differential-type, flow-measuring station.
- b. Each location should have 7.5 duct diameters of equivalent round duct upstream of the station and 2.5 diameters downstream.
- c. The duct traverse requires a Pitot tube long enough to fit the depth or width of the duct. The traverse determines the CFM and initial static pressure associated with the flow (CFM).
- d. If all conditions stay the same, then the static pressure changes with the flow difference is squared. The large change in static pressure in relation to a lower change in airflow makes this method useful in sensing and controlling air flow. It has limitations, however, since there cannot be any pressure changes other than the changes caused by the airflow for it to work.
- e. To change CFM from one level to another, calculate the new static pressure and adjust the fan speed to match the new static pressure. The CFM will be as predicted.

---

### **3.8 Static Pressure Flow Device Measurements (continued)**

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#### **3.8-6 Static Pressure and Resistance:**

- a. Static pressure is the pressure against the wall of a duct caused by resistance to airflow in the system.
- b. If the resistance is caused by anything other than airflow, like dampers, dirty filters, or duct leakage, the resistance could change, and the static pressure would need to be a pressure drop across a device where the pressure drop is known and listed, as with the static pressure differential device.
- c. Static pressure and velocity pressure are the two components of total pressure. Total pressure by itself is not a reliable measurement for pressure drop, unless the static pressure is zero. If this is the case, then total pressure equals velocity pressure. Velocity pressure is not measured, but subtraction of static pressure from total pressure yields velocity pressure.
- d. To be an accurate pressure measurement, the location cannot be in a turbulent airstream.

#### **3.8-7 Report:**

- a. Usually static pressure measurements are either recorded on the pressure profile data form or on the duct traverse data form.
- b. Include requirements from the Report Contents procedure.

#### **3.8-8 Compliance:**

- a. Compliance is met when static pressure measurements are taken with a Pitot tube and an accurate manometer.
- b. Measurements must be taken in the correct locations.
- c. This procedure must be used with proper precautions and awareness of the external effects.
- d. This procedure should not be confused with total pressure measurements.

---

## 3.9 Unit Heater Measurements

---

3.9-1 This procedure applies to the following:

Unit heater systems measurements

3.9-2 This procedure does not apply to the following:

Other device configurations

3.9-3 Operation:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.

3.9-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.

3.9-5 Procedures:

- a. Use the following procedures for hot water unit heaters:
  1. Use manufacturer's rated airflow (SCFM) unless ducted, then use a duct traverse to determine airflow.
  2. Measure and record the entering and leaving dry bulb temperature. Use the Coil Capacity Test procedure to determine BTUH capacity and flow.
  3. Measure and record the entering and leaving water temperature. Calculate flow by the heat-transfer method.
  4. If a flow station is installed, then measure the gpm and compare with the design. Adjust flow until within 10 %. Compare to heat transfer for accuracy within  $\pm 10\%$ . If not accurate, then repeat the procedure to eliminate the error or to determine the cause of the discrepancy.
  5. Verify that the controls work properly, note any deficiencies, and record.

---

### **3.9 Unit Heater Measurements (continued)**

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- b. Use the following procedures for electric unit heaters:
  - 1. Measure kw capacity according to the Electric Heating Coil Measurements procedure with the heater at maximum output through the control device.
  - 2. Verify that the controls work properly, note any deficiencies, and record.
- c. Use the following procedures for steam unit heaters:
  - 1. Use the manufacturer's airflow (SCFM) unless ducted, then use a duct traverse to determine the airflow.
  - 2. Measure the air temperature difference and calculate the total heating capacity at maximum steam flow according to the Coil Capacity Test procedure.
  - 3. Verify that the controls work properly, note any deficiencies, and record.
  - 4. Verify that the steam trap works properly, note any deficiencies, and record.
- d. Use the following procedures for gas-fired unit heaters:
  - 1. Use manufacturer's airflow (SCFM) unless ducted, then use a duct traverse to determine the airflow.
  - 2. Measure the air temperature differences and calculate the total heating capacity with the heater at maximum output through the control device using the Coil Capacity Test procedure.
  - 3. Verify that the controls work properly, note any deficiencies, and record.

#### **3.9-6 Report:**

- a. Record all test data on an approved unit heater data sheet, including required data from the Report Contents procedure.
- b. Include components that do not meet design requirements on a deficiency form.

#### **3.9-7 Compliance:**

Compliance with this procedure is met when the above are completed, and the units are balanced to within the limits of the system.

---

## 3.10 Fan Coil and Unit Ventilator Measurements

---

3.10-1 This procedure applies to the following:

Fan coil and unit ventilator systems

3.10-2 This procedure does not apply to the following:

Other terminal configurations

3.10-3 Operation:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.

3.10-4 Inspection:

Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.

3.10-5 Procedures:

- a. Use the following procedures for chilled-water fan coil units and unit ventilators:
  1. Use manufacturer's rated airflow (SCFM) unless ducted, then use a duct traverse to determine airflow. If duct traverse is impossible, then use summation of outlet readings.
  2. Set outside airflow to design specifications.
  3. Measure entering and leaving air dry and wet bulb temperatures.
  4. Measure entering and leaving water temperatures.
  5. Use the Coil Capacity Test procedure to determine BTUH capacity.
  6. If a flow station is installed, then measure and record gpm and compare to heat-balance gpm.
  7. Measure and record the water pressure drop across the coil and compare to the design. Only rely upon pressure drop for flow determination if other means noted are impossible to obtain.

---

### 3.10 Fan Coil and Unit Ventilator Measurements (continued)

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8. Measure and record all unit data.
  9. Measure and record motor operating amperage/voltage and compare against full-load nameplate.
  10. Verify that controls operate properly and in correct sequence. Note any deficiencies and record.
- b. Use the following procedures for direct expansion (DX) cooling fan coils and unit heaters:
1. Use manufacturer's airflow (SCFM) unless ducted, then use duct traverse method to determine airflow. If duct traverse is impossible, then use summation of outlets.
  2. Set outside airflow to design.
  3. Measure entering and leaving air dry and wet bulb temperatures.
  4. Use Coil Capacity Test procedure to determine BTUH capacity.
  5. Measure and record all unit data.
  6. Measure and record operating amperage/voltage and compare against full-load nameplate.
  7. Verify that the controls operate properly and in correct sequence. Note any deficiencies and record.
- c. Use the following procedures for electric-heat fan coil and unit ventilators:
1. Use manufacturer's rated airflow (SCFM) unless ducted, then use a duct traverse to determine airflow. If duct traverse is impossible, then use summation of outlets.
  2. Set outside airflow to design.
  3. Measure and record heating kw according to the Electric-Heating Coil procedure.
  4. Measure and record all unit data.
  5. Measure and record motor amperage/voltage and compare against full-load nameplate.
  6. Verify that the controls work properly, note any deficiencies, and record.

---

### **3.10 Fan Coil and Unit Ventilator Measurements (continued)**

---

- d. Use the following procedures for steam-heat, fan coil, and unit ventilators:
1. Use manufacturer's airflow (SCFM) unless ducted, then use traverse method to determine airflow, unless impossible, then use summation of outlets.
  2. Set outside airflow to design.
  3. Measure the entering and leaving air dry bulb temperature, and calculate the BTUH load at maximum steam flow according to the Coil Capacity Test procedures.
  4. Verify that the controls work properly, note any deficiencies, and record.
  5. Verify that the steam trap works properly, note any deficiencies, and record.

3.10-6 Report:

- a. Record all test data on an approved fan coil and unit ventilator data sheet including required data from the Report Contents procedure.
- b. Include components that do not meet design requirements on a deficiency form.

3.10-7 Compliance:

Compliance with this procedure is met when the above are completed and the units are balanced to within the limits of the system.

---

### **3.11 Induction Unit Measurements**

---

3.11-1 This procedure applies to the following:

Air induction unit systems

3.11-2 This procedure does not apply to the following:

Other terminal configurations

3.11-3 Operation:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.

3.11-4 Procedures:

- a. Balance the primary induction air to each induction unit by nozzle pressure.
- b. Verify the manufacturer-rated pressure versus CFM for each differently-sized unit by Pitot tube traverse. If nozzle pressure and CFM do not correlate with the manufacturer's data, traverse at least 10 % of the units to verify the discrepancy and report as a deficiency. Calculate the required nozzle pressure based upon the field traverses and proceed with balancing the units.
- c. Measure and record cooling coil air and water temperatures and calculate capacity as applicable according to the Coil Test procedure
- d. Measure and record heating coil air and water temperatures or kw for electric coils and calculate capacity as applicable according to the appropriate procedure.
- e. Measure and balance water flows to design according to appropriate water balancing procedures.
- f. Test and balance the primary air unit according to the High-Pressure Induction System procedure by the manufacturer of the unit.

3.11-5 Verification of automatic controls system:

Verify that the controls work properly, note any deficiencies, and record.

---

### **3.11 Induction Unit Measurements (continued)**

---

**3.11-6 Report:**

- a. Record all test data on an approved induction unit data sheet, including required data from the Report Contents procedure.
- b. Include components that do not meet design requirements on a deficiency form.

**3.11-7 Compliance:**

Compliance with this procedure is met when the above are completed and the units are balanced to within the limits of the system.

---

## 3.12 Laboratory Hood Measurements

---

3.12-1 This procedure applies to the following:

Laboratory hood systems

3.12-2 This procedure does not apply to the following:

Other device configurations

3.12-3 Operation:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.

3.12-4 Inspection:

Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.

3.12-5 Procedures:

- a. Laboratory hood measurements include the following:
  1. Set up and measure exhaust fan CFM data to design plus 10 % CFM, according to the Fan Test and Balance procedure.
  2. Measure airflow at the hood face in fpm. Record on a grid pattern of not more than 12-inches square.
  3. Release smoke or vapor to determine the direction of flow. Air must not flow out of the hood.
  4. Measure airflow of make-up air, if part of the hood. Determine if make-up air blows directly into the hood and causes turbulence or interferes with the hood operation.
  5. Inspect the hood sash bypass for excessive leakage.
  6. Record deficiencies, and, if they are not resolved, include them in the report.

---

### 3.12 Laboratory Hood Measurements (continued)

---

- b. Use manufacturer's rated airflow (CFM) for the design unless specified differently.
- c. The hood face velocity must be as specified for the use of the hood.
- d. Lower the sash to obtain the design velocity if the fan airflow is near to design but face velocity is low because of leakage in the hood. Mark the setting and velocity obtained.
- e. Most laboratory hoods are required to be under a negative pressure. No part of the hood should be under a positive pressure. Test the casing with smoke or vapor to determine the pressure status. Record the status as a deficiency if it is incorrect.
- f. Laminar flow hoods used in clean room applications may be under a positive pressure and need to be tested accordingly.
- g. Verify that the automatic controls system controls works properly, note any deficiencies, and record.

#### 3.12-6 Report:

- a. Record all test data on an approved laboratory hood data sheet, including required data from the Report Contents procedure.
- b. include components that do not meet design requirements on a deficiency form.

#### 3.12-7 Compliance:

Compliance with this procedure is met when the above are completed and the units are balanced to within the limits of the system.

---

### 3.13 Kitchen Hood Measurements

---

3.13-1 This procedure applies to the following:

Kitchen hood systems

3.13-2 This procedure does not apply to the following:

Other device configurations

3.13-3 Operation:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.

3.13-4 Inspection:

Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.

3.13-5 Procedures:

- a. Kitchen hood measurements include the following steps:
  1. Set up and measure the exhaust fan CFM data to design plus 10 % CFM, according to the Fan Test and Balance procedure.
  2. Record airflow measurements at the hood face in fpm on a grid pattern of not more than 12-inches square.
  3. Use filter measurements with a known  $A_k$  factor to determine the filter CFM. Add up the filter CFM for the hood CFM.
  4. Verify the hood filter  $A_k$  factor for the instrument used. Be aware of leakage around filters, which can be substantial.
  5. Measure and record the airflow measurement of make-up air if part of the hood.
  6. Record deficiencies, and, if they are not resolved, include them in the report.
- b. Use the manufacturers' or U.L. rated airflow (CFM) for the design, unless specified differently.

---

### **3.13 Kitchen Hood Measurements (continued)**

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- c. Verify that the hood filter face velocity is as specified for the type of hood used.
- d. Use a rotating vane anemometer to measure hoods; this is the typical instrumentation for this measurement.
- e. N.F.P.A. Code requirements state that a kitchen hood exhaust duct must have a minimum duct velocity of 1,500 fpm. The duct should not be penetrated for a duct traverse because of possible grease leakage and fire hazard, unless sealed liquid tight. Verify duct size, compare to measured CFM, and determine if the velocity meets the code requirement.

**3.13-6 Verification of automatic controls system:**

Verify that the controls work properly, note any deficiencies, and record.

**3.13-7 Report:**

- a. Record all test data on an approved kitchen hood data sheet, including required data from the Report Contents procedure.
- b. Include components that do not meet design requirements on a deficiency form.

**3.13-8 Compliance:**

Compliance with this procedure is met when the above are completed and the units are balanced to within the limits of the system.

---

### 3.14 Air-Cooled Condenser Measurements

---

3.14-1 This procedure applies to the following:

- a. Built-up refrigeration systems more than 20 tons
- b. DX condensing units more than 20 tons

3.14-2 This procedure does not apply to the following:

Water-cooled units

3.14-3 Operation:

- a. Condenser systems must be in operation before the test and balance technician begins the procedure. All controls must be installed, calibrated, and fully operational.
- b. The tested unit must operate at full load for a full-load capacity test.
- c. If operating at actual conditions, this test indicates actual load on the equipment at the time of the test.

3.14-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list the deficiencies, and proceed when they are corrected.
- b. Inspect multiple-motors and fans for correct operation sequence and cold weather dampers' function.
- c. Verify coils are clean and unobstructed.

3.14-5 Procedures:

- a. Verify design CFM through the coil from manufacturer's data.
- b. Use the Anemometer Coil Traverse procedure to verify airflow CFM. The coil traverse method can be used on the entering side of the coil with good results.
- c. Measure the air temperature entering and leaving the coil by using the Basic Temperature Measurements procedure
- d. Measure the power requirements before and after adjustments.

---

### 3.14 Air-Cooled Condenser Measurements (continued)

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- e. Upon completion of measurements, record the following minimum data on report forms. Refer to the Report Contents procedure
  - 1. Unit submittal data
  - 2. Airflow CFM coil traverse corrected to SCFM
  - 3. Traverse velocity (fpm)
  - 4. Pressure drop across coil
  - 5. Temperature and barometric pressure
  - 6. Power measurements (Refer to the Electric Power Measurements procedure)
  - 7. kw (if applicable)
  - 8. All nameplate data
  - 9. Motor rpm
  - 10. Fan rpm
  - 11. Design fan and motor rpm
  - 12. Existing drive sizes, belt type, size, and number
  - 13. Center-to-center distance and motor-base travel if belt driven
  - 14. Average temperature differential across coil from "c" above
- f. Calculate BTUH load on the condenser:  $CFM \times 1.08 \times TD = BTUH$  (This includes compressor heat.)
- g. Standard electric compressor heat rejection is 15,000 BTUH per ton of refrigeration effect.
- h. Divide condenser BTUH by 15,000 to obtain the net cooling effect in tons of refrigeration. One ton of refrigeration equals 12,000 BTU.
- i. Verify that the controls associated with the unit operate properly and that the sensors are calibrated.
- j. Set and verify that the dampers associated with the unit operate properly in all specified modes.

---

### **3.14 Air-Cooled Condenser Measurements (continued)**

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- k. Observe the unit's operation for excessive noise and vibration. Report excessive noise or vibration to the owner's representative.
- l. When sound and vibration tests are specified, use the following:
  - 1. Sound Testing and Noise Level procedure
  - 2. Vibration Testing and Noise Level procedure

#### **3.14-6 Report:**

- a. Include deficiencies not corrected on the deficiency report form and submit it with the report.
- b. Record all test data on an approved data sheet, including required data from the Report Contents procedure.

#### **3.14-7 Compliance:**

- a. Compliance with this procedure requires completion of all of the above steps with all data recorded on the report forms.
- b. All deficiencies that affect the test must be resolved by the installing contractors or included in the deficiency report.

---

### **3.15 Air-to-Air Heat Recovery Unit Measurements**

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3.15-1 This procedure applies to the following:

Air-to-air heat recovery units in all HVAC systems

3.15-2 This procedure does not apply to the following:

Other device configurations

3.15-3 Operation:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.

3.15-4 Inspection:

Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.

3.15-5 Procedures:

- a. Verify that the seals are properly installed and adjusted.
- b. Measure by Pitot tube traverse the air entering the exhaust section and leaving the outside air section for total airflow, not including purge CFM.
- c. Measure and record the dry and wet bulb of the air entering and leaving the exhaust side and outside air side.
- d. Calculate and record the sensible and total capacity of each airstream. The capacity should match within 10 %. If not, then there is an error in the testing methods. Retest until limits are within 10 %.
- e. Measure and record the pressure drop on each side of the recovery wheel.

3.15-6 Report:

- a. Record all test data on an approved recovery data sheet, including required data from the Report Contents procedure.
- b. List all deficiencies not corrected on the deficiency report form, and include it in the report.

---

### **3.15 Air-to-Air Heat Recovery Unit Measurements (continued)**

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3.15-7 Compliance:

- a. Compliance with this procedure requires completion of all of the above steps with all data recorded on the report forms.
- b. All deficiencies that affect the test must be resolved by the installing contractor or included in the deficiency report.

---

### 3.16 Water-to-Water Heat Exchanger Measurements

---

3.16-1 This procedure applies to the following:

Water-to-water heat exchanger units in HVAC systems

3.16-2 This procedure does not apply to the following:

Other device configurations

3.16-3 Operation:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.

3.16-4 Inspection:

Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.

3.16-5 Procedures:

- a. Measure and record the water flow on each side of the heat exchanger.
- b. Measure and record the entering and leaving temperatures on each side of the heat exchanger.
- c. Calculate and record the capacity on each side of the heat exchanger. The capacities should match within 10 %. If not, then there is an error in the testing methods or leakage within the exchanger.
- d. Measure and record the pressure drop across each side of the exchanger.

3.16-6 Report:

- a. Record all test data on an approved heat exchanger data sheet, including required data from the Report Contents procedure.
- b. List all deficiencies not corrected on the deficiency report form, and include it in the report.

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### **3.16 Water-to-Water Heat Exchanger Measurements (continued)**

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3.16-7 Compliance:

- a. Compliance with this procedure requires completion of all of the above steps with all data recorded on the report forms.
- b. All deficiencies that affect the test must be resolved by the installing contractor or included in the deficiency report.

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### **3.17 Fire Damper Operation Verification**

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3.17-1 This procedure applies to the following:

Fire Damper Units in HVAC systems when specifically specified

3.17-2 This procedure does not apply to the following:

Other device configurations

3.17-3 Operation:

- a. The systems must be put in operation by others.
- b. Access door must be provided by others.
- c. Fire damper must be installed by others.

3.17-4 Inspection:

Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.

3.17-5 Procedures:

- a. Fire damper operation tests verify the following:
  1. Access door-to-damper minimum: 12" x 12"
  2. Electric fusible links
  3. Spring-loaded fire damper
  4. Video camera and light for in duct
  5. Monitor located outside duct for camera view of linkage and damper operation
  6. Damper fusible link connected to power source with switch
- b. With AHU on, and camera in place to watch the fire damper operation, energize the electric fusible link and observe the damper close. If it closes properly, then it passes. If it does not close, then it fails and must be repaired or replaced and retested.

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### **3.17 Fire Damper Operation Verification (continued)**

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- c. If the damper passes, then the installing contractor must replace the fusible link with the standard approved type.
- d. Test the fire dampers specified.
- e. Retest any fire dampers that fail.

#### **3.17-6 Report:**

- a. Record all test data on an approved fire damper data sheet, including required data from the Report Contents procedure.
- b. List all deficiencies not corrected on the deficiency report form and include in the report.

#### **3.17-7 Compliance:**

- a. Compliance with this procedure requires completion of all of the above steps with all data recorded on the report forms.
- b. All deficiencies that affect the test must be resolved by the installing contractor or included in the deficiency report.

---

## 3.18 Pump Capacity Measurements

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3.18-1 This procedure applies to the following:

- a. All pumping systems
- b. Pumps in parallel
- c. Pumps in series

3.18-2 This procedure does not apply to the following:

Small in-line pumps

3.18-3 Operation:

Pump systems are to be in operation before the test and balance technician begins this procedure. All controls are to be installed, calibrated, and fully operational.

3.18-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list the deficiencies, and proceed when they are corrected.
- b. Verify that the pumps align properly. Do not run the unit with excessive vibration.
- c. Refer to the Prerequisite for Balancing.
- d. Verify that the check valves are installed properly and are open when the pump is on.
- e. Verify that gauge cocks are properly located.

3.18-5 Procedures:

- a. Measure and record pump entering and leaving shut-off head pressures. Plot on the pump curve to verify correct impeller size.
- b. Measure wide-open pump head and amperage. Note if pump overloads with the system set for maximum conditions. If it is a variable speed drive, then set it to 100 %.

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### 3.18 Pump Capacity Measurements (continued)

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- c. Set the pump to design flow and record entering and leaving pressures along with final head. Plot on pump curve. If it is a variable speed pump, then set the maximum limit to design flow.
- d. If the pump discharge valve was throttled to set the flow, then calculate the required impeller size with the valve wide open and note in the report.
- e. Upon completion of balancing, record the data required in the Report Contents procedure.
- f. When a standby pump is used, only one pump is tested at a time.
- g. When two or more pumps are in parallel, test each pump alone and then again with other pumps as dictated by the operation sequence.
- h. When the pumps are in series, test them together. If the operation sequence requires one pump to operate at certain times, then test the pumps both individually and together.
- i. When sound and vibration test are specified, follow the:
  - 1. Sound Testing and Noise Level procedure.
  - 2. Vibration Level Testing procedure.

#### 3.18-6 Report:

- a. List items not corrected on the deficiency report form and submit with the report.
- b. Record all test data on an approved pump data sheet.

#### 3.18-7 Compliance:

- a. Compliance with this procedure requires completion of all of the above steps with all data recorded on the report forms.
- b. All deficiencies must be resolved by the installing contractors or included in the deficiency report.

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## 3.19 Water Flow Station Measurements

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3.19-1 This procedure applies to the following:

- a. Venturi's
- b. Orifices
- c. Circuit setter balancing valves
- d. Automatic flow control valves
- e. Fixed-in-place Pitot tubes

3.19-2 This procedure does not apply to the following:

Other device configurations

3.19-3 Operation:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.

3.19-4 Inspection:

- a. Verify that the water-system valves are open, the strainers are clean, the expansion tank is properly charged, and the system is ready for proper operation.
- b. Verify that the water flow station is installed according to the manufacturer's recommendations for upstream and downstream clearances.
- c. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.

3.19-5 Procedures:

- a. Venturi's, orifices, and fixed Pitot tubes:
  - 1. Record the flow station, manufacturer, size, and specified gpm.
  - 2. Measure and record the differential pressure, using a meter of appropriate scale. This is usually in inches.
  - 3. Using the manufacturer's flow chart, record the indicated gpm.

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### 3.19 Water Flow Station Measurements (continued)

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4. Adjust all flow stations so the flows are within allowable limits at all flow stations.

b. Circuit-setter balancing valves:

1. Record the manufacturer, size, and specified gpm.
2. Measure and record the valve indicator position and pressure drop (usually in feet) using a differential pressure meter of appropriate scale. A single-pressure gauge can be used if the pressure gauge is graduated in 0.5-pound increments and the gauge is held in the same position for both readings.
3. Using the manufacturer's chart (generally a round "slide rule"), record the indicated gpm.
4. Adjust all valves until the flows are within allowable limits at all valves in the system.

c. Automatic flow-control valves:

1. Record the manufacturer, size, gpm, and required pressure-drop range.
2. Measure and record the valve pressure drop (usually in pounds), using a differential pressure meter or a pressure gauge. The meter or gauge should be graduated at a minimum of one-pound increments.
3. Using the manufacturer's flow-control valve chart, determine and record the gpm flow.

3.19-6 Report:

- a. Record test data on an approved water flow measurement form. Include required data from the Report Contents procedure.
- b. List deficiencies uncorrected on the deficiency report form and include in the report

3.19-7 Compliance:

- a. Compliance with this procedure requires all flow measurements to be accurate and recorded on the proper form.
- b. All deficiencies that affect the test must be resolved by the installing contractor or included in the deficiency report.

---

## 3.20 Chiller Capacity Measurements

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3.20-1 This procedure applies to the following:

HVAC water chillers

3.20-2 This procedure does not apply to the following:

- a. Other types of cooling units
- b. Full-load performance test

3.20-3 Operation:

Chillers must be in operation before the test and balance technician begins the procedure. All controls are to be installed, calibrated, and fully operational.

3.20-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the chiller is running at the maximum load available and at a normal water temperature setting.
- c. Verify that the condenser water temperatures are correct and the cooling tower operates properly.
- d. Verify that the chilled water pumps and condenser water pumps are lined up correctly and operate properly.
- e. Verify that the flow meters are installed in chilled water piping and in condenser piping. Flow meters are required for this test.
- f. Verify that the thermometer wells and test thermometers are installed properly in chilled water and condenser water piping according to the Basic Temperature Testing Measurements procedure.

3.20-5 Procedures:

- a. Balance and set the chilled and condenser water flow through the chiller.
- b. Measure and record the entering and leaving vessel pressure on the cooler and condenser, and compare to the manufacturer's submittal data, if available.

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### 3.20 Chiller Capacity Measurements (continued)

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- c. Load the chiller to the maximum obtainable load until an equilibrium steady state is reached in the chilled and condenser water temperatures.
- d. Log the entering and leaving condenser and chilled water temperature every five minutes for a one-hour duration (12 readings).
- e. Log the compressor motor input kw and verify water flow and vessel pressure drop every 15 minutes (four readings) during temperature log time.
- f. Average each station reading.
- g. Calculate the cooler (evaporator) capacity in tons.
- h. Calculate the condenser capacity in tons.
- i. Calculate the compressor motor input kw in tons.
- j. Add the cooler tonnage to the compressor motor kw tonnage. This sum should equal the condenser tonnage within 10 % for a valid heat balance and acceptable field test.
- k. Upon completion of the test record the following data on report forms. Refer to the Report Contents procedure.
  1. Factory and actual data of the installed chiller
  2. Water flow gpm for chilled and condenser water. Include flow meter data, if installed
  3. All water vessel pressure drops
  4. Final average temperatures of cooler and condenser measured to 0.10° F
  5. kw power readings, including amperage and voltage
  6. Cooler tons, condenser tons, kw tons, and heat balance equation results
- l. On a separate form, indicate all logged data.

#### 3.20-6 Report:

- a. Include all test data on a chiller capacity data sheet.
- b. List conditions at the time of the test and the results.

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### **3.20 Chiller Capacity Measurements (continued)**

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- c. List any uncorrected deficiencies that affected the test results on the deficiency report form.
- d. Include required data from the Report Contents procedure.

#### **3.20-7 Compliance:**

- a. Compliance with this procedure requires completion of all of the above steps with all data recorded on the report forms.
- b. All deficiencies that affect the test must be resolved by the installing contractors or included in the deficiency report.
- c. Instrumentation must be accurate and suitable for this type of testing. Test accuracy should be within 5 %.

---

## 3.21 Cooling Tower Performance Measurements

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3.21-1 This procedure applies to the following:

Water cooling towers

3.21-2 This procedure does not apply to the following:

- a. Air washers
- b. Spray ponds
- c. Scrubbers

3.21-3 Operation:

Cooling Towers must be in operation before the test and balance technician begins the procedure. All controls must be installed, calibrated, and fully operational. Fan pitch must be set by the factory or other personnel.

3.21-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the cooling tower is operating with sufficient load available and that outside air wet bulb is within 8° F of design.
- c. Verify that the chilled water pumps and condenser water pumps are lined up correctly and operating properly.
- d. Verify that the flow meters are installed in condenser piping according to the Water Flow Station procedure. Flow meter required for this test.
- e. Verify that the thermometer wells and test thermometers are installed properly in water piping according to the Basic Temperature Testing Measurements procedure.

3.21-5 Procedures:

- a. Balance hot water basins and set the total water flow through the cooling tower. Accurate water flow measurement is critical. Venturi's, orifices, or in-place Pitot tubes are the preferred measurement devices. If these flow meters are not installed, then two separate flow measurements must match within 10 % to establish test flow conditions (i.e., pump head and circuit balancing valve or pump head and chiller condenser pressure drop, etc).

---

### 3.21 Cooling Tower Performance Measurements (continued)

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- b. Set up wet bulb measurement stations. Thermometers must be graduated in 0.10° F increments with a minimum of one station per inlet and a maximum of 400 square feet per inlet station. In addition, a minimum of one wet bulb station per outlet, with a maximum station area of 100 square feet, or, in the case of a draw through tower or a tower with a round outlet, six stations must be established radially from the center, approximately 2/3 of the distance from the center point.
- c. Load the tower to the maximum obtainable load until it reaches a steady-state equilibrium.
- d. Turn off tower water make-up. Monitor the tower basin during log time to ensure that the basin does not get too low.
- e. Log all wet bulb stations every 10 minutes for a one-hour period (six readings).
- f. Measure the energy input to each cooling tower fan with a kw meter to determine the horsepower input every 15 minutes during log time (four readings).
- g. Verify the water flow every 15 minutes during log time (four readings).
- h. Upon completion of the test, record the following data on report forms. Refer to the Report Contents procedure.
  - 1. Unit factory data on each unit tested
  - 2. All water flow gpm
  - 3. All pressure measurements
  - 4. Fan and motor data, including rpm measurements
  - 5. Motor kw power measurements (Refer to the Electrical Power Measurements procedure)
  - 6. Average wet bulb temperatures, entering and leaving the cooling tower at the time of the test
  - 7. Final computed capacity and converted capacity to design conditions
- i. On separate forms, provide tower log data, performance curves, etc.
- j. When the log is complete, average all the readings. Calculate the tower capacity and compare it to the design requirements. If test conditions are at other than design conditions, then convert the test back to design conditions or verify performance at entering test wet bulb with the manufacturer's performance curve.

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### **3.21 Cooling Tower Performance Measurements (continued)**

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3.21-6 Report:

- a. Include all test data on an approved cooling tower data sheet.
- b. List conditions at the time of the test and the results.
- c. List any uncorrected deficiencies that affected the test results on the deficiency report form.
- d. Include required data from the Report Contents procedure.

3.21-7 Compliance:

- a. Compliance with this procedure requires completion of all of the above steps with all data recorded on the report forms.
- b. All deficiencies that affect the Cooling Tower Measurements must be resolved by the installing contractors or included in the deficiency report.
- c. Instrumentation must be accurate and suitable for this type of testing. Test accuracy must be as described in the instrumentation requirements and Temperature Measurements procedure.

---

## 3.22 Boiler Capacity Measurements

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3.22-1 This procedure applies to the following:

- a. Hot water boilers (low and medium temperature) in HVAC systems
- b. Hot water boilers (high temperature, up to 400° F)
- c. Steam boilers (low and medium pressure)

3.22-2 This procedure does not apply to the following:

- a. High-pressure steam boilers
- b. High-pressure and temperature reboilers or water boilers

3.22-3 Operation:

Boilers must be in operation before the test and balance technician begins the procedure. All controls must be installed, calibrated, and fully operational.

3.22-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the boiler is operating at maximum load available and at normal temperature or pressure settings.
- c. Verify that the safety devices are installed and tested. Do not test the boilers without verifying that the safety relief valves operate and are tested to their rating by others.
- d. Verify that the fuel isolation and safety valves operate.
- e. Verify that the make-up water, pressurization system, and condensate systems line up correctly and operate properly.
- f. Verify that the flow meters are installed, if required, in the piping for boilers, according to the Water Flow Station procedure.
- g. Verify that the thermometer wells and test thermometers are installed properly in the water piping according to the Temperature Measurements procedure.
- h. Verify that the pressure gauges are installed in the steam and condensate feed system, as required for testing.

---

### 3.22 Boiler Capacity Measurements (continued)

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#### 3.22-5 Procedures:

- a. Balance hot water flow through the water boilers. Accurate water flow measurement is critical. Venturi's, orifices, or in-place Pitot tubes are the preferred measurement devices. If these flow meters are not installed, then two flow measurements must match within 10 % to establish test flow conditions, i.e., pump head and circuit balancing valve, or pump head and boiler pressure drop, etc.
- b. Measure and record entering water pressure and leaving water or steam pressure in the piping of each steam and water boiler.
- c. Load boiler to the maximum obtainable until a steady-state equilibrium exists.
- d. Measure fuel energy input to each boiler every 15 minutes for a one-hour duration (four readings).
- e. Log entering and leaving water temperatures every five minutes for a one-hour duration (12 readings).
- f. At the completion of the log time, average all readings and calculate boiler capacity and fuel energy input. Calculate the boiler efficiency and record.
- g. Upon completion of the test, record the following data on report forms. Refer to the Report Contents procedure.
  1. Unit factory data on each unit tested
  2. All nameplate data
  3. All water flow measurements, including flow meter data, if installed
  4. All pressure measurements
  5. Energy-input measurements
  6. Average temperatures entering and leaving the boiler at the time of the test
  7. Capacity and efficiency calculations
- h. On a separate form, indicate all log data.

---

### **3.22 Boiler Capacity Measurements (continued)**

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3.22-6 Report:

- a. Include all test data on an approved boiler data sheet.
- b. List conditions at the time of the test and the results.
- c. List any uncorrected deficiencies on the deficiency report form.
- d. Include required data from the Report Contents procedure.

3.22-7 Compliance:

- a. Compliance with this procedure requires completion of all of the above steps with all data recorded on the report forms.
- b. All deficiencies that affect the Boiler Capacity Measurements must be resolved by the responsible party or included in the deficiency report.
- c. Instrumentation must be accurate and suitable for this type of test. Test accuracy must be as described in the Instrumentation Requirements and the Basic Temperature Testing Measurements procedure.

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## 3.23 Radiation Heat Measurements

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3.23-1 This procedure applies to the following:

- a. Hot water fin tube, plate, pipe, and floor radiation systems measurements
- b. Electric fin tube, plate, pipe, and floor radiation systems measurements

3.23-2 This procedure does not apply to the following:

Other device configurations

3.23-3 Operation:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.

3.23-4 Procedures:

a. Hot water radiator

1. Adjust the radiator thermostat to full heat.
2. Balance water flow to design using the flow meter or pressure drop method. If the pressure-drop method is used, then the manufacturer's pressure-drop data must be known.
3. Measure the entering and leaving water temperatures.
4. Calculate the radiator capacity in BTU/hour.
5. Upon completion of the test, record the following data on report forms. Refer to the Report Contents procedure.
  - a) Unit factory data and specified data on each radiator, including design capacity
  - b) Entering and leaving water pressure
  - c) Water flow gpm and flow meter data, if applicable
  - d) Entering and leaving water temperatures
  - e) Radiator test capacity in comparison to design capacity

b. Electric radiator

1. Adjust the radiator thermostat to full heat.

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### **3.23 Radiation Heat Measurements (continued)**

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2. Measure the input amps and volts according to the Electrical Power Measurements procedure.
3. Calculate the radiator capacity in kw.
4. Upon completion of the test, record the following data on report forms. Refer to the Report Contents procedure.
  - a) Unit factory data and specified data on each radiator, including design capacity
  - b) Amps, volts, and phase
  - c) Tested kw in comparison to design kw

#### **3.23-5 Controls:**

Verify that the controls are installed and working properly. Note any deficiencies and record.

#### **3.23-6 Report:**

- a. Record all test data on an approved radiation data sheet, including required data from the Report Contents procedure.
- b. Include components that do not meet design requirements on a deficiency form and include in the report.

#### **3.23-7 Compliance:**

- a. Compliance with this procedure is met when the above are completed and the units are balanced to within the limits of the system.
- b. The report must be typed in the proper format and submitted to the client.

---

## 3.24 Steam Humidifiers and Trap Measurements

---

3.24-1 This procedure applies to the following:

Humidifiers and trap measurements

3.24-2 This procedure does not apply to the following:

Other device configurations

3.24-3 Operataion:

- a. The systems must be put in operation by others.
- b. Access must be provided by others.

3.24-4 Procedures:

- a. The steam humidifier in-duct measurements include the following:
  1. Steam pressure at the humidifier
  2. Steam flow (lbs/hr) measurements
  3. Airflow measurements (CFM)
  4. Wet and dry bulb temperature measurements
  5. Grains of moisture increase
  6. Lbs/hr of moisture increase
- b. Adjust steam flow and pressure as required to balance the system.
- c. The water mist type in-duct measurements include the following:
  1. Airflow measurements (CFM)
  2. Wet and dry bulb temperature measurements
  3. Grains of moisture increase
  4. Lbs/hr of moisture increase
  5. Gallons of water required
- d. Adjust the air and water flow until the design conditions are met.

---

### **3.24 Steam Humidifiers and Trap Measurements (continued)**

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- e. Space or room moisture conditions require the following steps:
  - 1. Measure directly with an RH meter.
  - 2. Measure with a wet and dry bulb thermometer and calculate the RH.
- f. Steam Trap Measurements include the following steps:
  - 1. Verify the type and operation of the trap.
  - 2. Measure flow of condensate through trap (if safe to do so) in lbs/hr.
  - 3. Verify if the proper type of trap is installed for the service.
  - 4. Measure the surface temperature across the trap and record if it is operating properly.
- g. Verify that the controls are installed and working properly. Note any deficiencies and record.

#### **3.24-6 Report:**

- a. Record all test data on an approved humidifier and trap data sheet, including required data from the Report Contents Procedure.
- b. Include components that do not meet the design requirements on a deficiency form and include in the report.

#### **3.24-7 Compliance:**

- a. Compliance with this procedure is met when the above are completed and the units are balanced to within the limits of the system.
- b. The report is typed in the proper format and submitted to the client.

---

### **3.25 VAV and Constant Volume Box Test & Balance**

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3.25-1 This procedure applies to the following:

- a. Pressure-dependent VAV boxes
  - 1. Cooling only
  - 2. Reheat
  - 3. Fan powered
  - 4. Pressure compensating
- b. Pressure-independent VAV and constant volume boxes
  - 1. Cooling only
  - 2. Reheat
  - 3. Fan powered
  - 4. Dual duct

3.25-2 This procedure does not apply to the following:

- a. VAV fume hoods
- b. High-pressure induction boxes

3.25-3 Operation:

The equipment must be in operation before the start of inspection for balancing according to the Prerequisites for Balancing.

3.25-4 Inspections:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the equipment is in operation according to the Prerequisites for Balancing, contract specifications, and manufacturer's submittal. List any deficiencies that prevent proper testing and balancing.

3.25-5 Basic Procedures:

- a. For system prerequisites, refer to the appropriate system procedure.

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### 3.25 VAV and Constant Volume Box Test & Balance (continued)

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- b. Boxes should be adjusted and tested according to these procedures. Do not begin the adjustments until they are required by the system procedure, unless extenuating circumstances prevail.
- c. Before adjusting any box, verify that adequate flow and pressure are available. Make system adjustments as necessary, or investigate problems that prevent successful completion of the procedures and report any deficiencies. Boxes should have enough flow to obtain the maximum set point with the damper under control (not 100 % open). For DDC Control Systems requiring a box auto zero procedure, run the auto zero before beginning the balancing.
- d. Based on the manufacturer's recommendations, set controls to obtain design CFM in each mode of operation as described below. Record all settings on report forms. For pneumatic pressure-independent controls, the controller setting may require minimum adjustment first. If so, revise these procedures accordingly.
- e. Cycle thermostat several times to ensure that new set points will repeat. Flow at most box velocity sensors with less than a delta P of .03" WC can produce unstable repeatability. This step is important in all pressure-independent box procedures.
- f. Airflow measurements for these procedures generally rely on the summation of the downstream air distribution. As stated in the air distribution procedures, traverses for  $A_k$  verification is a requirement. In addition, traverses must be performed when the air distribution cannot be measured or the air distribution measurement is suspect. Box delta P measurements are only used as noted in these procedures and when traverses cannot be performed.
- g. This procedure's intent is that all box terminal settings are adjusted and confirmed by the TAB firm. However, it is the manufacturer's and control contractor's responsibility to calibrate terminal devices and prepare them for adjustment.

#### 3.26-6 Box adjustment procedures:

- a. Pressure-dependent boxes
  - 1. Single-duct VAV
    - (a) Adjust controls to obtain maximum flow.

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### 3.25 VAV and Constant Volume Box Test & Balance (continued)

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- (b) If the system provides an upstream balancing device, balance according to the VAV pressure-dependent system procedures.
  - (c) Proportionally balance downstream air distribution, and record outlet measurements and maximum CFM.
  - (d) Adjust controls to minimum position to verify proper operation.
  - (e) If manual stops are provided, then set minimum flow to design and record total minimum CFM. Measure minimum flow at air distribution.
2. Parallel fan-powered VAV
- (a) Adjust controls to obtain maximum primary flow. Verify that the box back draft damper closes and no primary air leaks out of the filter box.
  - (b) If the system provides an upstream balancing device, then balance according to the VAV pressure dependent system procedures.
  - (c) Proportionally balance downstream air distribution, and record outlet measurements and maximum CFM.
  - (d) Adjust controls to minimum position to verify proper operation.
  - (e) If manual stops are provided, then de-energize the parallel fan and set minimum primary flow to design by summation at air distribution, and record total. Verify that the fan energizes at the appropriate time and in the proper sequence.
  - (f) Re-energize the parallel fan, set the fan CFM to design flow, and record the fan CFM. Minimum primary air CFM must be subtracted from the total of the air distribution to determine the fan CFM.
3. Bypass constant volume
- (a) Adjust controls to obtain maximum flow. Verify that the box damper closes tight to the bypass section.
  - (b) If the system provides an upstream balancing device, then balance according to the VAV pressure-dependent system procedures.

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### 3.25 VAV and Constant Volume Box Test & Balance (continued)

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- (c) Proportionally balance downstream air distribution, and record outlet measurements and maximum CFM.
  - (d) Adjust controls to modulate the box to bypass, and verify that the damper closes to space. If minimum stops are provided, then set the minimum airflow to space. Adjust the bypass volume damper, if provided, to obtain the required bypass CFM and to assure by-pass plus minimum to space is equal to the box total CFM. Record minimum CFM to space. If no bypass damper is provided, record the bypass CFM.
- b. Pressure-independent boxes
- 1. Single-duct VAV
    - (a) Adjust the controls to obtain the maximum flow, and verify the box controls' action.
    - (b) Measure and proportionally balance the downstream air distribution.
    - (c) Adjust maximum flow to obtain design CFM and record. Record the final CFM of downstream air distribution.
    - (d) Adjust controls to obtain minimum flow.
    - (e) Measure minimum flow at downstream air distribution, adjust flow to minimum design CFM, then record.

Note: Do not rebalance air distribution if the system loses proportional balance at minimum, but recheck air distribution at maximum and adjust only if necessary.
  - 2. Constant-volume, single-duct
    - (a) Adjust the controls to simulate full cooling.
    - (b) Measure and proportionally balance downstream air distribution.
    - (c) Adjust the controller to obtain the specified total airflow and record the setting. Record the final CFM of the downstream air distribution.
    - (d) Adjust the controls to simulate full heating.

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### 3.25 VAV and Constant Volume Box Test & Balance (continued)

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- (e) Measure airflow to ensure that the setting does not change. If the airflow changes, then investigate and correct. If adjustments do not eliminate the variation, then write up the variation as a deficiency.
3. VAV dual-duct
- (a) Adjust the control to simulate full cooling.
  - (b) Measure and proportionally balance downstream air distribution.
  - (c) Adjust cooling maximum flow to design and record. Record the final CFM of downstream air distribution.
  - (d) Adjust controls for cooling minimum and set by box delta P, if applicable.
  - (e) Adjust the heating maximum flow to design and record.
  - (f) Adjust controls for heating minimum and set by box delta P.
  - (g) Verify damper control box sequence and airflow to ensure proper operation and flow delivery over the operating range of the box. If unable to verify, then write up as a deficiency.
  - (h) Test hot and cold duct dampers for proper closure by the temperature method. If leakage is discovered, then report the deficiency.
4. Constant-volume, dual-duct, single controller
- (a) Adjust the control to simulate full cooling.
  - (b) Measure and proportionally balance downstream air distribution.
  - (c) Adjust the controller to design flow and record. Record the final CFM of downstream air distribution.
  - (d) Verify that the CFM remains constant over the range of operation and that the control sequence is correct. If unable to verify, then write up as a deficiency.
  - (e) Test hot and cold duct dampers for proper closure by the temperature method. If leakage is discovered, then report as a deficiency.

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### 3.25 VAV and Constant Volume Box Test & Balance (continued)

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5. Constant-volume, dual-duct, dual controls
  - (a) Adjust the control to simulate full cooling.
  - (b) Measure and proportionally balance downstream air distribution.
  - (c) Adjust the cooling controller to design flow and record. Record final CFM of downstream air distribution.
  - (d) Adjust the controls to simulate full heating.
  - (e) Adjust the heating maximum to design CFM and record.
  - (f) Verify that the CFM remains constant over the range of operation (cooling midpoint and heating) and that the control sequence is correct. If not, write it up as a deficiency.
  - (g) Test hot or cold duct dampers for proper closure by temperature method. If leakage is discovered, then report as a deficiency.
6. Parallel fan-powered VAV box
  - (a) Adjust the controls to obtain maximum flow, and verify the action of the box controls. Verify that the box back draft damper closes and no primary air is leaking out of the filter box fan section.
  - (b) Measure and proportionally balance downstream air distribution.
  - (c) Adjust maximum flow to obtain design CFM and record the final CFM of the downstream air distribution.
  - (d) Adjust controls to obtain minimum primary flow and heat.
  - (e) De-energize the parallel fan and set minimum primary flow to design by summation at air distribution and record the total.

Note: The box velocity pressure taps may be used to set minimum flow if verified as accurate during Step (c) only if the velocity pressure is greater than 0.02 inches WC.
  - (f) Re-energize the parallel fan, set the fan CFM to design flow, and record the fan CFM. Subtract the minimum primary air CFM from the total of the air distribution to determine fan CFM.
  - (g) Verify that the fan energizes at the appropriate time and in the proper sequence.

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### 3.25 VAV and Constant Volume Box Test & Balance (continued)

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7. Series fan-powered box
  - (a) Adjust controls to close primary air damper.
  - (b) Read and proportionally balance downstream air distribution.
  - (c) Adjust fan CFM to obtain design flow.
  - (d) Adjust controls to obtain maximum primary airflow.
  - (e) Measure and set primary airflow by Pitot tube traverse or by box delta P by using box flow chart, if a traverse is impossible. Record the maximum primary flow.
  - (f) Check the return air inlet of the box to ensure neutral airflow with primary maximum set. If access to the return inlet is not possible, then test for return air "leakage" by temperature mixture method. If neutral conditions do not exist, adjust fan speed to obtain neutral airflow. Recheck air distribution and record final fan CFM.
  - (g) Adjust heat controls and set minimum primary airflow by box delta P. Record the final minimum primary flow.

#### 3.25-7 Instrumentation:

- a. Air capture hood for ceiling air distribution
- b. Digital multimeter
- c. Inclined or digital manometer
- d. Velocity instruments for sidewalls, open duct, or other air distribution not suited for an air capture hood
- e. Glass stem or digital thermometers

#### 3.25-8 Report:

- a. Boxes must be balanced to  $\pm 10\%$  of design criteria at all required set points. The balancing agency must be responsible for field adjustment of set points.
- b. For direct digital control (DDC) systems, the Automatic Temperature Control Contractor (ATC) provides the balancing agency with computers, software, equipment, and help as required for balancing the system. The ATC installs all software and provides initial design set points.

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### **3.25 VAV and Constant Volume Box Test & Balance (continued)**

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- c. The report must contain maximum and minimum specified settings for each box. List the design and actual CFMs. Record the fan CFM for fan-powered boxes. For DDC system boxes, record computer set points, CFM readout, calibration factor, K factor, etc., of the box for future reference.
- d. Refer to the Report Contents procedure for reports and include any additional data as required.

#### **3.25-9 Compliance:**

- a. Compliance requires that all procedure steps from above are accomplished, as applicable to installation.
- b. A list of unresolved deficiencies is compiled.
- c. A typed report of test and balance data on approved forms is completed.

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## **Chapter 4: AIR SYSTEMS TESTING AND BALANCING PROCEDURE**

Associated Air Balance Council

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### **4.1 Single-Zone Systems**

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4.1-1 This procedure applies to the following:

All constant volume systems that have one zone control per air-handling unit.

4.1-2 This procedure does not apply to the following:

- a. Ductless type air-conditioning units
- b. Other types of air systems

4.1-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed and operational.

4.1-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the controls are installed, calibrated, and fully operational.
- c. Verify that access is available to components requiring adjusting.
- d. Verify that there are no adverse system effects or duct leakage that will affect this procedure.
- e. Perform a complete read out of all air-distribution devices as the first step to determine if inherent system pressure losses exist. See "d" above.

4.1-5 Procedures:

- a. Measure the airflow quantity of the supply, return, and outside air by Pitot tube traverse, unless it is impossible to do so.

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## 4.1 Single-Zone Systems (continued)

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- b. When the quantity cannot be obtained by Pitot tube traverse, then use the sum of the outlet or inlet quantities as the total CFM of the fan. If a Pitot tube traverse is not performed, then note the reason why on the test and balance report.
- c. Proportionally balance the air distribution systems. Verify that at least one outlet or inlet damper is fully open on every branch duct and at least one branch-duct balancing damper is fully open.
- d. Adjust fan speed to obtain 100 to 110 percent of design airflow.
- e. Record final measurements of the air distribution.
- f. Set the system in the normal mode and record the following final conditions:
  - 1. Supply, return, and outside air quantity
  - 2. Motor voltage, current, kw, and actual motor speed
  - 3. Fan speed
  - 4. Static pressure profile
  - 5. Coil capacity tests (including outside and return air temperatures)
- g. If the system is equipped with an economizer, then repeat the data in "f" above in the economizer mode. (Coil capacity tests need not be repeated if the coils are not pertinent to the economizer mode.)

### 4.1-6 Report:

- a. Include all test data on the appropriate data sheet forms.
- b. List any uncorrected deficiencies that affect the test results on the deficiency form and include it with the report.
- c. Include the Report Contents procedure requirements.

### 4.1-7 Compliance:

- a. To comply with this procedure, complete all of the above steps and record all data in the report.

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#### **4.1 Single-Zone Systems (continued)**

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- b. All deficiencies that affect the test and air balancing must be resolved by the installing contractors or included in the deficiency report.
- c. Instruments must be accurate, calibrated, and suitable for this type of testing.

---

## 4.2 Multi-Zone Systems

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4.2-1 This procedure applies to the following:

Multi-zone air-handling units

4.2-2 This procedure does not apply to the following:

- a. Single zone or VAV systems
- b. Other types of air systems

4.2-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed and operational.

4.2-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list deficiencies, and proceed when they are corrected.
- b. Verify that the controls are installed, calibrated, and fully operational.
- c. Verify that access is available to components requiring adjusting.
- d. Verify that there are no adverse system effects or duct leakage that will affect this procedure.
- e. Perform a complete readout of all air-distribution devices as the first step to determine if inherent system pressure losses exist.

4.2-5 Procedures:

- a. Measure total airflow quantity for each zone, return, and outside air by Pitot tube traverse, unless it is impossible to do so.
- b. When the quantity cannot be obtained by Pitot tube traverse, use the sum of the outlet quantities as the total CFM of the zones. If a Pitot tube traverse is not performed, then note the reason why on the test and balance report.
- c. Proportionally balance the outlets in each zone.

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## 4.2 Multi-Zone Systems (continued)

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- d. Proportionally balance each zone.
- e. Proportionally balance return air system
- f. At completion of balancing the air distribution system:
  - 1. At least one outlet or inlet damper must be fully open on every branch duct.
  - 2. At least one branch duct-balancing damper must be fully open.
  - 3. At least one zone-balancing damper must be fully open.
- g. Set fan speed to obtain 100 to 110 percent of design airflow.
- h. Take final measured data with the zone dampers in full cool and repeat in full heat or bypass.
- i. Test the zone temperature control-mixing dampers for proper shut-off of both hot and cold decks, and report the percentage of leakage.
- j. Verify all zone-mixing dampers are controlled by the proper space thermostat or sensor.
- k. At the completion of the balancing, set the system as indicated in "f" above. If the system is equipped with an economizer, then data shall also be recorded in the economizer mode. (Coil capacity tests unrelated to the economizer need not be repeated.) Record the following final conditions:
  - 1. Supply, return, and outside air quantity
  - 2. Motor, voltage, current, kw, actual motor speed
  - 3. Fan speed
  - 4. Static pressure profile (including a static pressure in each zone)
  - 5. Coil capacity test

### 4.2-6 Report:

- a. Include all test data on the appropriate data forms.
- b. List any uncorrected deficiencies that affect the test results on the deficiency form and include with report.
- c. Include Report Contents procedure requirements.

---

## 4.2 Multi-Zone Systems (continued)

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### 4.2-7 Compliance:

- a. To comply with this procedure, complete all of the above steps and record all data in the report.
- b. All deficiencies that affect the test and air balancing must be resolved by the installing contractors or included in the deficiency report.
- c. Instruments must be accurate, calibrated, and suitable for this type of testing.

---

### **4.3 Return Air/Outside Air/Relief Air Systems**

---

4.3-1 This procedure applies to the following:

All air-handling units with return air, outside air, and relief air systems

4.3-2 This procedure does not apply to the following:

- a. Ductless type air-conditioning units
- b. Other types of air systems

4.3-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed and operational.

4.3-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the controls are installed, calibrated and fully operational.
- c. Verify that access is available to components requiring adjusting.
- d. Verify that the air-handling unit is operating at design plus CFM.
- e. Verify that there are no adverse system effects or duct leakage that will affect this procedure.
- f. Verify that the dampers are tight, closed off, and track properly.
- g. Verify that outside air has proper devices to balance airflow.
- h. Verify that outside air has a control system that assures the required minimum outside air to remain constant under either constant or variable supply airflows for indoor air quality (IAQ) and constant building pressure purposes.
- i. Verify that the building exhaust equals the outside air make-up plus or minus the pressurization required.

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### 4.3 Return Air/Outside Air/Relief Air Systems (continued)

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#### 4.3-5 Procedures:

- a. Set supply air quantities according to the procedure for the type of system.
- b. Determine the total airflow quantity for return and outside air by Pitot tube traverse, unless it is impossible to do so.
- c. When the quantity cannot be obtained by Pitot tube traverse, use the sum of the inlet quantities as the total CFM of the returns. If a Pitot tube traverse is not performed, then note the reason why on the test and balance report.
- d. After balancing the air distribution system:
  1. At least one outlet or inlet damper must be fully open on every branch duct.
  2. At least one branch duct-balancing damper must be fully open.
  3. The return air must be set to supply CFM minus outside air quantity.
- e. Take final measured data with minimum and maximum flow and repeat in full-cool, full-heat, or bypass positions.
- f. Test all control dampers for proper shut-off and report the percentage of leakage.
- g. Verify the operation of all mixing dampers to control the proper temperature.
- h. After balancing, set the system as indicated in "d" above. If the system is equipped with an economizer, then data shall also be recorded in the economizer mode (tests unrelated to the economizer need not be repeated). Record the following final conditions:
  1. Motor, current, voltage, and kw
  2. Motor actual rpm
  3. Fan speed
  4. Static pressure profile (including exhaust/return air fan)
  5. Final temperature profile

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### **4.3 Return Air/Outside Air/Relief Air Systems (continued)**

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6. Outside airflow at each mode of operation
7. Exhaust airflow at each mode of operation
8. Return airflow at each mode of operation
9. Supply airflow at each mode of operation
10. Under any condition, outside airflow must not be less than that required for IAQ and/or that required to maintain constant building pressure when required

#### **4.3-6 Report:**

- a. Include all test data on the appropriate data sheet forms.
- b. List any uncorrected deficiencies that affect the test results on the deficiency form and include with the report.
- c. Include Report Contents procedure requirements.

#### **4.3-7 Compliance:**

- a. To comply with this procedure, complete all of the above steps and record all data in the report.
- b. All deficiencies that affect the test and air balancing must be resolved by the installing contractors or included in the deficiency report.
- c. Instruments must be accurate, calibrated, and suitable for this type of testing.

---

## **4.4 Constant Primary/Variable Secondary Bypass Systems**

---

4.4-1 This procedure applies to the following:

Air-handling units with the above terminal boxes

4.4-2 This procedure does not apply to the following:

- a. Ductless type air-conditioning units
- b. Other types of air systems

4.4-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed and operational.

4.4-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the controls are installed, calibrated, and fully operational.
- c. Verify that access is available to components requiring adjusting.
- d. Verify that there are no adverse system effects or duct leakage that will affect this procedure.

4.4-5 Procedures:

- a. Determine the airflow quantity of the supply, return, and outside air by Pitot tube traverse, unless it is impossible to do so.
- b. When the quantity cannot be obtained by Pitot tube traverse, use the sum of the outlet or inlet quantities as the total CFM of the fan. If a Pitot tube traverse is not performed, then note the reason why on the test and balance report.
- c. Set the terminal box air distribution according to the appropriate procedure given in the component section for VAV box testing.
- d. Balance all terminal boxes proportionally to receive the same ratio of

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#### **4.4 Constant Primary/Variable Secondary Bypass Systems (continued)**

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primary air. To do this, adjust the manual damper at the terminal inlet duct with all terminals in a full-cooling mode (maximum CFM to the space).

- e. At completion of balancing, the inlet manual damper to at least one terminal box on each branch duct shall be fully open.
- f. If branch dampers are provided, then set them so the airflow in each branch is proportionally balanced. At the completion of balancing, at least one damper in each branch must be fully open.
- g. At completion of proportional balancing, at least one terminal box damper shall be fully open on every branch duct, and at least one branch duct-balancing damper must be fully open.
- h. If the system incorporates ducted return, then set the return for each box as indicated in the component section of these procedures for the constant volume bypass terminal box.
- i. Balance the return-air branch dampers proportionally with at least one branch damper wide open at the completion of the balance.
- j. Set the system in the normal mode with all terminal boxes in the full-cooling mode, and record the following final conditions:
  - 1. Supply, return, and outside air quantity
  - 2. Motor, voltage, current, kw and actual motor speed
  - 3. Fan speed
  - 4. Static pressure profile
  - 5. Coil capacity tests (including outside and return air temperatures)
- k. If the system is equipped with an economizer, repeat the data in "j" above in the economizer mode. (Coil capacity tests need not be repeated if the coils are not pertinent to the economizer mode.)

##### **4.4-6 Report:**

- a. Include all test data on the appropriate data sheet forms.
- b. List any uncorrected deficiencies that affect the test results on the deficiency form and include it with the report.
- c. Include the Report Contents procedure requirements.

---

## **4.4 Constant Primary/Variable Secondary Bypass Systems (continued)**

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### 4.4-7 Compliance:

- a. To comply with this procedure, complete all of the above steps and record all data in the report.
- b. All deficiencies that affect the test and air balancing must be resolved by the installing contractors or included in the deficiency report.
- c. Instruments must be accurate, calibrated, and suitable for this type of testing.

---

## **4.5 Single-Duct, Variable Primary/Variable Secondary, Pressure-Dependent Systems**

---

4.5-1 This procedure applies to the following:

Air-handling units with the above terminal units

4.5-2 This procedure does not apply to the following:

- a. Ductless type air-conditioning units
- b. Other types of air systems

4.5-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed and operational.

4.5-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the controls are installed, calibrated and fully operational.
- c. Verify that access is available to components requiring adjusting.
- d. Verify that there are no adverse system effects or duct leakage that will affect this procedure.
- e. Perform a complete set-point read out of the control system and actual control points. Verify that the control system is calibrated.

4.5-5 Procedures:

- a. Determine the airflow quantity of the supply, return, and outside air by Pitot tube traverse, unless it is impossible to do so.
- b. Proportionally balance the downstream VAV air distribution.
- c. If branch dampers are provided, set them so the air pressure in each branch is proportionally balanced when the system is at maximum flow. Leave the damper fully open in the branch that is most difficult to supply.

---

#### 4.5 Single-Duct, Variable Primary/Variable Secondary, Pressure-Dependent Systems (continued)

---

- d. If VAV boxes have inlet dampers, then balance all VAV terminal boxes proportionally to receive the same ratio of required quantities of primary air. Do this by setting the boxes to full cooling (maximum CFM) and adjusting the manual damper in the inlet to the terminal. The inlet manual damper to at least one VAV terminal box on each branch duct must be fully open.
- e. Set space thermostats to either full heating or full cooling, as required to satisfy the design diversity factor. The thermostats selected simulate, as near as is practical, the manner in which the system will respond to the building's cooling-load shift.
- f. Proportionally balance return air system.
- g. With proper diversity established, adjust the supply fan capacity to provide design total CFM with its automatic volume-control device fully open.
- h. Determine final total airflow quantity by Pitot tube traverse unless it is impossible to do so.
- i. Where the quantity cannot be determined by a Pitot tube traverse, use the sum of all low pressure terminals as the total CFM of the fan. If a Pitot tube traverse is not performed, then note the reason why on the test and balance report.
- j. Measure and record the static pressure at the sensor for the automatic volume-control device under maximum and minimum conditions. This is the static pressure control set point, unless otherwise noted.
- k. Set the system in the normal mode and record the following final conditions:
  - 1. Supply, return, and outside air quantity
  - 2. Motor, voltage current, kw, and actual motor speed
  - 3. Fan speed
  - 4. Static pressure profile (including pressure at static sensor)
  - 5. Coil capacity tests
- l. If the system is equipped with an economizer, then repeat the data in "k" above in the economizer mode. (Coil capacity tests need not be repeated if the coils are not pertinent to the economizer mode.)

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### **4.5 Single-Duct, Variable Primary/Variable Secondary, Pressure-Dependent Systems (continued)**

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#### 4.5-6 Report:

- a. Include all test data on the appropriate data sheet forms.
- b. List any uncorrected deficiencies that affect the test results on the deficiency form and include it with the report.
- c. Include the Report Contents procedure requirements.

#### 4.5-7 Compliance:

- a. To comply with this procedure, complete all of the above steps and record all data in the report.
- b. All deficiencies that affect the test and air balancing must be resolved by the installing contractors or included in the deficiency report.
- c. Instruments must be accurate, calibrated, and suitable for this type of testing.

---

## **4.6 Constant-Volume, Dual-Duct Systems with Single-Volume Regulators**

---

4.6-1 This procedure applies to the following:

- a. Air-handling units with the above terminals
- b. Air-handling units with fan(s) common to both hot and cold decks

4.6-2 This procedure does not apply to the following:

- a. Air-handling units with separate fan(s) common to both hot and cold decks
- b. Ductless type air-conditioning units
- c. Other types of air systems

4.6-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed and operational.

4.6-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the controls are installed, calibrated and fully operational.
- c. Verify that access is available to components requiring adjusting.
- d. Verify that there are no adverse system effects or duct leakage that will affect this procedure.

4.6-5 Procedures:

- a. Set the mixing box constant-volume regulator for design CFM requirement and check for proper operation with the room thermostat in the full-cooling mode.
- b. After adjusting the regulator, place the thermostat in the full-heating mode and verify the operation.
- c. Balance the low-pressure air distribution from each terminal.

---

#### **4.6 Constant-Volume, Dual-Duct Systems with Single-Volume Regulators (continued)**

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- d. After adjusting all mixing boxes, set the thermostats so that the proper diversity is achieved.
- e. Proportionally balance return air system.
- f. Determine the final total airflow quantity of hot duct supply, cold duct supply, return, and outside air by Pitot tube traverse unless it is impractical to do so.
- g. Where the quantity cannot be determined by a Pitot tube traverse, use the sum of all low-pressure terminals as the total CFM of the fan. If a Pitot tube traverse is not performed, then note the reason why on the test and balance report.
- h. The fan setting must ensure that the inlet static pressure is adequate for the mixing box volume regulators to control, and that the pressure does not exceed the manufacturer's rating.
- i. Measure and record the static pressure with the system diversity set at the system static sensor. If the system does not have static control, then measure and record the static pressure in the duct to the most difficult to supply terminal.
- j. Verify and record the mixing box dampers for proper shut-off of both hot and cold ducts according to the temperature mixture procedure. Verify that the dampers are controlled by the correct space thermostat.
- k. Set the system in the normal mode and record the following final conditions:
  - 1. Hot duct supply, cold duct supply, return and outside air quantity
  - 2. Motor, voltage, current, kw, and actual motor speed
  - 3. Fan speed
  - 4. Static pressure profile including static pressure at the static sensor
  - 5. Coil capacity tests
- l. If the system is equipped with an economizer, then repeat the data in "k" above in the economizer mode (coil capacity tests need not be repeated if the coils are not pertinent to the economizer mode).

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## **4.6 Constant-Volume, Dual-Duct Systems with Single-Volume Regulators (continued)**

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### **4.6-6 Report:**

- a. Include all test data on the appropriate data sheet forms.
- b. List any uncorrected deficiencies that affect the test results on the deficiency form and include it with the report.
- c. Include the Report Contents procedure requirements.

### **4.6-7 Compliance:**

- a. To comply with this procedure, complete all of the above steps and record all data in the report.
- b. All deficiencies that affect the test and air balancing must be resolved by the installing contractors or included in the deficiency report.
- c. Instruments must be accurate, calibrated, and suitable for this type of testing.

---

## **4.7 Constant-Volume, Dual-Duct Systems with Two-Volume Regulators**

---

4.7-1 This procedure applies to the following:

- a. Air-handling units with the above terminals
- b. Air-handling units with fan(s) common to both hot and cold decks

4.7-2 This procedure does not apply to the following:

- a. Air-handling units with separate fan(s) common to both hot and cold decks
- b. Ductless type air-conditioning units
- c. Other types of air systems

4.7-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed and operational.

4.7-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the controls are installed, calibrated, and fully operational.
- c. Verify that access is available to components requiring adjusting.
- d. Verify that there are no adverse system effects or duct leakage that will affect this procedure.
- e. Perform a complete read out of all air-distribution devices as the first step to determine if inherent system pressure losses exist. See "d" above.

4.7-5 Procedures:

- a. Set the cooling-volume regulator for design CFM requirements and check for proper operation with the room thermostat in a full-cooling mode.
- b. After the cooling regulator is adjusted, place the thermostat in a full-heating mode and set the heating regulator to design CFM.

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### 4.7 Constant-Volume, Dual-Duct Systems with Two-Volume Regulators (continued)

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- c. Once both regulators are set for design airflow, adjust the thermostat to modulate the box to its midpoint position (hot and cold dampers open). At this point, verify that the airflow remains constant. If the flow varies more than the allowable tolerance, then list the box as deficient.
- d. Balance the low pressure air distribution from each terminal.
- e. After adjusting all mixing boxes, set the thermostats so that the proper diversity is achieved.
- f. Proportionally balance return air system.
- g. Determine the final total airflow quantity of the hot and cold duct supply, return, and outside air by Pitot tube traverse unless it is impractical to do so.
- h. Where the quantity cannot be determined by a Pitot tube traverse, use the sum of all low-pressure terminals as the total CFM of the fan. If a Pitot tube traverse is not performed, note the reason why on the test and balance report.
- i. The fan setting must ensure that the inlet static pressure is adequate for the volume regulators to control, and that the pressure does not exceed the manufacturer's rating.
- j. Record the static pressure at the system static sensor with the system under final control. If the system does not have static control, then measure and record the static pressure in the duct connected to the terminal that is most difficult to supply.
- k. Verify and record the mixing box dampers for proper shut-off of both hot and cold ducts according to the temperature mixture procedures. Verify that the dampers are controlled by the correct space thermostat.
- l. Set the system in the normal mode and record the following final conditions:
  - 1. Hot duct and cold duct supply, return and outside air quantity
  - 2. Motor, voltage, current, kw, and actual motor speed
  - 3. Fan speed
  - 4. Static pressure profile including static pressure at the static sensor
  - 5. Coil capacity tests

---

## **4.7 Constant-Volume, Dual-Duct Systems with Two-Volume Regulators (continued)**

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- m. If the system is equipped with an economizer, then repeat the data in "l" above in the economizer mode. (Coil capacity tests need not be repeated if the coils are not pertinent to the economizer mode.)

### 4.7-6 Report:

- a. Include all test data on the appropriate data sheet forms.
- b. List any uncorrected deficiencies that affect the test results on the deficiency form and include it with the report.
- c. Include the Report Contents procedure requirements.

### 4.7-7 Compliance:

- a. To comply with this procedure, complete all of the above steps and record all data in the report.
- b. All deficiencies that affect the test and air balancing must be resolved by the installing contractors or included in the deficiency report.
- c. Instruments must be accurate, calibrated, and suitable for this type of testing.

---

## **4.8 Single-Duct, Variable Primary/Variable Secondary, Pressure-Independent Systems**

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4.8-1 This procedure applies to the following:

Air-handling unit with the above terminals

4.8-2 This procedure does not apply to the following:

- a. Ductless type air-conditioning units
- b. Other types of air systems

4.8-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed and operational.

4.8-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the controls are installed, calibrated, and fully operational.
- c. Verify that access is available to components requiring adjusting.
- d. Verify that there are no adverse system effects or duct leakage that will affect this procedure.
- e. Perform a complete readout of all air-distribution devices as the first step to determine if inherent system pressure losses exist. See "d" above.

4.8-5 Procedures:

- a. Set the terminal box according to the appropriate procedure given in the component section for VAV box testing.
- b. After all VAV terminals are adjusted, set space thermostats in either a full-heating or cooling position, as required to satisfy the design diversity factor of the system, if applicable. Select thermostats to be set for heating or cooling so as to simulate as nearly as practical the manner in which the system will respond to the cooling-load shift of the building.

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### **4.8 Single-Duct, Variable Primary/Variable Secondary, Pressure-Independent Systems (continued)**

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- c. With proper diversity established, adjust the supply fan capacity to provide total design CFM with its automatic volume control device fully open to provide adequate, but not excessive, static pressure in the branch duct to the VAV terminal which is the most difficult to supply.
- d. Proportionally balance return air system.
- e. Determine final total airflow quantity of supply, return, and outside air by Pitot tube traverse unless it is impractical to do so.
- f. Where the quantity cannot be determined by a Pitot tube traverse, use the sum of all low-pressure terminals as the total CFM of the fan. If a Pitot tube traverse is not performed, note the reasons why on the test and balance report.
- g. Measure and record the static pressure at the sensor for the automatic volume control device under maximum and minimum conditions. This is the static pressure control set point, unless otherwise noted. Verify the control system read out.
- h. With the system set for diversity, record the following final conditions:
  - 1. Supply, return and outside air quantity
  - 2. Motor, voltage, current, kw, and actual motor speed
  - 3. Fan speed
  - 4. Static pressure profile, including the pressure at the static sensor
  - 5. Coil capacity tests
- i. If the system is equipped with an economizer, repeat the data in "h" above in the economizer mode. (Coil capacity tests need not be repeated if the coils are not pertinent to the economizer mode.)

#### **4.8-6 Report:**

- a. Include all test data on the appropriate data sheet forms.
- b. List any uncorrected deficiencies that affect the test results on the deficiency form and include it with the report.
- c. Include the Report Contents procedure requirements.

---

**4.8 Single-Duct, Variable Primary/Variable  
Secondary, Pressure-Independent Systems (continued)**

---

4.8-7 Compliance:

- a. To comply with this procedure, complete all of the above steps and record all data in the report.
- b. All deficiencies that affect the test and air balancing must be resolved by the installing contractors or included in the deficiency report.
- c. Instruments must be accurate, calibrated, and suitable for this type of testing.

---

## **4.9 Single-Fan, Dual-Duct, Variable Primary/Variable Secondary, Pressure-Independent Systems**

---

4.9-1 This procedure applies to the following:

Air-handling units with the above terminals

4.9-2 This procedure does not apply to the following:

- a. Ductless type air-conditioning units
- b. Other types of air systems

4.9-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed and operational.

4.9-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the controls are installed, calibrated and fully operational.
- c. Verify that access is available to components requiring adjusting.
- d. Verify that there are no adverse system effects or duct leakage that will affect this procedure.
- e. Perform a complete read out of all air-distribution devices as the first step to determine if inherent system pressure losses exist. See "d" above.

4.9-5 Procedures:

- a. Set the terminal box according to the appropriate procedure given in the component section for VAV box testing.
- b. After all VAV terminals are set to design flow, adjust space thermostats to either full heating, neutral, or cooling as required to satisfy the design diversity factor of the system, if applicable. Select thermostats to be set for heating or cooling and simulate the manner in which the system will respond to the cooling-load shift of the building as nearly as is practical.

---

#### **4.9 Single-Fan, Dual-Duct, Variable Primary/Variable Secondary, Pressure-Independent Systems (continued)**

---

- c. Proportionally balance return air system.
- d. With proper diversity established, adjust the supply fan capacity to provide total design CFM with its automatic volume control device fully open to provide adequate, but not excessive, static pressure in the branch duct to the VAV terminal which is the most difficult to supply.
- e. Determine the final total airflow quantity of hot and cold duct supply, return, and outside air by Pitot tube traverse unless it is impractical to do so.
- f. Where the quantity cannot be determined by a Pitot tube traverse, use the sum of all low-pressure terminals as the total CFM of the fan. If a Pitot tube traverse is not performed, note the reason why on the test and balance report.
- g. Measure and record the static pressure at the sensor for the automatic volume control device under maximum conditions. This is the static pressure set point, unless otherwise noted. Verify the control system read out.
- h. With the system set for diversity, record the following final conditions:
  - 1. Hot duct and cold duct supply, return, and outside air quantity
  - 2. Motor, voltage, current, kw, and actual motor speed
  - 3. Fan speed
  - 4. Static pressure profile, including the pressure at the static sensor
  - 5. Coil capacity tests
- i. If the system is equipped with an economizer, then repeat the data in "g" above in the economizer mode. (Coil capacity tests need not be repeated if the coils are not pertinent to the economizer mode.)

##### **4.9-6 Report:**

- a. Include all test data on the appropriate data sheet forms.
- b. List any uncorrected deficiencies that affect the test results on the deficiency form and include it with the report.
- c. Include the Report Contents procedure requirements.

---

**4.9 Single-Fan, Dual-Duct, Variable Primary/Variable  
Secondary, Pressure-Independent Systems (continued)**

---

4.9-7 Compliance:

- a. To comply with this procedure, complete all of the above steps and record all data in the report.
- b. All deficiencies that affect the test and air balancing must be resolved by the installing contractors or included in the deficiency report.
- c. Instruments must be accurate, calibrated, and suitable for this type of testing.

---

## **4.10 Variable Primary/Variable Secondary, System-Powered Bladder or Spring-Regulator Terminal Systems**

---

4.10-1 This procedure applies to the following:

Air-handling units with the above terminals

4.10-2 This procedure does not apply to the following:

- a. Ductless type air-conditioning units
- b. Other types of air systems

4.10-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed and operational.

4.10-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the controls are installed, calibrated and fully operational.
- c. Verify that access is available to components requiring adjusting.
- d. Verify that there are no adverse system effects or duct leakage that will affect this procedure.

4.10-5 Procedures:

- a. Balance the terminal boxes according to the appropriate terminal box procedure.
- b. Balance the low-pressure air distribution from each terminal.
- c. Proportionally balance return air system.
- d. Determine the final total airflow quantity of supply, return, and outside air by Pitot tube traverse unless it is impractical to do so.
- e. Where the quantity cannot be determined by a Pitot tube traverse, use the sum of all low-pressure terminals as the total CFM of the fan. If a Pitot tube traverse is not performed, then note the reason why on the test and balance report.

---

#### **4.10 Variable Primary/Variable Secondary, System-Powered Bladder or Spring-Regulator Terminal Systems (continued)**

---

- f. The fan setting should ensure that the inlet static pressure is adequate for the volume regulator to control, and that the pressure does not exceed the manufacturer's rating.
- g. Measure and record the static pressure at the sensor for the automatic volume control device under maximum and minimum conditions. If the system does not have static control, then measure and record the static pressure in the duct to the most difficult to supply terminal.
- h. Set the system in the normal mode and record the following final conditions:
  - 1. Supply, return, and outside air quantity
  - 2. Motor, voltage , current, kw, and actual motor speed
  - 3. Fan speed
  - 4. Static pressure profile, including the pressure at the static sensor
  - 5. Coil capacity tests
- i. If the system is equipped with an economizer, the data in "h" above shall be repeated in the economizer mode. (Coil capacity tests need not be repeated if the coils are not pertinent to the economizer mode.)

##### **4.10-6 Report:**

- a. Include all test data on the appropriate data sheet forms.
- b. List any uncorrected deficiencies that affect the test results on the deficiency form and include it with the report.
- c. Include the Report Contents procedure requirements.

##### **4.10-7 Compliance:**

- a. To comply with this procedure, complete all of the above steps and record all data in the report.
- b. All deficiencies that affect the test and air balancing must be resolved by the installing contractors or included in the deficiency report.
- c. Instruments must be accurate, calibrated, and suitable for this type of testing.

---

## 4.11 High-Pressure Induction Systems

---

4.11-1 This procedure applies to the following:

Air-handling units with the above terminals

4.11-2 This procedure does not apply to the following:

- a. Ductless type air-conditioning units
- b. Other types of air systems

4.11-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed and operational.

4.11-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the controls are installed, calibrated and fully operational.
- c. Verify that access is available to components requiring adjusting.
- d. Verify that there are no adverse system effects or duct leakage that will affect this procedure.
- e. Perform a complete read out of all air-distribution devices as the first step to determine if inherent system pressure losses exist. See "d" above.

4.11-5 Procedures:

- a. Determine the total supply, return, and outside airflow quantity by Pitot tube traverse unless it is impossible to do so.
- b. Where the supply quantity cannot be determined by a Pitot tube traverse, use the sum of the primary air quantities at all induction units as the total CFM of the fan. If a Pitot tube traverse is not performed, then note the reason why on the test and balance report.

---

### 4.11 High-Pressure Induction Systems (continued)

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- c. Determine and set the primary airflow to each terminal unit by measuring the plenum pressures and comparing them to manufacturer's rated values. If no manufacturer's data is available, then field verify the pressure and flow to each size terminal by Pitot tube traverse.
- d. At the completion of balancing:
  - 1. The primary air damper of at least one induction unit on each branch duct must be fully open.
  - 2. At least one branch balancing damper must be fully open.
- e. Measure the plenum static pressure of each induction unit under the final balanced condition and record the final flow at each unit in the report.
- f. Set the system in the normal mode and record the following final conditions:
  - 1. Supply, return, and outside air quantity
  - 2. Motor, voltage, current, kw, and actual motor speed
  - 3. Fan speed
  - 4. Static pressure profile
  - 5. Coil capacity tests (including induction unit coils)
- g. If the system is equipped with an economizer, then repeat the data in "f" above in the economizer mode. (Coil capacity tests need not be repeated if the coils are not pertinent to the economizer mode.)

#### 4.11-6 Report:

- a. Include all test data on the appropriate data sheet forms.
- b. List any uncorrected deficiencies that affect the test results on the deficiency form and include it with the report.
- c. Include the Report Contents procedure requirements.

---

## 4.11 High-Pressure Induction Systems (continued)

---

### 4.11-7 Compliance:

- a. To comply with this procedure, complete all of the above steps and record all data in the report.
- b. All deficiencies that affect the test and air balancing must be resolved by the installing contractors or included in the deficiency report.
- c. Instruments must be accurate, calibrated, and suitable for this type of testing.

---

## 4.12 Return or Exhaust Low-Pressure Air Systems

---

4.12-1 This procedure applies to the following:

- a. Return air systems on constant volume air-handling units and constant volume exhaust-air systems
- b. Variable-volume systems without return air fans.

4.12-2 This procedure does not apply to the following:

- a. Ductless type air-conditioning units
- b. Other types of air systems

4.12-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed and operational.

4.12-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the controls are installed, calibrated, and fully operational.
- c. Verify that access is available to components requiring adjusting.
- d. Verify that there are no adverse system effects or duct leakage that will affect this procedure.
- e. Perform a complete readout of all air-distribution devices as the first step to determine if inherent system pressure losses exist. See "d" above.

4.12-5 Procedures:

- a. At the completion of the supply air proportional balance, balance the return air proportionally.

---

## 4.12 Return or Exhaust Low-Pressure Air Systems (continued)

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- b. Adjust inlets to within tolerance of AABC Procedures or according to the project specifications, whichever is more stringent. In fan systems with diversity, the sum of the individual return inlet CFM may exceed the volume possible for the return system, therefore, the most airflow that can be expected from a single return inlet is the proportional ratio of the return system maximum total to the summation of the return inlets, multiplied by the individual return-inlet-specified CFM.
- c. At the completion of the balancing, at least one inlet damper on each branch must be fully open, and at least one branch damper in the system must be fully open.
- d. Set the return air total in proportion to supply and outside air for return air systems.
- e. After the fan is set to design, measure the total return or exhaust by Pitot tube traverse, if possible. If not, then use the summation of the inlets for airflow determination. If a Pitot tube traverse is not performed, then note the reasons in the test and balance report.
- f. Measure static pressure as required by the static pressure profile for the system.

### 4.12-6 Report:

- a. Include all test data on the appropriate data sheet forms.
- b. List any uncorrected deficiencies that affect the test results on the deficiency form and include it with the report.
- c. Include the Report Contents procedure requirements.

### 4.12-7 Compliance:

- a. To comply with this procedure, complete all of the above steps and record all data in the report.
- b. All deficiencies that affect the test and air balancing must be resolved by the installing contractors or included in the deficiency report.
- c. Instruments must be accurate, calibrated, and suitable for this type of testing.

---

### 4.13 Return/Relief Fan Set-up for CV or VAV Systems

---

4.13-1 This procedure applies to the following:

Air-handling units with the above configuration.

4.13-2 This procedure does not apply to the following:

- a. Ductless type air-conditioning units
- b. Other types of air systems

4.13-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed and operational.

4.13-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list deficiencies, and proceed when they are corrected.
- b. Verify that the controls are installed, calibrated, and fully operational.
- c. Verify that access is available to components requiring adjusting.
- d. Verify air-handling unit is operating at design plus CFM.
- e. Verify that there are no adverse system effects or duct leakage that will affect this procedure.

4.13-5 Procedures:

- a. In the normal return air mode, with the supply fan at maximum capacity, balance return inlets proportionally to the return air system total. Note that supply fan total minus the minimum outside air is the return system's maximum total. In fan systems with diversity, the sum of the individual return inlet CFM may exceed the volume possible for the return system, therefore, the most airflow that can be expected from a single return inlet is the proportional ratio of the return system maximum total to the summation of the return inlets, multiplied by the individual return-inlet-specified CFM.

---

### 4.13 Return/Relief Fan Set-up for CV or VAV Systems (continued)

---

- b. With the supply fan at maximum and the return system in the relief mode, adjust the return fan to provide the return system's maximum CFM, with the return volume control device at maximum.
- c. With the supply fan at maximum and the return system in the normal mode, adjust the manual damper in the return duct connection to the mixed air plenum to obtain minimum outside air CFM requirements. Traverse the return fan volume in this mode as well, since leakage in the relief dampers could cause negative building conditions.
- d. Determine the total return air CFM by Pitot tube traverse in both modes, unless it is impossible to do so.
- e. If a Pitot tube traverse is impossible, then use the sum of the inlet quantities as the total CFM of the fan.
- f. At the completion of the traversing, place the return fan in each mode and record the following for each mode. Note that the supply fan is at maximum for this testing.
  1. Return and relief air
  2. Motor, voltage, current, kw, and actual motor speed
  3. Fan speed
  4. Static pressure profile (in both modes)
  5. Mixed air temperatures stratification results
- g. If the system uses airflow rate, then these procedures remain the same except for:
  1. The manual damper at the mixed air plenum is not required, and
  2. The airflow measuring stations must be verified by Pitot tube traverse.
- h. If the system uses a fan-tracking control strategy, then verify the tracking capability of the fans through a minimum of four points (maximum,  $\pm 75\%$ ,  $\pm 50\%$ , and minimum). Include tracking verification in the report.
- i. Observe the return/relief fan and verify that it is as stable throughout its range of operation.
- j. Check the building or area served by the system for proper pressurization over the full range of operation.

---

### **4.13 Return/Relief Fan Set-up for CV or VAV Systems (continued)**

---

4.13-6 Report:

- a. Include all test data on the appropriate data sheet forms.
- b. List any uncorrected deficiencies that affect the test results on the deficiency form and include it with the report.
- c. Include the Report Contents procedure requirements.

4.13-7 Compliance:

- a. To comply with this procedure, complete all of the above steps and record all data in the report.
- b. All deficiencies that affect the test and air balancing must be resolved by the installing contractors or included in the deficiency report.
- c. Instruments must be accurate, calibrated, and suitable for this type of testing.

---

## 4.14 Outside Air-Intake

---

4.14-1 This procedure applies to the following:

Setting of outside air on constant-volume, variable-volume, and economizer systems

4.14-2 This procedure does not apply to the following:

Other types of systems

4.14-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed and operational.

4.14-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the controls are installed, calibrated, and fully operational.
- c. Verify that access is available to components requiring adjusting.
- d. Verify air-handling unit is operating at design plus CFM.
- e. Verify that there are no adverse system effects or duct leakage that will affect this procedure.

4.14-5 Procedures:

- a. Outside air on constant-volume systems
  1. Determine airflow quantity by Pitot tube traverse, unless it is impossible to do so.
  2. When the quantity cannot be determined by a Pitot tube traverse, indicate the method actually used, along with area factors etc., in the test and balance report.

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#### 4.14 Outside Air-Intake (continued)

---

3. Set the outside air initially at the time of the supply and return air proportional balance. The quantity must be in proportion to the total fan CFM to avoid adding any undue static on the fan or return air system.
  4. At the completion of the supply and return airflow setting, measure the outside air quantity and adjust as required to meet the design requirements.
  5. Mark the final setting of the manual dampers. For DDC systems, record the final software settings and indicate in the test and balance report.
- b. Variable-volume systems
1. Determine the airflow quantity by Pitot tube traverse, unless it is impossible to do so.
  2. When the quantity cannot be determined by a Pitot tube traverse, indicate the method actually used, along with area factors, etc., in the test and balance report.
  3. At the completion of the supply air-fan setup, according to the appropriate procedure, set the outside air quantity with the system in the maximum mode, allowing for diversity as required.
  4. With the system modulated to the minimum mode, measure and verify the outside air quantity.
  5. Report deviations in quantity between maximum and minimum modes and note in the test and balance report.
  6. Mark the final setting of manual dampers. Record motorized control dampers' set point and record the DDC control's final software settings and indicate in the test and balance report.
  7. Record outside air fan data according to the fan procedure. Record static pressures and motor amperage at minimum and maximum supply fan modes.

---

#### 4.14 Outside Air-Intake (continued)

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8. Set up all airflow stations devices according to the airflow station procedure. Record all correction factors, velocities, and conversion factors in the final test and balance report.

c. Economizer Systems

1. Determine airflow quantity by Pitot tube traverse, unless it is impossible to do so.
2. When the quantity cannot be determined by a Pitot tube traverse, indicate the method actually used, along with area factors etc., in the test and balance report.
3. At the completion of the supply air-fan setup, set the outside air quantity with the system in the normal mode (and maximum mode for a VAV system).
4. Measure the outside air quantity with the system in the economizer mode. If more than one system has economizer modes, all systems must be modulated to 100 percent outside air. In this mode, verify the total airflow and check the building pressure to insure that over-pressurization does not occur.
5. For systems with return/relief tracking fans, measure the outside air at all modulating points, as outlined in the Return/Relief Fan Tracking procedure.

4.14-6 Report

- a. Include all test data on the appropriate data sheet forms.
- b. List any uncorrected deficiencies that affect the test results on the deficiency form and include it with the report.
- c. Include the Report Contents procedure requirements.

4.14-7 Compliance:

- a. To comply with this procedure, complete all of the above steps and record all data in the report.

---

#### **4.14 Outside Air-Intake (continued)**

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- b. All deficiencies that affect the test and air balancing must be resolved by the installing contractors or included in the deficiency report.
- c. Instruments must be accurate, calibrated, and suitable for this type of testing.

---

## 4.14 Outside Air-Intake

---

4.14-1 This procedure applies to the following:

Setting of outside air on constant-volume, variable-volume, and economizer systems

4.14-2 This procedure does not apply to the following:

Other types of systems

4.14-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed and operational.

4.14-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that the controls are installed, calibrated, and fully operational.
- c. Verify that access is available to components requiring adjusting.
- d. Verify air-handling unit is operating at design plus CFM.
- e. Verify that there are no adverse system effects or duct leakage that will affect this procedure.

4.14-5 Procedures:

- a. Outside air on constant-volume systems
  1. Determine airflow quantity by Pitot tube traverse, unless it is impossible to do so.
  2. When the quantity cannot be determined by a Pitot tube traverse, indicate the method actually used, along with area factors etc., in the test and balance report.

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## **Chapter 5: HYDRONIC SYSTEMS**

Associated Air Balance Council

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### **5.1 Primary Constant Flow Systems**

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- 5.1-1 This procedure applies to the following:  
Heating, cooling, and condenser water systems
- 5.1-2 This procedure does not apply to the following:
- Other types of water systems
  - Full-load performance tests
- 5.1-3 Operation:
- All equipment in the system must be in operation before the test and balance technician begins the procedure.
  - All controls must be installed, calibrated, and fully operational.
- 5.1-4 Inspection:
- Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
  - Verify that this water system is vented, free of air, and at a normal water temperature setting.
  - Check expansion/compression tank levels and pressures.
  - Verify that the cooling tower is operating properly, with hot water basins at equal levels.
  - Verify that the pumps are lined up correctly and are operating properly.
  - Verify that the flow meters are installed in the water piping according to the Water Flow Station procedure.
  - Verify that the thermometer wells and test thermometers are installed properly in water piping according to the Basic Temperature Test Measurements procedure.

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## 5.1 Primary Constant Flow Systems (continued)

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### 5.1-5 Procedures:

- a. Perform shut-off head-pressure test on each pump to determine impeller size and pump operating curve.
- b. Make initial setting of pump flow at approximately 110 % of design flow, with all system coil valves in the wide-open position. If a pressure bypass valve is used to maintain constant flow in a two-way valve system, verify the pressure bypass valve is closed.
- c. Balance the flow through each coil or element in the system. Make at least two passes to obtain a proportional balance. More passes may be required to obtain a proportional balance, however, a minimum of two passes must be performed.
- d. If three-way valves are present at each coil or element, cycle the controls to modulate the valve to bypass after setting the coil flow, and set the flow through the bypass to match the coil flow. Modulate the control valve from the coil to bypass position, and monitor the flow to assure that flow does not increase with the valve in the mid position. If the flow does increase, adjust the bypass balancing valve until the modulated flow equals the coil flow. Remeasure the full bypass flow, record all flows, and report the excess modulated flow as a deficiency.
- e. Make a final adjustment at the pump, if necessary, to obtain 100 to 110 % flow. If this flow is not attainable, make a note of the reason for the deviation.
- f. Perform a final pass through each coil or element, recording the final flows and pressure drops.
- g. Record all final pump operating heads and flows.
- h. Measure and record the power on all pumps before and after the system balancing.
- i. Verify that all control valves are the three-way type, or that a pressure bypass is installed in the proper location to maintain constant flow. If a pressure bypass valve is installed, measure and record the system operating pressure at the control point with all valves in the system at full flow. Modulate the coil valves to simulate minimum flow to the coils, and verify total system flow and operation of the bypass valve. Record the control pressure operating point.

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## 5.1 Primary Constant Flow Systems (continued)

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- j. Upon completion of the test and balance, record the data below on appropriate report forms. Refer to the Report Contents procedure.
  - 1. Design water flow, GPM.
  - 2. Design pressure criteria.
  - 3. All nameplate data.
  - 4. Power measurements, refer to the Electrical Power Measurements procedure.
  - 5. kw (where applicable).
  - 6. Design pump and motor RPM.
  - 7. Actual motor RPM (if accessible).
  - 8. Actual pump RPM if different from the motor RPM.
  - 9. Pump shut-off head pressure.
  - 10. Pump operating head pressure.
  - 11. Pump suction pressure (both operating and shut-off).
  - 12. Pump discharge pressure (both operating and shut-off).
  - 13. Position of the balancing valve at the final balance.
  - 14. Actual water flow GPM.
  - 15. Actual pressure measurements at the flow elements, coils, etc.
  - 16. Actual bypass pressure and control setting at the final balance (if installed).

### 5.1-6 Report:

- a. Include all test data on approved Water Balance Data Sheets as required by the Report Contents procedure.
- b. In the conclusion, list both the conditions at the time of the test and the results.
- c. List any uncorrected deficiencies that affect the test results on the deficiency report form.

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## **5.1 Primary Constant Flow Systems (Continued)**

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d. Include required data from the Report Contents procedure.

### 5.1-7 Compliance:

- a. To comply with this procedure, complete all of the above steps and record all data on the report forms.
- b. All deficiencies that affect the water balancing should have been resolved by the installing contractors or included in the deficiency report.
- c. Instrumentation shall be accurate and suitable for this type of testing as required by the instrumentation and basic measurements procedures.

---

## 5.2 Primary/Secondary Constant Flow Systems

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5.2-1 This procedure applies to the following:

Heating, cooling, and condenser water systems using the primary/secondary piping concept

5.2-2 This procedure does not apply to the following:

- a. Other types of water systems
- b. Full-load performance test

5.2-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed, calibrated, and fully operational.

5.2-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that this water system is vented, free of air, and at a normal water temperature setting.
- c. Check expansion/compression tank levels and pressures.
- d. Verify that the cooling tower is operating properly, with hot water basins at equal levels.
- e. Verify that the pumps are lined up correctly and are operating properly.
- f. Verify that the flow meters are installed in the water piping according to the Water Flow Station procedure.
- g. Verify that the thermometer wells and test thermometers are installed properly in water piping according to the Basic Temperature Test Measurements procedure.

5.2-5 Procedures:

- a. Perform shut-off head pressure test on each pump to determine impeller size and pump operating curve.

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## 5.2 Primary/Secondary Constant Flow Systems (continued)

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- b. With all system valves in the wide-open position, set the primary and secondary pump operating head at approximately 110 % of design.
- c. Balance the water flow in the primary loop to 100 to 110 %. Balance between the primary elements (chillers, boilers, etc.) if there is more than one element per pump.
- d. Balance the secondary system, make at least two passes to obtain a proportional balance. More passes may be required to obtain a proportional balance; however, a minimum of two passes must be performed.
- e. If three-way valves are present in the secondary system at each coil or element, cycle the controls to bypass after setting the coil flow, and set the flow through the bypass to match the coil flow. Modulate the control valve from the coil to bypass position, and monitor the flow to assure that flow does not increase with the valve in the mid position. If the flow does increase, adjust the bypass balancing valve until the modulated flow equals the coil flow. Remeasure the full bypass flow, record all flows, and report excess modulated flow as a deficiency.
- f. Make final adjustments at pumps to obtain 100 to 110 % flow. If this flow is not obtainable, make a note of the reason for the deviation.
- g. Perform a final pass through each coil or element in the primary and secondary system, recording the final flows and pressure drops.
- h. Record all final pump operating heads and flows.
- i. Assure proper flow direction at the primary/secondary bridge.
- j. Measure and record the power on all pumps before and after the system balancing.
- k. Verify that all control valves in the secondary system are the three-way type, or that a pressure bypass is installed to maintain a constant flow. If a pressure bypass valve is installed, measure and record the system operating pressure at the control point with all coil valves in the system at full flow. Modulate the coil valves to simulate minimum flow, and verify total system flow and operation of the bypass valve. Record the control pressure operating point.
- l. Upon completion of the test and balance, record the data below on the appropriate report form. Refer to Report Contents procedure.
  1. Design water flow, GPM.

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## 5.2 Primary/Secondary Constant Flow Systems (continued)

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2. Design pressure criteria.
3. All nameplate data.
4. Power measurements, refer to the Electrical Power Measurements procedure.
5. kw (where applicable).
6. Design pump and motor RPM.
7. Actual motor RPM (if accessible).
8. Actual pump RPM if different from the motor RPM.
9. Pump shut-off head pressure.
10. Pump operating head pressure.
11. Pump suction pressure (both operating and shut-off).
12. Pump discharge pressure (both operating and shut-off).
13. Position of the balancing valve at the final balance.
14. Actual water flow GPM.
15. Actual pressure measurements at the flow elements, coils, etc.
16. Actual bypass pressure and control setting at the final balance (if installed).

### 5.2-6 Report:

- a. Include all test data on approved Water Balance Data sheets as required by the Report Contents procedure.
- b. In the conclusion, list both the conditions at the time of the test and the results.
- c. List any uncorrected deficiencies that affect the test results on the deficiency report form.
- d. Include required data from the Report Contents procedure.

---

## **5.2 Primary/Secondary Constant Flow Systems (continued)**

---

### 5.2-7 Compliance:

- a. To comply with this procedure, complete all of the above steps and record all data on the report forms.
- b. All deficiencies that affect the water balancing should have been resolved by the installing contractors or included in the deficiency report.
- c. Instrumentation must be accurate and suitable for this type of testing as required by the instrumentation and basic measurements procedure.

---

### **5.3 Constant Flow Primary/Variable Flow Secondary Systems**

---

5.3-1 This procedure applies to the following:

Heating and cooling water systems using the constant flow primary/  
variable flow secondary pumping and piping concept

5.3-2 This procedure does not apply to the following:

- a. Other types of water systems
- b. Full-load performance test

5.3-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed, calibrated, and fully operational.

5.3-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that this water system is vented, free of air, and at a normal water temperature setting.
- c. Check expansion/compression tank levels and pressures.
- d. Verify that the cooling tower is operating properly, with hot water basins at equal levels.
- e. Verify that the pumps are lined up correctly and are operating properly.
- f. Verify that the flow meters are installed in the water piping according to the Water Flow Station procedure.
- g. Verify that the thermometer wells and test thermometers are installed properly in water piping according to the Basic Temperature Test Measurements procedure.

5.3-5 Procedures:

- a. Perform shut-off head pressure test on each pump to determine impeller size and pump operating curve.

---

### 5.3 Constant Flow Primary/Variable Flow Secondary Systems (continued)

---

- b. With all system valves in the wide-open position, set the primary and secondary pump operating head at approximately 110 % of design.
- c. Balance the water flow in the primary loop to 100 to 110 %. Balance between the primary elements (chillers, boilers, etc.) if there is more than one element per pump.
- d. If there is no diversity in the secondary system, balance the system making at least two passes to obtain a proportional balance. More passes may be required to obtain a proportional balance; however, a minimum of two passes must be performed. If there is diversity in the secondary system, select enough coils to match the secondary pump design GPM closing the remaining valves. Proportionally balance the flow through the selected valves as indicated above. Once the system has been proportionally balanced, select enough open valves to match the diversity and close them. Balance the flow at the newly opened valves.
- e. Make final adjustments at pumps to obtain 100 to 110 % flow. If this flow is not obtainable, make note of the reason for the deviation.
- f. Perform a final pass through the primary and secondary components, recording final flow and pressure drops with the system set for diversity as described above, if applicable.
- g. Record all final pump operating heads and flows.
- h. With the system set at maximum flow, assure proper flow direction at the primary/secondary bridge.
- i. Record the actual pressure at the control point for the variable volume secondary system. Compare this to the actual control device readout or set point.
- j. Assure pump control of secondary at minimum flow.
- k. Measure and record the power on all pumps before and after the system balancing.
- l. Upon completion of the test and balance, record the data below on appropriate report forms. Refer to Report Contents procedures.
  - 1. Design water flow, GPM.
  - 2. Design pressure criteria.
  - 3. All nameplate data.

---

### **5.3 Constant Flow Primary/Variable Flow Secondary Systems (continued)**

---

4. Power measurements, refer to the Electrical Power Measurements procedure.
5. kw (where applicable).
6. Design pump and motor RPM.
7. Actual motor RPM (if accessible).
8. Actual pump RPM if different from the motor RPM.
9. Pump shut-off head pressure.
10. Pump operating head pressure.
11. Pump suction pressure (both operating and shut-off).
12. Pump discharge pressure (both operating and shut-off).
13. Position of the balancing valve at the final balance.
14. Actual water flow GPM.
15. Actual pressure measurements at the flow elements, coils, etc.
16. Actual bypass pressure and control setting at the final balance (if installed).

#### **5.3-6 Report:**

- a. Include all test data on approved Water Balance Distribution Equipment Data Sheets as required by the report contents procedure.
- b. In the conclusion, list conditions at the time of the test and the results.
- c. List any uncorrected deficiencies that affect the test results on the deficiency report form.
- d. Include required data from the Report Contents procedure.

#### **5.3-7 Compliance:**

- a. To comply with this procedure, complete all of the above steps and record all data on the report forms.

---

### **5.3 Constant Flow Primary/Variable Flow Secondary Systems (continued)**

---

- b. All deficiencies that affect the water balancing should have been resolved by the installing contractors or included in the deficiency report.
- c. Instrumentation shall be accurate and suitable for this type of testing as required by the instrumentation and basic measurements procedures.

---

## **5.4 Constant Flow Primary/Constant Flow Secondary/ Constant Flow Tertiary Systems**

---

5.4-1 This procedure applies to the following:

Heating and cooling water systems using the constant flow primary/  
constant flow secondary/constant flow tertiary pumping and piping system  
as a third pump at the coil or third loop concept.

5.4-2 This procedure does not apply to the following:

- a. Other types of water systems
- b. Full-load performance test

5.4-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed, calibrated, and fully operational.

5.4-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that this water system is vented, free of air, and at a normal water temperature setting.
- c. Check expansion/compression tank levels and pressures.
- d. Verify that the cooling tower is operating properly, with hot water basins at equal levels.
- e. Verify that the pumps are lined up correctly and are operating properly.
- f. Verify that the flow meters are installed in the water piping according to the Water Flow Station procedure.
- g. Verify that the thermometer wells and test thermometers are installed properly in water piping according to the Basic Temperature Test Measurements procedure.

---

## **5.4 Constant Flow Primary/Constant Flow Secondary/ Constant Flow Tertiary Systems (continued)**

---

### 5.4-5 Procedures:

- a. Perform shut-off head pressure test on each pump to determine impeller size and pump operating curve.
- b. With all system valves in the wide-open position, set the primary, secondary, and tertiary pump operating head at approximately 110 % of design.
- c. Balance the water flow in the primary loop to 100 to 110 %. Balance between the primary elements (chillers, boilers, etc.) if there is more than one element per pump.
- d. Balance the tertiary system, making at least two passes to obtain a proportional balance. More passes may be required to obtain a proportional balance; however, a minimum of two passes must be performed.
- e. If three-way valves are present at each coil or element in the tertiary system, cycle the coil controls to bypass after setting the coil flow, and set the flow through the bypass to match the coil flow. Modulate the valve from full coil flow to bypass, and monitor the flow to assure that the flow does not increase with the valve in the mid position. If the flow does increase, adjust the bypass balancing valve until the modulated flow equals the coil flow. Remeasure full bypass flow, record all flows, and report excess modulated flow as a deficiency.
- f. Balance the secondary system, making at least two passes to obtain a proportional balance. More passes may be required to obtain a proportional balance, however, a minimum of two passes must be performed.
- g. Set the secondary bypass bridge to match the secondary flow to the tertiary system, when the tertiary system is in full recirculation mode. Monitor the modulated flow between the full tertiary flow and secondary bypass to assure that the secondary flow does not increase when in a modulated condition. If the flow does increase, make adjustments to assure that the secondary flow does not exceed design under modulated condition, record the full bypass flow setting after the adjustment, and report the excess modulated flow as a deficiency.
- h. Make final adjustments at the pumps to obtain 100 to 110 % flow. If this flow is not obtainable, make a note of the reason for the deviation.
- i. Make a final pass through the primary, secondary, and tertiary components, recording all final flows and pressure drops.

---

#### **5.4 Constant Flow Primary/Constant Flow Secondary/ Constant Flow Tertiary Systems (continued)**

---

- j. Assure that proper flow direction at the primary, secondary, and secondary tertiary bridges are as designed.
- k. Record all final pump operating heads and flows.
- l. Verify that all control valves are the three-way type, or that a pressure bypass is installed in the proper location to maintain constant flow. If pressure bypass valves are installed, measure and record the system operating pressure at the control point of each valve in the system at full flow. Modulate the coil or element control valves to simulate minimum flow, verify total system flow, and operation of the bypass valve. Verify that the control point is set as required with all valves in the wide-open position, and record the control set point.
- m. Measure and record the power on all pumps before and after the system balancing.
- n. Upon completion of the test and balance, record the data below on appropriate report forms. Refer to Report Contents procedures 6.0.
  - 1. Design water flow, GPM.
  - 2. Design pressure criteria.
  - 3. All nameplate data.
  - 4. Power measurements, refer to the Electrical Power Measurements procedure.
  - 5. kw (where applicable).
  - 6. Design pump and motor RPM.
  - 7. Actual motor RPM (if accessible).
  - 8. Actual pump RPM if different from the motor RPM.
  - 9. Pump shut-off head pressure.
  - 10. Pump operating head pressure.
  - 11. Pump suction pressure (both operating and shut-off).
  - 12. Pump discharge pressure (both operating and shut-off).
  - 13. Position of the balancing valve at the final balance.

---

#### **5.4 Constant Flow Primary/Constant Flow Secondary/ Constant Flow Tertiary Systems (continued)**

---

14. Actual water flow GPM.
15. Actual pressure measurements at the flow elements, coils, etc.
16. Actual bypass pressure and control setting at the final balance (if installed).

##### **5.4-6 Report:**

- a. Include all test data on approved Water Balance Data sheets as required by the Report Contents procedure.
- b. In the conclusion, list both the conditions at the time of the test and the results.
- c. List any uncorrected deficiencies that affect the test results on the deficiency report form.
- d. Include required data from the Report Contents procedure.

##### **5.4-7 Compliance:**

- a. To comply with this procedure, complete all of the above steps and record all data on the report forms.
- b. All deficiencies that affect the water balancing should have been resolved by the installing contractors or included in the deficiency report.
- c. Instrumentation shall be accurate and suitable for this type of testing as required by the instrumentation and basic measurement procedures.

---

## **5.5 Constant Flow Primary/Variable Flow Secondary/ Constant Flow Tertiary Systems**

---

5.5-1 This procedure applies to the following:

Heating and cooling water systems using the constant flow primary/  
variable flow secondary/constant flow tertiary pumping and piping concept.

5.5-2 This procedure does not apply to the following:

- a. Other types of water systems
- b. Full-load performance test

5.5-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed, calibrated, and fully operational.

5.5-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that all hydronic systems are vented, free of air, and at a normal water temperature setting.
- c. Check expansion/compression tank levels and pressures.
- d. Verify that the condenser water temperatures are correct and that the cooling tower is operating properly.
- e. Verify that the chilled and heated water pumps are lined up correctly and are operating properly.
- f. Verify that the flow meters are installed in the hydronic piping according to the Water Flow Station procedure.
- g. Verify that the thermometer wells and test thermometers are installed properly in hydronic piping according to the Temperature Measurements procedure.

---

## **5.5 Constant Flow Primary/Variable Flow Secondary/ Constant Flow Tertiary Systems (continued)**

---

### 5.5-5 Procedures:

- a. Perform shut-off head pressure test on each pump to determine impeller size and pump operating curve.
- b. With all system valves in the wide-open position, set the primary, secondary, and tertiary pump operating head at approximately 110 % of design.
- c. Balance the water flow in the primary loop to 100 to 110 %. Balance between the primary elements (chillers, boilers, etc.) if there is more than one element per pump.
- d. Balance the tertiary system, making an initial and secondary pass to obtain a proportional balance. More passes may be required to obtain a proportional balance; however, a minimum of two passes must be performed.
- e. If three-way valves are present at each coil or element in the tertiary system, cycle the coil controls to bypass after setting the coil flow, and set the flow through the bypass to match the coil flow. Modulate the valve from full coil flow to bypass, and monitor the flow to assure that the flow does not increase with the valve in the mid position. If the flow does increase, adjust the bypass balancing valve until the modulated flow equals the coil flow. Remeasure full bypass flow, record all flows, and report excess modulated flow as a deficiency.
- f. If there is no diversity in the secondary system, balance the system making an initial and secondary pass to obtain a proportional balance. More passes may be required to obtain a proportional balance; however, a minimum of two passes must be performed. If there is diversity in the secondary system, select enough tertiary systems to match the secondary pump design GPM, closing off the remaining tertiary systems to the secondary system. Proportionally balance the flow through the selected secondary tertiary valves, as indicated above. Once the system has been proportionally balanced, select enough open valves to match the diversity and close them, while opening the valves that were initially closed, and balance the remaining tertiary flows through the newly opened valves.
- g. Make final adjustments at the pumps to obtain 100 to 110 % flow. If this flow is not obtainable, make a note of the reason for the deviation.
- h. Make a final pass through the primary, secondary, and tertiary components, recording all final flows and pressure drops.

---

### **5.5 Constant Flow Primary/Variable Flow Secondary/ Constant Flow Tertiary Systems (continued)**

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- i. With the system at maximum flow, record the actual pressure drop at the control point for the variable volume secondary system. Compare this to the actual control device readout or set point.
- j. Record all final pump operating heads and flows.
- k. Measure and record the power on all pumps before and after the system balancing.
- l. Upon completion of the test and balance, record the data below on appropriate report forms. Refer to Report Contents procedures.
  1. Design water flow, GPM.
  2. Design pressure criteria.
  3. All nameplate data.
  4. Power measurements, refer to the Electrical Power Measurements procedure.
  5. kw (where applicable).
  6. Design pump and motor RPM.
  7. Actual motor RPM (if accessible).
  8. Actual pump RPM if different from the motor RPM.
  9. Pump shut-off head pressure.
  10. Pump operating head pressure.
  11. Pump suction pressure (both operating and shut-off).
  12. Pump discharge pressure (both operating and shut-off).
  13. Position of the balancing valve at the final balance.
  14. Actual water flow GPM.
  15. Actual pressure measurements at the flow elements, coils, etc.
  16. Actual bypass pressure and control setting at the final balance (if installed).

---

**5.5 Constant Flow Primary/Variable Flow Secondary/  
Constant Flow Tertiary Systems (continued)**

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5.5-6 Report:

- a. Include all test data on approved Water Balance Data Sheets as required by the Report Contents procedure.
- b. In the conclusion, list both the conditions at the time of the test and the results.
- c. List any uncorrected deficiencies that affect the test results on the deficiency report form.
- d. Include required data from the Report Contents procedure.

5.5-7 Compliance:

- a. To comply with this procedure, complete all of the above steps and record all data on the report forms.
- b. All deficiencies that affect the water balancing should have been resolved by the installing contractors or included in the deficiency report.
- c. Instrumentation shall be accurate and suitable for this type of testing as required by the instrumentation and basic measurements procedures.

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## 5.6 Condenser Water Economizer Systems

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5.6-1 This procedure applies to the following:

- a. Free winter cooling from the cooling tower systems using a plate heat exchanger between the chilled water distribution system and the cooling tower system with a storage tank concept.
- b. Evaporative cooling tower with condenser water in a coil.

5.6-2 This procedure does not apply to the following:

Other types of economizer systems

5.6-3 Operation:

- a. All equipment in the system must be in operation before the test and balance technician begins the procedure.
- b. All controls must be installed, calibrated, and fully operational.

5.6-4 Inspection:

- a. Inspect the system to determine if it is complete and operable. If not, then end the procedure, list any deficiencies, and proceed when they are corrected.
- b. Verify that this water system is vented, free of air, and at a normal water temperature setting.
- c. Check expansion/compression tank levels and pressures.
- d. Verify that the cooling tower is operating properly, with hot water basins at equal levels.
- e. Verify that the pumps are lined up correctly and are operating properly.
- f. Verify that the flow meters are installed in the water piping according to the Water Flow Station procedure.
- g. Verify that the thermometer wells and test thermometers are installed properly in water piping according to the Basic Temperature Test Measurements procedure.

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## 5.6 Condenser Water Economizer Systems (continued)

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### 5.6-5 Procedures:

- a. Balance condenser waterflow through the plate heat exchanger. Set up pumps for constant flow. Balance chilled waterflow through the plate heat exchanger. Set up pumps for constant flow.
- b. Measure water temperature in and out of the heat exchanger on both systems.
- c. Calculate BTUH heat exchange according to the Water-Water Heat Exchanger Measurements procedure.
- d. Set controls for the specified operation.
- e. If there are automatic change over controls, then verify their operation.
- f. Balance the flow, measure the temperature and pressure at each location, and compare with the design.
- g. Measure the power to each pump according to the Electrical Power Measurements procedure.
- h. Measure and record the power before and after the test on all pumps.
- i. Upon completion of the test and balance, record the data below on appropriate report forms. Refer to the Report Contents procedure.
  1. Unit factory (submittal) data on each unit
  2. Design waterflow GPM
  3. Design pressure criteria
  4. Design temperature criteria
  5. Actual water flow GPM
  6. Actual pressure measurements
  7. Actual temperature measurements
  8. Power measurements: refer to the Electrical Power Measurements procedure.
  9. kw (where applicable)
  10. All nameplate data

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## 5.6 Condenser Water Economizer Systems (continued)

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11. Motor rpm (if accessible)
12. Pump rpm if different from the motor RPM
13. Design pump and motor RPM
14. Pump total head pressure
15. Pump suction pressure
16. Pump discharge pressure
17. Head foot = + discharge pressure  $\pm$  suction pressure (in pounds per square inch (PSI)) x 2.31 / specific gravity
18. Position of balancing valve at final balance
19. Bypass pressure setting at final balance, if any

### 5.6-6 Report:

- a. Include all test data on an approved Condenser Water Economizer form and equipment and distribution data sheets.
- b. In the conclusion, list both the conditions at the time of the test and the results.
- c. List any uncorrected deficiencies that affected the test results on the deficiency report form.
- d. Include required data from the Report Contents procedure.

### 5.6-7 Compliance:

- a. To comply with this procedure, complete all of the above steps and record all data on the report forms.
- b. All deficiencies that affect the water balancing should have been resolved by the installing contractors or included in the deficiency report.
- c. Instrumentation shall be accurate and suitable for this type of testing as required by the instrumentation and basic measurements procedures.

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## **Chapter 6: REPORT CONTENTS**

Associated Air Balance Council

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### **6.1 Report Contents Procedure**

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6.1-1 This procedure applies to the following:

- a. HVAC systems
- b. Air systems
- c. Hydronic systems
- d. Direct expansion systems

6.1-2 This procedure does not apply to the following:

- a. Preliminary testing and balancing
- b. Partial testing and balancing

6.1-3 Prerequisites for reports:

- a. Field testing and balancing is complete.
- b. Discrepancy items are either corrected before publication of the report or the discrepancies are noted in the report.

6.1-4 Reports

- a. This section sets forth an outline for the reporting of data on operating conditions and compares this data to the design or required data.
- b. The forms indicated in this procedure shall be selected for the equipment and systems installed on the project and submitted in the final report.

6.1-5 Reporting:

- a. Forms and data must be prepared logically. This section lists form titles and data entries required by these procedures. The forms may need to be formatted to suit each agency's office procedures or as required by the project.

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## 6.1 Report Contents Procedure (continued)

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- b. Accuracy in preparing the final report forms is important for several reasons.
1. They provide a permanent record of the system operating conditions after the last adjustment is made.
  2. They confirm that prescribed procedures were followed.
  3. They serve as a maintenance reference for the owner's use.
  4. They confirm that the system is within design tolerance or if there is a deviation.
  5. They serve as a base line for future expansion.
- c. All forms must include the following:
1. A heading that identifies the project, project location, date, and the test and balance (TAB) firm.
  2. A footer that includes the remarks, page number, and the technician who tested the project.
- d. Standard items required in the report:
1. Title page:
    - Date
    - Name, address, and telephone number of the TAB agency
    - Name and address of the project
    - Name of the architect and engineer
    - Name of the owner's representative
    - Name of the general contractor
    - Name of the TAB technician
    - Signature and certification of the Testing and Balancing Engineer
  2. Table of contents
  3. List of discrepancies not corrected
  4. Air balance section
  5. Hydronic balance section

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## 6.1 Report Contents Procedure (continued)

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- e. Optional items as specified
  - 1. Automatic control system verification
  - 2. Sound testing
  - 3. Vibration testing
  - 4. Duct leakage testing
  - 5. I.A.Q. testing
  - 6. Room-pressurization testing
  - 7. Smoke-control system testing

- f. Forms, Titles, and Entries:

Listed below are the forms, titles, and entries required for testing and balancing. Each form has a variety of detailed parts requiring specific entries. All performance test data should be compared to the design data on the form.

- 1. System diagrams include the following:
  - This form includes a single line diagram indicating outside air, return air, supply air, the volume control box, and each outlet and inlet. It is used for a schematic layout of the air distribution system.
  - The diagram includes room numbers, duct size at traverse locations, temperatures, and pressures.
  - Hydronic diagrams are optional but are used if room and identification numbers are not on the drawings.
- 2. Fan data sheet entries include the following:
  - System number
  - Location
  - Manufacturer and model number
  - Serial number
  - Drive size, type, number of grooves, and open turns on variable pitch drives

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## 6.1 Report Contents Procedure (continued)

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- Number and size of belts, motor and fan shaft sizes, center to center of shafts in inches, and adjustment available
  - Motor data, including nameplate data, actual amps, rated and actual motor rpm, volts, phase, hp, kw, starter heater size, and capacity
  - Fan CFM, return CFM, and outside air CFM
  - Fan static pressure, suction, and discharge; static profile and static control point as applicable
  - Fan RPM
  - Notes
3. Traverse data sheet entries include the following:
- Traverse location
  - Size of duct (inside dimensions)
  - Area of duct in square feet (meters)
  - Column for each hole traversed
  - Lines for each reading
  - Barometric pressure
  - Temperature in the duct
  - Static pressure in the duct
  - Actual CFM corrected to SCFM if required
  - Notes
4. Air distribution entries include the following:
- Room identification
  - Outlet or intake balance sequence number
  - Size of outlet or inlet
  - $A_x$  Factor
  - Design FPM
  - Design CFM
  - Actual FPM

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## 6.1 Report Contents Procedure (continued)

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- Actual CFM
  - Notes
5. Air effectiveness forms (if specified) include the following:
- Location/room identification
  - Number of occupants in room
  - Sequence number of occupant location being tested
  - Residual air velocity at occupant location
  - Temperature at occupant location
  - Relative humidity at occupant location
  - CO<sub>2</sub> measurement at occupant location or air effectiveness
6. IAQ forms (if specified) include the following:
- Location/room identification
  - Contaminants specified for testing
  - Measured results of contaminant tests
  - Number of occupants in the room
  - CO<sub>2</sub> level
  - Allowable level of CO<sub>2</sub> alongside measurements
  - Pass or fail indications for each space tested
  - Any deficiencies
  - Temperature and humidity
7. Hydronic coil test form entries include the following:
- Air flow through the coil in CFM
  - Dry bulb and wet bulb temperatures entering coil
  - Dry bulb and wet bulb temperatures leaving coil
  - Enthalpy or total heat differences in BTU/lb
  - Capacity in BTU/HR at time of test
  - Water temperature entering/leaving coil

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## 6.1 Report Contents Procedure (continued)

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- Water pressure entering/leaving coil
  - Waterflow GPM through coil
  - Notes
8. Fintube radiation and convection unit entries include the following:
- Water temperature entering
  - Water temperature leaving
  - Differential temperature
  - GPM flow through the unit
9. DX coils test data entries include the following:
- Air flow through the coil in CFM
  - Dry and wet bulb temperatures entering coil
  - Dry and wet bulb temperatures leaving coil
  - Enthalpy or total heat difference across coil in BTU/lb
  - Capacity in BTU/hr at time of test
  - Notes
10. Steam heat exchanger data sheet entries include the following:
- Exchanger identification number
  - Nameplate data; manufacturer, model and serial number
  - Temperature entering unit
  - Temperature leaving unit
  - Flow through unit in GPM
  - Pressure drop through unit
  - Entering steam pressure
  - Notes
11. Electric heating coil entries include the following:
- Heating coil identification number
  - Nameplate data; manufacturer, model and serial number

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## 6.1 Report Contents Procedure (continued)

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- Amperage on each phase
  - Voltage on each phase
  - Phase
  - KW
  - Stages
  - Safety device installed
  - Alternative method test as air-side heating coil procedure
  - Notes
12. Water cooled chiller entries include the following:
- Chiller identification number
  - Nameplate data; manufacturer, model and serial number
  - Chilled waterflow through evaporator in GPM
  - Water temperature entering evaporator
  - Water temperature leaving evaporator
  - Pressure drop through evaporator
  - Condenser water flow through condenser
  - Pressure drop through condenser
  - Water temperature entering condenser
  - Water temperature leaving condenser
  - Motor data, amps, volts, rpm, starter type, overload protection type, phase, hertz, nameplate, and actual measured KW input
  - Type of refrigerant
  - Pounds of refrigerant in the system (if available)
  - Notes
- Note: The performance test for rated capacity is not included or part of this procedure.
13. Cooling tower entries include the following:
- Cooling tower identification number

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## 6.1 Report Contents Procedure (continued)

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- Nameplate data; manufacturer, model and serial number
- Waterflow through the tower in GPM
- Water temperature entering tower
- Water temperature leaving tower
- Outside air dry and wet bulb temperatures
- Motor data, amps, volts, phase, hertz, and kw input
- Starter size and type and heater size and capacity
- Water droplets leaving tower—yes/no
- Water balanced across tower pans and basins
- Airflow across the tower within design rating according to fan curves (if available)
- Notes

Note: The performance test for rated capacity is not included or part of this procedure.

14. Boilers (1 million BTU's or over) entries include the following information:

- Boiler identification number
- Nameplate data; manufacturer, model and serial number
- Fuel flow input at full load and at part load
- Water temperature entering the boiler
- Temperature or pressure of water leaving the boiler
- Combustion gas temperature
- Combustion gas analysis
- Outside conditions: temperature, humidity, general cloud cover
- Barometric pressure
- Temperature of the fuel, if applicable

Note: The performance test for rated capacity is not included or part of this procedure.

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## 6.1 Report Contents Procedure (continued)

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15. Air-cooled condensing units (applicable to 20 tons and over) entries include the following information:
  - Air cooled condensing unit identification number
  - Nameplate data; manufacturer, model and serial number.
  - Compressor nameplate and actual amps, volts, phase, and hertz
  - RPM of motors, where applicable
  - Refrigerant type
  - Refrigerant pounds in the system (if available)
  - Suction pressure when gauge installed
  - Discharge pressure when gauge installed
  - Number of stages
  - Low-pressure control setting
  - High-pressure control setting
  - Condenser fan sequence stages
  - Crankcase heater watts (nameplate)
  - Hot gas bypass installed—yes/no
  - SCFM Air Flow Measurement vs. Design CFM
16. For sound entries include the following:
  - Area or location
  - Sound level in dB(A)
  - Sound level at the center band frequencies of eight unweighted octaves with equipment on and off.
  - Plot corrected sound-level reading on Noise Criteria curve, if specified.
17. Vibration-level entries include the following:
  - Equipment number
  - Vibration levels at all accessible bearings, motors, fans, pumps, casings, and isolators

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## 6.1 Report Contents Procedure (continued)

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- Measurements in mils deflection and velocity in inches per second
- Each measurement taken in horizontal, vertical, and axial planes as accessible.

18. Mixing damper leakage test data entries include the following:

- Equipment identification number (unit, box, zone, etc.)
- Dry bulb temperature in the cold deck
- Dry bulb temperature in the hot (or bypass) deck
- Dry bulb temperature in the mixed air stream
- Calculated percent leakage
- Data above taken in the full cool and full heat (or bypass) mode
- Notes

19. Airflow station test data entries include the following:

- Station identification number
- Nameplate data including effective area
- Differential test pressure or velocity
- Calculated CFM
- Actual CFM (From Pitot tube traverse form)
- Read out CFM
- Notes

20. Unit heater test data entries include the following:

- Equipment identification number
- Nameplate data; manufacturer, model and serial number
- Test CFM (use manufacturer rated CFM if not ducted)
- Heat test data per applicable procedure (hot water, electric, etc.)
- Notes

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## 6.1 Report Contents Procedure (continued)

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21. Fan coil and unit ventilator test data entries include the following:
- Equipment identification number
  - Nameplate data; manufacturer, model and serial number
  - Test supply CFM (use manufacturer rated CFM if not ducted)
  - Test outside air CFM
  - Motor data and actual amps and volts
  - Cooling test data per chilled water or dx coil procedure included on this form
  - Heating test data per applicable procedure (hot water, electric, etc.) included on this form
  - Notes
22. Induction unit test data entries include the following:
- Unit identification number
  - Nameplate data; manufacturer, model and serial number
  - Manufacturer rated nozzle pressure and CFM
  - Test nozzle pressure and CFM per Manufacturer Rating
  - Cooling test data per chilled water or dx coil procedure included on this form
  - Heating test data per applicable procedure (hot water, electric, etc.) included on this form
23. Laboratory hood test data entries include the following:
- Hood identification number
  - Nameplate data; manufacturer, model and serial number
  - Exhaust and supply (when part of hood) CFM
  - Exhaust and supply (when part of hood) test velocities shown on hood face diagram
  - Hood opening dimensions
  - Notes

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## 6.1 Report Contents Procedure (continued)

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24. Kitchen hood test data entries include the following:
- Hood identification number
  - Nameplate data; manufacturer, model and serial number
  - Exhaust and supply (when part of hood) CFM
  - Exhaust and supply (when part of hood) test velocities shown on hood diagram
  - Hood opening and/or grease filter/extractor dimensions and quantity
  - Notes
25. Air-to-air heat recovery unit test data entries include the following:
- Unit identification number
  - Nameplate data; manufacturer, model and serial number
  - Exhaust air CFM
  - Outside air CFM
  - Entering and leaving pressures across the heat recovery media
  - Dry bulb and wet bulb entering the exhaust and outside air sections
  - Dry bulb and wet bulb leaving the exhaust and outside air sections
  - Capacity of the exhaust side compared to the outside air side
  - Notes
26. Water-to-water heat exchanger test data entries include the following:
- Exchanger identification number
  - Nameplate data; manufacturer, model and serial number
  - GPM through each side
  - Pressure drop through each side
  - Capacity of each side
  - Notes

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## 6.1 Report Contents Procedure (continued)

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27. Pump test data entries include the following:
- Pump number
  - Nameplate data; manufacturer, model and serial number
  - Motor data including nameplate data, actual amps, volts, RPM, horsepower, starter heater size and capacity
  - Pump discharge and suction pressure along with total dynamic head in the following modes
    - Shut-off head FT
    - Wide open Head FT
    - Final operating Head FT
  - Final GPM
  - Test plotted on a pump curve (if available)
  - Notes
28. Waterflow station test data entries include the following:
- Station identification number
  - Nameplate data; manufacturer, model, and serial number
  - Design and actual GPM
  - Differential test pressure
  - Setting (open turns, degree, etc.) if required GPM
  - Notes
29. Steam humidifier test data entries include the following:
- Humidifier identification number
  - CFM
  - Steam flow
  - Steam pressure
  - Entering dry and wet bulb temperature and grains of moisture
  - Leaving dry and wet bulb temperature and grains of moisture
  - Capacity in pounds per hour
  - Capacity in grains of moisture added per hour

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## 6.1 Report Contents Procedure (continued)

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30. Terminal box data entries include the following:
- Box identification number
  - Box size
  - Cooling CFM
  - Minimum CFM (if applicable)
  - Heating CFM (if applicable)
  - Box fan amps and volts (if applicable)
  - Record heat test data on appropriate heat test form
  - Record box delta P setting if direct CFM measurement cannot be made
  - For DDC controlled boxes, record computer readout maximum, minimum, and heat, along with box correction factor for calibrating to true CFM
  - Notes
- g. Special system reports include the following:
1. Measure and record test parameters, including design, nameplate, and actual test readings. Form shall have proper heading and footers as required by this procedure.
  2. Reference requirements for the test and the authority requesting the test.
- h. Instrumentation calibration reports record the following:
1. Manufacturer and model and serial number for each instrument used on the project.
  2. Current calibration date for each instrument.
- i. Deficiency reports include the following:
1. Deficiencies found in the system that prevent proper balancing.
  2. Discrepancies between the installation and the plans and specifications that affect the performance or longevity of the system.
  3. If the deficiency still exists at the completion of balancing, then include it in the report.

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## 6.1 Report Contents Procedure (continued)

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- j. The final test and balance report requires the following:
1. Complete data sheets and diagrams of all equipment and systems in the scope of work organized in a logical order.
  2. All reports with the printed or typed name and title of the report on the cover.
  3. A minimum of four copies submitted to the client at the completion of testing and balancing.

Note: Any preliminary reports should be stamped "preliminary" and should not be considered the final report.

- k. Compliance:

The test and balance report or reports for other phases of work included within these procedures, should contain the following:

1. All test data on proper forms containing complete information
2. Summary of deficiencies not corrected
3. Diagrams of systems showing locations of outlets, inlets, and traverse locations
4. Pressure and temperature profiles
5. Certification of the report signed and sealed by a test and balance engineer (TBE)
6. Typed and bound in a neat and professional manner