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USACE / NAVFAC / AFCEA / NASA UFGS-23 05 93.00 40 (June 2006)

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UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated October 2007

SECTION 23 05 93.00 40

TESTING, ADJUSTING, AND BALANCING FOR HVAC SYSTEMS 06/06

NOTE: This specification covers the requirements
for testing and balancing of mechanical system.

Edit this guide specification for project specific
requirements by adding, deleting, or revising text.
For bracketed items, choose applicable items(s) or
insert appropriate information.

Remove information and requirements not required in
respective project, whether or not brackets are
present.

Comments and suggestions on this guide specification
are welcome and should be directed to the technical
proponent of the specification. A listing of
technical proponents, including their organization
designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as
a Criteria Change Request (CCR).

PART 1 GENERAL

1.1 REFERENCES

NOTE: This paragraph is used to list the
publications cited in the text of the guide
specification. The publications are referred to in
the text by basic designation only and listed in
this paragraph by organization, designation, date,
and title.

Use the Reference Wizard's Check Reference feature
when you add a RID outside of the Section's
Reference Article to automatically place the
reference in the Reference Article. Also use the
Reference Wizard's Check Reference feature to update
the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

ASHRAE 111 (1988; Errata 1997) Practices for Measurement, Testing, Adjusting, and Balancing of Building Heating, Ventilation, Air-Conditioning, and Refrigeration Systems

ASHRAE 147 (2002) Standard for Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems

ASME INTERNATIONAL (ASME)

ASME B31.5 (2001; Addenda 2004) Refrigeration Piping and Heat Transfer Components

ASME B40.100 (2006) Pressure Gauges and Gauge Attachments

ASSOCIATED AIR BALANCE COUNCIL (AABC)

AABC MN-1 (2002) National Standards for Total System Balance

NATIONAL ENVIRONMENTAL BALANCING BUREAU (NEBB)

NEBB TABES (2005) Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems

SHEET METAL AND AIR CONDITIONING CONTRACTORS' NATIONAL ASSOCIATION (SMACNA)

SMACNA 1143 (1985) HVAC Air Duct Leakage Test Manual

SMACNA 221 (2002) HVAC Systems - Testing, Adjusting and Balancing

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

40 CFR 82 Protection of Stratospheric Ozone

1.2 SUBMITTALS

NOTE: Review Submittal Description (SD) definitions

in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are [for Contractor Quality Control approval.] [for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Records of Existing Conditions shall be submitted in accordance with paragraph entitled, "General Requirements," of this section.

SD-03 Product Data

Equipment and Performance Data shall be submitted in accordance with paragraph entitled, "General Requirements," of this section.

SD-06 Test Reports

Test Reports shall be submitted in accordance with paragraph entitled, "General Requirements," of this section.

SD-07 Certificates

Certificates shall be submitted in accordance with paragraph entitled, "General Requirements," of this section.

1.3 GENERAL REQUIREMENTS

NOTE: If Section 23 00 00.00 40 HEATING, VENTILATING, AND AIR-CONDITIONING is not included in the project specification, applicable requirements therefrom should be inserted and the following paragraph deleted.

Section 23 00 00.00 40 HEATING, VENTILATING, AND AIR-CONDITIONING applies to work specified in this section.

Records of Existing Conditions shall be submitted consisting of the results of Contractor's survey of work area conditions and features of existing structures and facilities within and adjacent to the jobsite. Commencement of work shall constitute acceptance of existing conditions.

Equipment and Performance Data shall be submitted for instruments and equipment to be used during testing.

Test Reports shall be submitted to the Contracting Officer for approval. Six bound copies of the testing, adjusting, and balancing report shall be provided.

Certificates shall be submitted by the Contractor showing independent laboratory certification of test-apparatus calibration data, dated after the award of the contract.

PART 2 PRODUCTS

Not Used

PART 3 EXECUTION

NOTE: The Systems Engineer/Condition Monitoring Office/Predictive Testing Group should inspect the installation during acceptance testing using advanced monitoring technologies such as Infrared Imaging or Ultrasonic Listening. These technologies can identify plugged or restricted tubing, insulation voids, and system/pressure/vacuum leaks.

NOTE: Variable pitch sheaves should only be used for system balance purposes. After balance is determined they should be replaced with fixed sheaves.

3.1 WATER SYSTEM INTEGRITY TESTING

NOTE: Determine whether system supports are adequate for loads normal to specified hydrostatic testing.

Prior to acceptance of the work, systems shall be tested in the presence of

the Contracting Officer.

Tests shall be performed prior to insulation of surfaces, painting, and concealment of work. Systems containing repaired defects shall be retested to original criteria for acceptance, except when waived by the Contracting Officer.

Tests shall be hydrostatic, unless otherwise specified. Water used for testing shall be potable.

Government will supply testing water, but the Contractor shall provide for approved disposal of contaminated water.

NOTE: Due to the expansive force of compressed air
at 690 to 1050 kilopascal 100- to 150-pounds per
square inch, pneumatic testing requires special
precautions and competent supervision to guard
against injury and damage if a failure occurs.
High-pressure pneumatic testing is discouraged.

[Tests may be pneumatic when freezing conditions may occur and upon prior approval by the Contracting Officer. Only oil-free compressed air shall be used for testing.]

[Pneumatic testing shall include swabbing all joints under a test pressure of 35 kilopascal 5 psig, maximum, with standard high-film-strength soap solution and observing for bubbles.]

Contractor may conduct tests for his own purposes, but the acceptance test shall be conducted as specified herein.

If the test demonstrates that leakage rate exceeds specified limits, the source(s) of leakage shall be determined, defective materials and workmanship shall be repaired or replaced, and the system shall be retested until specified requirements are met.

Other than standard piping flanges, plugs, caps, and valves, only commercially manufactured expandable-elastomer plugs shall be used for sealing off piping for test purposes. Safe test-pressure rating of any plug used shall be not less than two times the actual test pressure being applied.

Precautions shall be taken to vent the expansive force of compressed air trapped during high-pressure hydrostatic testing to preclude injury and damage.

Contracting Officer may require the removal of system components, such as plugs or caps, to ascertain that the water has reached all parts of the system if purging or vent valves are not provided.

Piping system components, such as valves, shall be checked for functional operation under system test pressure. Components that could sustain damage due to test pressure shall be removed from piping systems prior to hydrostatic testing.

Leaking gasket joints shall be remade with new gaskets. Leaking copper joints shall be remade with new fittings and new tube ends.

Temperature of water used for testing shall not cause condensation on system surfaces.

Test media shall not be added to a system during a test for a period specified or to be determined by the Contracting Officer.

Duration of a test will be determined by the Contracting Officer and shall be for a minimum of 2 hours, with a maximum of 24 hours. Test may be terminated by direction of the Contracting Officer at any time during this period after it has been determined that the permissible leakage rate has not been exceeded.

Test records of piping systems tests shall be prepared and maintained. Records shall show test personnel responsibilities, dates, test gage identification numbers, ambient and test water temperatures, pressure ranges, rate of pressure drop, leakage rates, and other system characteristics.

3.1.1.1 Test Gages

Test gages shall have a 115 millimeter 4-1/2 inch or larger dial, be accurate to plus or minus one-half of 1 percent of full-scale range, and have dial graduations and pointer width compatible with readability and one-half the accuracy extremes. Maximum permissible scale range for a given test shall be such that the pointer shall have a test pressure position at midpoint of the dial or within the middle third of the scale range. Certification of accuracy and correction table shall bear a date within 90 calendar days prior to use, test gage number, and project number.

3.1.1.2 Test and Acceptance Criteria

[Aboveground water systems shall be tested at 1050 kilopascal 150 pounds per square inch (psi) and the applied test pressure shall be maintained without further addition of test media for not less than 2 hours. All joints must remain dry.]

[Underground rubber-jointed ferrous-pipe water systems shall be tested at 1380 kilopascal 200 psi and the applied test pressure shall be maintained for not less than 2 hours. Where no thrust blocks are to be provided, piping shall be tested at an approved pressure. Satisfactory hydrostatic testing shall include the following:]

[Duration of each leakage test shall be not less than 2 hours. During the test, the main shall be subjected to 1380 kilopascal 200 psi pressure, based on the elevation of the lowest section under test and corrected to the elevation of the test gage.]

[Leakage is defined as the additional quantity of water supplied into the laid pipe, or any valved section thereof, that is necessary to maintain the specified leakage test pressure after the pipe has been filled with water and the air expelled.]

Maximum allowable leakage for the piping installation (liter gallons per hour) shall be [_____].

[Hydrostatic tests shall be applied only to piping with concrete thrust blocking that has cured for a minimum of 7 calendar days.]

[Backflow prevention devices in potable water systems and other water system devices shall be tested for proper functioning under conditions normal to their application.]

3.2 AIR-HANDLING DUCTWORK INTEGRITY TESTING

Structural integrity and leakage testing of air-handling ductwork shall be performed by system or by duct mains and branches.

Tests shall be performed prior to insulation of surfaces, painting, or concealment of work. Unless waived by the Contract Officer, systems containing repaired defects shall be retested to original criteria for acceptance.

Pressure Testing shall be performed per **SMACNA 1143** except as modified herein.

DUCT PRESSURE-VELOCITY CLASSIFICATION

STATIC PRESSURE CLASS (pascal)	Type of PRESSURE	Seal CLASS	VELOCITY (m/s)
2500	Positive	A	[_____]
1500	Positive	A	[_____]
1000	Positive	A	20
750	Pos/Neg	B	20
500	Pos/Neg	C	12.5
250	Pos/Neg	C	12.5
125	Pos/Neg	C	10

DUCT PRESSURE-VELOCITY CLASSIFICATION

STATIC PRESSURE CLASS (INCHES)	Type of PRESSURE	Seal CLASS	VELOCITY (fpm)
10	Positive	A	[_____]
6	Positive	A	[_____]
4	Positive	A	4000
3	Pos/Neg	B	4000
2	Pos/Neg	C	2500
1	Pos/Neg	C	2500
1/2	Pos/Neg	C	2000

Seal Class A: All seams, joints, and wall penetrations

Seal Class B: Transverse joints and seams

Seal Class C: Transverse joints only

3.2.1 Duct Systems 0 To 2 Inches 500 Pascal Pressure

Portions of systems shall be inspected and tested to positive or negative pressures, or both, whichever is normal to the portion of system under test, in accordance with the following:

There are no visible mechanical defects.

There is no audible leakage at any point when area ambient noise is at normal-occupancy level.

No leakage is perceptible to the hand, when placed within 150 millimeter 6 inches of a joint.

Measured total system leakage shall not exceed 1 percent of total system cubic meter per second (m/s) feet per minute (cfm) when tested in accordance with "Leak Tests."

3.2.2 Duct Systems over 2 Inches 500 Pascal Pressure

[Duct systems shall be structurally tested at static pressures 50 percent in excess of total fan pressure. Leakage testing shall be at a pressure 25 percent higher than normal operating pressure, and, in dual duct systems at maximum pressure at mixing box, when inlet valve is shut off. System will be acceptable provided:

- a. There are no visible mechanical defects.
- b. Measured total system leakage does not exceed 1 percent of total system cubic meter per second (m/s) feet per minute (cfm) capacity when tested in accordance with "Leak Test."
- c. There is no audible leakage at any point when area ambient noise is at normal-occupancy level.]

[Duct systems shall be structurally tested at static pressures 25 percent in excess of air-handling apparatus discharge pressure. Leakage testing shall be at a pressure 25 percent higher than normal operating pressure, and, in dual-duct systems at maximum pressure at mixing box, when inlet valve is shut off. System will be acceptable provided:

- a. There are no visible mechanical defects.
- b. Measured total system leakage does not exceed 1 percent of total system cubic meter per second cfm capacity when tested in accordance with "Leak Test."
- c. There is no audible leakage at any point when area ambient noise is at normal-occupancy level.]

3.2.3 Leak Tests

Test apparatus and procedures shall be similar in all respects to those defined in SMACNA 221 and SMACNA 1143. Filtered blower inlet and automatic safety relief device shall be provided to protect system. Accuracy of measurement of leakage flow rate shall be certified to be within 1 percent of total system flow.

3.2.3.1 Test Apparatus

Test apparatus shall consist of:

- a. A source of high pressure air - a portable rotary blower or tank type vacuum cleaner.

- b. A flow measuring device usually an orifice assembly consisting of straightening vanes and an orifice plate mounted in a straight tube with properly located pressure taps. Each orifice assembly shall be accurately calibrated to its own calibration curve. Pressure and flow readings are usually taken with U-tube manometers.

3.2.3.2 Test Procedures

Test for audible leaks as follows:

- a. Close off and seal openings in the duct section to be tested. Connect the test apparatus to the duct by means of a flexible duct section.
- b. Start the blower with its control damper closed (some small blowers popularly used for testing ducts may damage the duct because they can develop pressures up to 6250 pascal 25 inches wg).
- c. Gradually open the inlet damper until the duct pressure reaches 500 pascal 2 inches wg in excess of designed duct operating pressure. Test pressure is read on manometer No. 1. Note that the pressure is indicated by the difference in level between the two legs of the manometer and not by the distance from zero to the reading on one leg only.
- d. Survey joints for audible leaks. Mark each leak and repair after shutting down blower. Do not apply a retest until sealants have set.

After all audible leaks have been sealed, the remaining leakage should be measured with the test apparatus orifice section as follows:

- a. Start blower and open damper until duct pressure reaches 25 percent in excess of designed duct operating pressure.
- b. Read the pressure differential across the orifice on manometer No. 2. Leakage rate in cubic meter per second cfm is read directly from the calibration curve. If leakage does not occur, the pressure differential will be zero.
- c. Total allowable leakage should not exceed 1 percent of the total system design air flow rate. When partial sections of the duct system are tested, the summation of the leakage for all sections shall not exceed the total allowable leakage.
- d. If all audible leaks have been corrected, it is unlikely that the measured leakage will exceed one percent of capacity. If it does, the leaks shall be located by careful listening or feeling along the joint.
- e. It should be noted that even though a system may pass the measured leakage test, a concentration of leakage at one point may result in a noisy leak that shall be corrected.

3.2.4 Smoke-Test Apparatus and Procedures

NOTE: Identify system to which test is applicable.

System shall be tested with smoke bombs while under structural-integrity testing, with 5-minute, ignitable-wick, titanium-tetrachloride smoke bombs.

A sufficient number of bombs shall be provided to produce the same smoke density for all portions tested. Testing shall be conducted under substantially draft-free conditions, and the area shall be free of smoke of any nature. Bombs shall be placed inside sand-filled buckets and then placed inside air-handling unit or duct and ignited. Care shall be exercised in placing smoke bombs to ensure that no surface is damaged by the burning candle. After the bombs have burned for approximately 3 minutes, the system shall be purged at various extremities until detectable smoke appears and then pressurized until the exterior surfaces and all joints have been inspected for signs of smoke. Pressurization shall be done with a test fan started at less than 10 percent maximum-volume flow. Test pressure-relief device shall be tested for proper operation. All joints from extremities to source of smoke shall be checked.

3.2.5 Test Report Criteria

A test report shall be provided for each system tested, identified by system or section thereof, and containing leak-test curves for apparatus used and data pertinent to acceptance requirements.

3.3 REFRIGERATION SYSTEMS INTEGRITY TESTING

NOTE: The following text applies to any halogenated hydrocarbon refrigerant listed in referenced ANSI Standard.

Structural integrity, pressure, vacuum and leakage tests shall be applied to all systems and shall be conducted in accordance with the provisions of ASME B31.5 Paragraph 537, ASHRAE 147, and 40 CFR 82 and also as modified and supplemented herein.

Systems shall be tested in the presence of the Contracting Officer.

Tests shall be performed prior to insulation of surfaces, painting, and concealment of work. Systems containing repaired defects shall be retested to original criteria for acceptance.

Factory sealed refrigeration equipment assemblies shall be kept isolated from field installed piping until final acceptance of high vacuum test.

Brazed and mechanical joints that fail structural, or leakage tests shall be disassembled, cleaned, and remade with new materials, including tubing, fittings, and filler metal. Flanged joints shall received new gasket material.

After repairs have been made, tests shall be repeated until satisfactory results are obtained.

Manufacturer's instructions shall be followed for the protection of system equipment and devices to preclude damage by system test pressures.

Safety precautions shall be observed to protect human life and equipment. Personnel not directly involved in pneumatic pressure testing shall be

evacuated from the area.

3.3.1 Pressure Testing

[Test gages shall have a 150 millimeter 6-inch or larger dial with accuracy of plus or minus one half of one percent of full scale range. Dial graduations and pointer width shall be readable within one quarter of one percent of full scale range. Maximum permissible scale range for a given test shall be such that the pointer shall have an indicating position at midpoint of the dial or within the middle third of the scale range.]

[Certification of accuracy and correction table shall bear a date within 90 calendar days prior to use, test gage number, and project number.]

[Test gages on a standard gage manifold may be used for pressure testing.]

Pressure shall be applied to field installed piping in accordance with ASHRAE 147 and ASME B31.5.

Structural integrity and leak tightness testing under positive pressure shall be performed in accordance with the following basic procedures, modified as necessary to suit specific systems and refrigerants.

Initial pressure tests shall be conducted with dry nitrogen to avoid large refrigerant leaks to atmosphere.

The system under test shall be isolated by valves except for connections to the test media. Openings to atmosphere shall be closed.

Condenser purge valves and receiver drain valves shall be closed and cover caps shall be installed and tightly secured.

A cylinder of dry nitrogen shall be connected to the charging connection through a nitrogen gas pressure regulator. Pressure in the system or section shall be raised to a low pressure (20 psig for R22) in accordance with ASME B31.5 and ASHRAE 147.

Preliminary low pressure leak detection methods may include audible sound and visual bubbling (swabbing of joints with standard high film strength soap solution).

A cylinder of substance to be used as refrigerant in the finished working system shall be connected to the charging connection. System pressure shall be raised with this composite medium to an appropriate steady state low pressure, the system closed and the cylinder disconnected.

Low pressure leak detection methods may include audible sound and visual bubbling (swabbing of joints with standard high film strength soap solution), halogen gas detector torch, ultrasonic detectors and electronic refrigerant detectors.

The system must maintain the low pressure steady state condition for a minimum of four [_____] hours. Any leaks shall be repaired and the procedure repeated until satisfactory results are obtained from the low pressure leak test.

Large systems may be low pressure tested by testing successive sections of the system. A cylinder of dry nitrogen shall be connected to the

charging connection through a nitrogen gas pressure regulator. Pressure in the next section shall be raised to a low pressure in accordance with ASME B31.5 and ASHRAE 147 and the leak test repeated. All steps shall be repeated until the entire system has been low pressure tested.

Final high pressure test pressure, per ASME B31.5 and ASHRAE 147, shall be held for not less than two hours. There shall be no perceptible drop in pressure at the end of the test period, corrected for temperature change of the system during the test.

After the dry nitrogen cylinder has been disconnected and the system pressure lowered to comply with 40 CFR 82.156 Table 1 the composite testing medium may be purged to atmosphere.

System components disconnected to the test, and factory sealed assemblies, shall be connected but the shutoff valves shall remain closed until after the acceptance of high vacuum test of the field installed portion of the system.

System shall be dehydrated in a preliminary manner by passing hot air or dry nitrogen at 107 degrees C 225 degrees F through the field installed system. Direct heating of the system surfaces is not acceptable.

3.3.2 Vacuum Testing

After a successful pressure test and preliminary dehydration, each system shall be connected to a high vacuum pump capable of reducing absolute pressure in the system to a point where any water present will vaporize at a temperature appreciably lower than ambient and will be withdrawn from the system.

Vacuum shall be checked with a gage capable of reading to 10 microns. Calibration certification shall be provided as specified under pressure testing herein.

[The system may be evacuated by drawing a deep vacuum to 50 microns of mercury, absolute, and held for a minimum of six hours at an ambient temperature of 40 degrees F or higher. With the system isolated the pressure shall not increase noticeably.]

[The system may be evacuated by a triple evacuation method. The system shall be evacuated twice to a vacuum of 49,000 microns of mercury, absolute. The first vacuum shall be held for a minimum of one hour and then broken with dry nitrogen. The second vacuum shall be held for a minimum of one hour and then broken with vapor of the substance to serve as refrigerant in the finished working system. The third vacuum shall be drawn to 2,500 microns of mercury, absolute, and held for a minimum of six hours at an ambient temperature of 40 degrees F or higher. With the system isolated the pressure shall not increase noticeably.]

Record test pressures.

3.3.2.1 Hermetic Compressor Systems

System shall be evacuated with a two-stage pump connected in parallel for 2 hours; the attained pressure shall be held for an additional 2 hours.

After satisfactory initial evacuation, pump shall be connected in series and system evacuated to an absolute pressure not higher than 0.10 mm Hg; i.e., 100 micrometer, at not less than 2 degrees C 35 degrees F ambient. After this condition has been attained, the system shall be isolated from the pump. Pressure shall be maintained for 24 hours.

3.3.2.2 Open-Compressor System

System shall be evacuated with a high-vacuum pump to an absolute pressure not higher than 0.20 mm Hg; i.e., 200 micrometer, at not less than 2 degrees C 35 degrees F ambient. After this condition has been attained, the system shall be isolated from the pump. Pressure shall be maintained for 12 hours.

Valves to sealed equipment shall be opened and the system shall be charged to normal operating condition.

3.3.3 Operating Test

After repairs have been made and tests completed, sealed equipment valves shall be opened, and system shall be charged with refrigerant and lubricant, if necessary. Compressor may then be operated.

For the first 8 hours of operation under load, each system shall be operated with the refrigerant dryers in the circuit. If the sight glass or moisture indicator reveals moisture in the system, dryer cartridges shall be replaced and the operation shall be repeated. This procedure shall be followed until there is no indication of moisture in the system. Dryer cartridges shall be replaced and the dryers shall be bypassed. Oil levels shall be checked frequently and oil added only from sealed cans furnished by the compressor manufacturer.

System shall be operated for not less than 8 hours under full load. Refrigerant cycle pressures and temperatures shall be checked for correspondence to thermodynamic characteristics of refrigerant. Final check of equipment and piping shall be made with a halogen gas-leak detector.

If there is excessive hot-gas pulsation during operation, mufflers with not more than 6900 pascal 1 psi drop at design conditions shall be provided. After installation of mufflers, steps necessary to bring system to specified operating condition shall be repeated.

Refrigeration system is now ready for operation for air-handling systems acceptance testing.

3.4 AIR AND HYDRONIC SYSTEMS TESTING AND ADJUSTMENT

**NOTE: Select this paragraph for large
air-conditioning systems.**

**The following is arranged for the contractor or an
independent professional balancing agency to do the
work.**

[Operational balancing and adjustment of air-handling and hydronic systems shall be performed under the direction of an independent balancing agency

whose field representative is a registered professional engineer. All work shall be done in accordance with NEBB TABES, ASHRAE 111, AABC MN-1 or SMACNA 221, where applicable, the requirements of the contract documents, and in the presence of the Contracting Officer.]

[Operational balancing and adjustment of air-handling and hydronic systems shall be done in accordance with SMACNA 221, the requirements of the contract documents, and in the presence of the Contracting Officer.]

**NOTE: Select following paragraph only when testing
high velocity systems.**

Government reserves the right to require recalibration of any or all test apparatus in accordance with the frequency recommended by the component manufacturer, or when reasonable doubt of accuracy exists.

Hydronic systems structural and leakage testing shall be performed in accordance with requirements specified herein under "Water Systems Testing."

Air-handling systems structural and leakage testing shall be performed in accordance with requirements specified herein under "Air-Handling System Testing."

Components of the various air systems shall be adjusted to operate within the design and operating characteristics published by the equipment manufacturer. Government will require the services of an authorized representative of the manufacturer if the Contractor is unable to adjust any equipment.

Equipment shall not be operated until properly lubricated and brought into specified service condition.

Air- and hydronic-system final adjustments shall be permanently marked to be readily restorable if disturbed.

Systems acceptance is predicated upon successful completion of specified work, receipt by the Contracting Officer of certified data summarizing the performance of all systems within design intent, and approval thereof. Data shall be arranged by system and identified by apparatus and item, using standard forms, where possible, and supplementing with reasonable facsimiles, where necessary.

3.4.1 Air-Handling Systems

**NOTE: Variable pitch sheaves should only be used
for system balance purposes. After balance is
determined they should be replaced with fixed
sheaves.**

3.4.1.1 Balancing, Adjustment, and Acceptance Criteria

Final volume conditions for all systems shall be within the following limits:

NOTE: Check the following criteria when forward curved centrifugal scroll air movement data (amd) are used. Should amd be selected at a duty point to the left of the second static-pressure peak pressure, instability and high power changes may occur in aileron-modified scroll amd. Select 5-percent air handler and primary air delivery when necessary.

[Air-handler delivery: Plus 10 percent, minus 0 percent of design cubic meter per second cfm at design temperature]

[Primary air delivery: Plus or minus 10 percent of design cubic meter per second cfm at design temperature]

[Air-handler delivery: Plus 5 percent, minus 0 percent of design cubic meter per second cfm at design temperature]

[Primary air delivery: Plus or minus 5 percent of design cubic meter per second cfm at design temperature]

3.4.1.2 Balancing and Adjustment, Apparatus and Procedures

NOTE: Select the following paragraph when work is to be done by the Contractor.

Balancing and adjustment apparatus and procedures shall be in accordance with [SMACNA 221] [NEBB TABES] [AABC MN-1].

NOTE: Select the following paragraph when work is to be done by balancing agency.

Balancing and adjustment apparatus and procedures shall be in accordance with [NEBB TABES] [AABC MN-1].

Instrumentation shall be provided to record air movement data, motor kilowatt (kW) input, and power factor. If motor identification plate current value is exceeded, the next size larger motor, starter, and wiring (if necessary) shall be provided.

3.4.1.3 Test Reports

Test reports shall be provided on all systems tested together with test-apparatus data and air-diffusion device flow coefficients, and the following:

NOTE: Select from the following paragraphs for SMACNA or AABC format.

[Air-handling apparatus data]

[Exhaust-fan data]

[Air-diffusion devices data]

[Duct-traverse data for the following:

- Main supply duct
- Main exhaust duct
- Outside air-intake duct
- Other ducts as indicated]

[Duct zone-traverse data for the following:

- All zones
- Air-handling apparatus
- Air-diffusion devices data
- Each main duct, exhaust duct, and outside intake data]

[Filter apparatus data, including visual condition, inlet pressure, and differential pressure for each filter installation]

[Coil data, including visual condition, inlet pressure, and differential pressure for each coil installation]

[Pressure at inlet to face zone duct on multizone units]

3.4.2 Hydronic Systems

3.4.2.1 System Balancing, Adjustment, and Acceptance Criteria

Systems final flow conditions shall be within the following limits:

[Pump delivery: Plus 10 percent, minus 0 percent of design liter per second gallons per minute (gpm) at design temperature]

[Flow-station delivery: Plus or minus 10 percent of design liter per second gpm at design temperature]

[Pump delivery: Plus 5 percent, minus 0 percent of design liter per second gpm at design temperature]

[Flow station delivery: Plus or minus 5 percent of design liter per second gpm at design temperature]

3.4.2.2 Test Apparatus and Procedures

Test apparatus shall consist of devices required for hydronic systems flow measuring and balancing including:

[Pressure gages and fittings]

[Dry bulb thermometers]

[Wet bulb thermometers]

[Pyrometers]

[Balancing-cock adjustment wrenches]

[Differential-pressure gages or manometers]

[Thermometer wells, where necessary for balancing, but where permanent installation of thermometers is not indicated or required]

Complete air balance shall have been accomplished before water balance begins.

3.4.2.3 Hydronic Systems Preparation

Hydronic systems shall be prepared in the following manner:

Proper installation of valves and balancing devices shall be verified.

Valves shall be opened to full-open position, including coil-stop valves, bypass valves, and return-line balancing cocks.

Strainer screens shall be removed and cleaned.

Water in each system shall be examined to determine that it has been treated.

Rotation of pumps shall be checked only after obtaining approval.

Expansion tanks shall be checked to determine that they are not air-bound and that system is full of water.

Air vents shall be checked at high points to verify proper installation and operation.

Temperature controls shall be set so that coils are on full cooling. Automatic bypass valves at coils and liquid chiller should close. Follow the same procedure when balancing heating coils are set on full heating.

Water-circulating pumps shall be set to proper **liter per second** **gpm** delivery.

Flow of chilled water through chillers shall be adjusted.

Water flow through convertors shall be adjusted.

Leaving-water and return-water temperatures through chiller and convertors shall be checked.

Water temperature shall be checked at inlet side of cooling and heating coils. Note rise or drop of temperature from source.

Next, each coil shall be balanced.

Upon completion of flow reading and adjustment of coils, all settings shall be marked and all data recorded.

After adjustments to coils have been made, settings at pumps, chiller, and convertors shall be rechecked and readjusted if required.

Pressure drop through coils shall be measured at set flow rate on call for full cooling and on full heating.

Pressure drop across bypass valve shall be set to match coil

full-pressure drop to prevent unbalanced flow conditions when coils are on full bypass.

Same procedure on chiller to adjust chiller bypass valves shall be followed.

Instrumentation shall be provided to record apparatus motor kW input and power factor. If motor identification plate current capacity and larger starter is exceeded, next-size larger motor and wiring shall be provided, as necessary.

Cooling-water flow shall be checked.

3.4.2.4 Operational Test Report

Operational test report shall provide data on systems tested, test apparatus data, and orifice or Venturi data, and shall include:

**NOTE: Select from the following for SMACNA or AABC
or ASHRAE format.**

[For each heating and cooling element:

[Inlet water temperature]

[Leaving water temperature]

[Inlet air temperature]

[Leaving air temperature]

[Pressure drop across each element]

[Pressure drop across bypass valve]

[Calculated and measured flow rates through coils and radiation elements]]

[For each pump:

[Balanced-condition suction and discharge pressures]

[Flow rate]

[Mechanical specifications of unit]

[Rated and actual kW input and power factor]]

[For each apparatus such as chiller, cooling tower, and converter:

[Inlet water temperature]

[Leaving water temperature]

[Pressure drop across units]

[Calculated and measured waterflow]

[Mechanical specifications of units]

[Rated and actual kW input and power factor for motors]

[Heating- and cooling-element data]

[Pump data]]

3.4.3 System and Temperature-Control Adjustment

3.4.3.1 Adjustment and Acceptance Criteria

After balance and adjustment operations have been completed, the system shall be tested as a whole to see that components perform as an integral part of the system and that temperature and conditions are evenly controlled. Corrections and adjustment shall be made as necessary to meet the specified design requirements.

3.4.3.2 System Test Report

Test report shall be provided on the system and shall include:

Outdoor temperature

Room-by-room temperature and humidity conditions (center of cooled area at table top)

Calculation for total wattage British thermal units per hour (Btu/hr) cooling required, including time of day and dry bulb outside temperature

Calculation for total wattage Btu/hr heating required, including time of day and dry bulb outside temperature

3.5 STEAM AND CONDENSATE SYSTEMS TESTING

Prior to acceptance of the work, completed systems shall be tested in the presence of the Contracting Officer.

System shall be subjected to pressure tests to determine structural integrity, and to operational and cyclic tests, as necessary, to determine that system functions and operates as required.

After pressure tests and cleaning operations have been satisfactorily completed, system components shall be adjusted for proper operation within the design and operating characteristics published by the component manufacturer. In addition to the services of an authorized representative of the manufacturer, the Government reserves the right to require the services of an authorized representative of a component manufacturer if the Contractor is unable to adjust a component. Contractor shall arrange for such services and defray the cost.

3.5.1 Test Duration

Duration of a test will be determined by the Contracting Officer.

A pressure test shall be held for a minimum of 2 hours and a maximum of 24 hours.

[An operational test shall be held for a minimum of [6] [_____] hours and a maximum of [24] [_____] hours.]

A test may be terminated by the Contracting Officer at any time after it has been determined that the system meets specified requirements.

3.5.2 Test Gages

Contractor's test gages shall conform to ASME B40.100 and shall have 200 millimeter 8-inch or larger dials. Maximum permissible scale range for a given test shall be such that the pointer shall have a starting position at midpoint of the dial or within the middle third of the scale range. Certification of accuracy and correction table shall bear a date within 90 calendar days prior to use, test gage number, and project number.

3.5.3 Acceptance Pressure Testing

Testing shall take place during steady-state ambient temperature conditions.

Tests shall be hydrostatic unless otherwise specified.

NOTE: Due to the expansive force of compressed air at 690 to 1050 kilopascal 100- to 150-pounds per square inch, pneumatic testing requires special precautions and competent supervision to guard against injury and damage if a failure occurs. High-pressure pneumatic testing should be discouraged.

Subject to prior approval, tests may be pneumatic when freezing conditions may occur. Personnel not directly involved in pneumatic testing of piping in excess of 35 kilopascal 5 psi shall be evacuated from the area.

Pneumatic testing shall include swabbing joints under test pressure of 35 kilopascal 5 psi with standard high-film-strength soap solution and observing for bubbles.

Tests of steam and condensate systems shall be made using potable water.

Compressed air used for steam and condensate systems pneumatic testing shall be oil-free.

Systems shall be tested at 1-1/2 times primary working steam pressure rating of system components, and the applied pressure shall be maintained without further addition of test media for not less than 1 hour. Maximum allowable pressure drop shall be 6900 pascal 1 psi, or as approved.

Contractor may conduct tests for his own purposes, but the acceptance test shall be conducted as specified herein.

If testing reveals that leakage exceeds specified limits, the leaks shall be isolated and repaired, defective materials shall be replaced where necessary, and the system shall be retested until specified requirements are met. Leaking gasket joints shall be remade with new gaskets and new flange bolting. Old gaskets and bolting shall be discarded. Leaking tubing joints shall be remade with new fittings and new tube ends.

Other than standard piping flanges, plugs, caps, and valves, only commercially manufactured expandable elastomer plugs shall be used for sealing off piping for test purposes. Safe test-pressure rating of any plug used shall be not less than two times the test pressure.

Precautions shall be taken, when venting compressed air trapped during high-pressure hydrostatic testing, to preclude injury and damage. If adequate purging or vent valves are not provided to ensure removal of compressed-air cushion, the Contracting Officer may require the removal of any system component such as plugs and caps to ascertain that the water has reached all parts of the system. Components shall be removed from piping systems prior to hydrostatic testing whenever the component could be damaged by shock or test pressure.

[Movement limiting provisions shall be used to protect expansion joints against overextension from system pressures.]

Piping system components, such as valves, shall be checked for functional operation under system test pressure.

Piping shall be subjected to shock developed by a vigorously applied ~~1 kilogram~~ 2-pound hammer, as directed by the Contracting Officer.

Temperature of water used for testing shall not cause condensation on system surfaces.

3.5.4 Operational Testing

System shall be cycled five times, from start to operating thermal conditions, to verify adequacy of construction, system controls, and component performance, unless otherwise approved.

3.6 DRAINAGE AND VENTING SYSTEM TESTING

Drainage and venting system piping shall be tested before the fixtures are installed. Soil and waste piping installed underground shall be tested before backfilling. Testing shall be applied to the system in its entirety or in sections. If the entire system is tested, openings in pipes, except the highest opening, shall be tightly closed and the system shall be filled with water to the point of overflow. the highest opening of the section under test, shall be tightly plugged and each section shall be filled and tested with not less than a ~~3000 millimeter~~ 10-foot head of water. In testing successive sections, at least the upper ~~3000 millimeter~~ 10 feet of the next preceding section shall be tested so that each joint or pipe in the system, except the uppermost ~~3000 millimeter~~ 10 feet, has been submitted to a test with not less than a ~~3000 millimeter~~ 10-foot head of water. Water shall be kept in the system, or the portion under test, for at least 15 minutes before the inspection starts. System shall be tight at all joints.

3.7 TEST REPORTS

Final test reports shall be provided to the Contracting Officer. Reports

shall have a cover letter/sheet clearly marked with the System name, Date, and the words "Final Test Reports - Forward to the Systems Engineer/Condition Monitoring Office/Predictive Testing Group for inclusion in the Maintenance Database."

-- End of Section --