American National Standard for Nitrogen Generators

ANSI/FM Approvals 1035-2018
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Foreword

This standard is intended to be used to evaluate components and performance of nitrogen generators.

This American National Standard has been developed by the canvass method of standards development of the American National Standards Institute (ANSI). FM Approvals is an ANSI-accredited standards developing organization (SDO).

Approval of an American National Standard requires verification by ANSI that the principles of openness and due process have been followed and that a consensus of those directly and materially affected by the standard has been achieved. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution. Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached.

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ANSI regulations require that this American National Standard shall be revised, reaffirmed, or withdrawn within five years of the date of publication.

FM Approvals
1151 Boston-Providence Turnpike
P.O. Box 9102
Norwood, MA 02062
U.S.A.

Phone: 781-762-4300
FAX: 781-762-9375
Email: information@fmglobal.com

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1. INTRODUCTION

1.1 Purpose

1.1.1 This standard states examination criteria for nitrogen generators for use in fire protection systems. Nitrogen generators provide pressurized nitrogen to the sprinkler piping to minimize interior pipe corrosion.

1.1.2 Examination criteria may include, but are not limited to, performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a follow-up program.

1.2 Scope

1.2.1 This standard encompasses the design and performance requirements for nitrogen generators.

1.2.2 Nitrogen generators may use membranes or pressure swing adsorption as the nitrogen separation mechanism. Other technologies may be evaluated on a case-by-case basis. The use of nitrogen storage bottles or plant nitrogen is not in the scope of this standard.

1.3 Basis for Requirements

1.3.1 The requirements of this standard are based on experience, research and testing, and/or the standards of other organizations. The advice of manufacturers, users, trade associations, jurisdictions, and/or loss control specialists was also considered.

1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of nitrogen generators. Nitrogen generators having characteristics not anticipated by this standard may be tested if demonstrated performance is equal, or superior, to that required by this standard, or if the intent of the standard is met.

Alternatively, Nitrogen generators that meet all of the requirements identified in this standard may not be acceptable if other conditions that adversely affect performance exist or if the intent of this standard is not met. It is the sole discretion of the testing laboratory.

1.4 Basis for ANSI Specification

1.4.1 Certification is based upon satisfactory evaluation of the product and the manufacturer in the following major areas:

- The suitability of the product;
- The performance of the product as specified by the manufacturer;
- The durability and reliability of the product.

1.4.2 A satisfactory review of the manufacturer's installation and maintenance instructions for the Nitrogen generators is required. The evaluation shall be performed to ensure that the document is accurate and complete.

1.5 System of Units

Units of measurement used in this standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Appendix A lists the selected units and conversions to SI units for measures appearing in this standard. Conversion of U.S. customary units is in accordance with the Institute of Electrical and Electronics Engineers (IEEE)/American Society for Testing Materials (ASTM) SI 10-2002, *American National Standard for Use of the International System of Units (SI): The Modern Metric System*.

1.6 Applicable Documents

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document (including any amendments) applies:

American Society of Mechanical Engineers (ASME) B16.5, *Pipe Flanges and Flanged Fittings: NPS ½ through NPS24 Metric/Inch Standard*
American National Standards Institute (ANSI)/American Water Works Association (AWWA) C606, *Grooved and Shouldered Joints*
ASME B1.20.1, *Pipe Threads, General Purpose (Inch)*
ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 – *Rules for Construction of Pressure Vessels*
FM Global Property Loss Prevention Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
IEEE/ASTM SI 10, *American National Standard for Metric Practice*
International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) 17025, *General Requirements for the Competence of Testing and Calibration Laboratories*
SAE International J10, *Automotive and Off-Highway Air Brake Reservoir Performance and Identification Requirements – Truck and Bus*
Code of Federal Regulations Title 49, Section 178.61 – *Specification 4BW welded steel cylinders with electric-arc welded longitudinal seam*

1.7 Definitions

For purposes of this standard, the following terms apply:

Accepted

This term refers to installations acceptable to the authority enforcing the applicable installation rules. Acceptance is based upon an overall evaluation of the installation. Acceptance is not a characteristic of a product. It is installation specific. A product accepted for one installation may not be acceptable elsewhere.

Air Pressure Maintenance Device

This term refers to a device that automatically maintains the air pressure within a dry pipe or pre-action sprinkler system within pre-set limits. These devices may also be used with pressurized nitrogen in a nitrogen filled system.

Bypass Mode

Most nitrogen generators can not produce enough nitrogen to pressurize the sprinkler system with nitrogen at 40 psig within 30 minutes. Therefore, they contain valves that allow the nitrogen separator to be bypassed so the system can be filled with compressed air. For the purposes of this standard the valve settings that bypass the nitrogen separator is called Bypass Mode. (Contrast with ***Nitrogen Generating Mode***)

In situations where 'Bypass' mode is insufficient to provide enough flow of air to pressurize a sprinkler system in 30 minutes, a supplemental air compressor or nitrogen gas supplied from cylinders can be used. These alternates are not addressed in detail in this standard.

Bypass Capacity

The nitrogen generator must be capable of producing a minimum of this volume of compressed air at 40 psi (275 kPa) in 30 minutes in bypass mode (contrast with System Capacity).

Control Panel

The control panel is the portion of the nitrogen generator that contains the controls. Minimum requirements for the control panel are found in Section 3.2.4.

Conditioning Equipment

For the purposes of this standard, conditioning equipment refers to all filters and other devices used to condition the compressed air before it enters the nitrogen separating mechanism.

End Connections

The term "End Connections" refers to the method of connecting components of a fire protection system. Typical end connections in fire protection service are flanged, grooved, threaded, and welding end.

Pressure Swing Adsorption (PSA)

A method of generating nitrogen using the process of adsorption by which a thin layer of molecules temporarily adheres to the surface of another material. A PSA nitrogen generator consists of two or more towers filled with adsorbent material. Air is drawn into one tower and oxygen adheres to the adsorbent material. The remaining atmospheric gas, which is mostly nitrogen, passes through. The towers are cycled so that waste oxygen is being "cleaned" from one tower while the other is used to produce nitrogen, and the two are switched periodically.

Membrane nitrogen generator

A method of generating nitrogen using the process of passing compressed air through a membrane. Different gases have different rates of permeation and this can be used to separate nitrogen from the other atmospheric gases. The resulting product is mostly nitrogen.

Nitrogen Generating Mode

Most nitrogen generators can not produce enough nitrogen to completely fill the sprinkler system in 30 minutes. Therefore, they contain valves that allow the nitrogen separator to be bypassed so the system can be filled with compressed air. For the purposes of this standard, the valve settings that include the nitrogen separator is called ***Nitrogen Generating Mode***. (Contrast with ***Bypass Mode***)

Purging

Purging is defined as the removal of air/nitrogen from the sprinkler system via a purge valve. Purging is not required by this standard. The purge valve allows some gas to escape from the system, which then requires the nitrogen generator to supply nitrogen to maintain system pressure. This process therefore increases the nitrogen concentration within the system piping over time. The purge valve and any associated controls are not within the scope of this standard. The control panel may, but is not required to, accept signals from an automatic purging valve/system.

Rated Working Pressure

This is the maximum sustained pressure at or below which the device shall operate trouble free for its entire design life. This value sets the basis for the testing described in Section 4. The rated working pressure will be different for different parts of the nitrogen generator. For example, the rated working pressure of the conditioning filters would be the maximum output of the compressor, but the rated working pressure of a valve downstream of the nitrogen separator may be lower due to pressure drops between it and the compressor.

Regeneration

The process where a portion of the air flow is used to regenerate one adsorption tower, preparing it to enter a new period of operation. At atmospheric pressure the bond between the oxygen and the adsorbent material is broken and the waste oxygen can be removed.

System Pressure

The maximum output pressure the system is rated for. This pressure is chosen by the manufacturer and verified by the tests.

2. GENERAL INFORMATION

2.1 Product Information

2.1.1 Nitrogen generators provide compressed nitrogen to fire protection systems. Replacing oxygen with nitrogen minimizes the corrosion in the system.

2.1.2 In order to meet the intent of this standard, nitrogen generators must be examined on a model-by-model, type-by-type, manufacturer-by-manufacturer, and plant-by-plant basis. This is predicated on the basis that identical designs, fabricated using identical materials and components by different manufacturers, or even by different plants of the same manufacturer, have been seen to perform differently in testing. Sample assemblies, selected in conformance to this criterion, shall satisfy all of the requirements of this standard.

2.2 Application Requirements

The manufacturer shall provide the following preliminary information that gives a full description of the construction of the Nitrogen generator. All documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level.

Test programs will be scheduled only upon receipt of all materials listed herein. All foreign language documents shall be provided with English translation.

- A complete list of all models, types, sizes, and options for the products or services being submitted for Approval consideration;
- General assembly drawings, critical manufacturing drawings, materials list, anticipated marking format, piping and electrical schematics, nameplate format, brochures, sales literature, spec. sheets, installation, operation and maintenance procedures; and
- The number and location of manufacturing facilities.

2.3 Requirements for Samples for Examination

Sample requirements are to be determined by the testing laboratory following review of the preliminary information. Sample requirements may vary depending on design features and/or the results of any testing. It is the manufacturer's responsibility to submit samples representative of production. Any decision to use data generated utilizing prototype components or prototype systems is at the sole discretion of the testing laboratory.

3. GENERAL REQUIREMENTS

3.1 Review of Documentation

3.1.1 During the initial investigation and prior to physical testing, the manufacturer's specifications, technical data sheets, and design details shall be reviewed to assess the ease and practicality of installation and use. The product shall be capable of being used within the limits of the investigation.

3.1.2 The manufacturer's dimensional specifications and/or design drawings shall fully describe the product. All critical dimensions shall be indicated with allowed upper and lower tolerance limits clearly shown.

3.2 Physical or Structural Features

3.2.1 Nitrogen generators supply compressed nitrogen to an air maintenance device. They shall be compatible with the piping and threads of the country of installation.

3.2.2 Nitrogen generators submitted for testing shall be true production samples and shall be free of sharp edges, burrs, or other imperfections which might injure the installer or interfere with proper assembly of the unit**.**

3.2.3 Nitrogen generators generally contain four main parts: a control panel, an air compressor (may be supplied by others), a compressed gas storage tank, and a nitrogen separating mechanism. Two common types of nitrogen separation are membrane separation and pressure swing adsorption.

3.2.4 The control panel shall be a metal enclosure containing all equipment necessary to control the nitrogen separator. The panel shall include a run time meter, and a storage tank pressure gauge or pressure gauge for other critical systems.

3.2.5 The separating mechanism shall have easily changed water separators, pre-filters, adsorption material and/or membrane. Other components needing regular service shall be readily accessible.

3.2.6 Typical end connections are cut grooved in accordance with ANSI/AWWA C606, threaded in accordance with ASME B1.20.1, or flanged in accordance with ASME B16.5. Other types of end connections may be evaluated on a case-by-case basis, provided such ends are compatible with the requirements of FM Global Property Loss Prevention Data Sheet 2-0, "Installation Guidelines for Automatic Sprinklers".

3.2.7 Pressure Vessels (Storage Tanks and Adsorption Towers)

3.2.7.1 Pressure vessels utilized in nitrogen generators shall conform to the appropriate regulations and design standards for the installation location. They shall be new vessels, cleaned and dried, and have safety relief valves as required by the design standards for the installation location. In the U.S.A., pressure vessels must typically conform to the following regulations:

- ASME Boiler & Pressure Vessel Code, Section VIII, Division 1 – "*Rules for Construction of Pressure Vessels*" or SAE International J10, *Automotive and Off-Highway Air Brake Reservoir Performance and Identification Requirements – Truck and Bus* or Code of Federal Regulations Title 49, Section 178.61 – *Specification 4BW welded steel cylinders with electric-arc welded longitudinal seam*

3.2.7.2 Samples of the following documents shall be submitted for each size pressure vessel design, to demonstrate compliance with the relevant design standard:

- Calculation of wall thicknesses in accordance with the method specified in the design standard, with appropriate supporting references, as necessary
- Certificate of chemical analysis of materials
- Certificate of physical properties of materials

3.3 Materials

All materials used in these nitrogen generators shall be suitable for the intended application. When unusual materials are used, special tests may be necessary to verify their suitability. All components shall withstand the normal abuse of shipping, handling, and installation.

3.4 Conditioning of Compressed Air

The nitrogen generator shall contain sufficient equipment to condition the air produced by the compressor in order to protect the nitrogen separating mechanism. The air shall be conditioned to the membrane or adsorption media

manufacturer's specifications. This typically includes a prefilter, a coalescing filter, and a particle filter with water removal. Coalescing filters and filters with water removal shall have provisions for piping the water to a drain fitting on the nitrogen generator.

The conditioning should be designed to accommodate air intake conditions typically found in sprinkler rooms (high humidity, minor levels of dust, etc).

3.5 Bypass Mode Operation

The nitrogen generator shall be equipped with a mechanism to prevent it being left in bypass mode accidentally. This may be an interlock so that bypass mode can't be engaged with the control panel door closed, a visual indication with a minimum of 2" (50mm) diameter flashing light or an audible alarm with a minimum of 75dB if the system is in bypass, or an automatic system to switch from bypass to nitrogen generating mode after 1 hour.

3.6 Markings

3.6.1 Each nitrogen generator discussed in this standard shall be permanently marked with the following information:

- Manufacturer's name or trademark
- Model designation
- Sprinkler System capacity
- Electrical input voltage/phase/Hz
- Date of manufacture or serial number
- (optional) purity level of N2 produced if over 98%

3.6.2 Additional pertinent marking information required by a national or international Standard to which the product is manufactured shall be permanently marked on the outside surface of each assembly.

3.6.3 Each required marking listed in Section 3.6.1 shall be legible, durable, and applied by casting, die stamping, forging, roller embossing and/or electro-etching. As an alternate method, the markings may be inscribed on a label or tag applied to the assembly that has been shown to be durable and non-fading.

3.6.4 All markings shall be legible and durable throughout the useful life of the product.

3.7 Manufacturer's Installation Instructions

3.7.1 The manufacturer shall provide the user with:

- Instructions for the installation, maintenance, and operation of the product
- Adequate facilities for repair of the product and replacement parts
- The manufacturer (or his designee) shall be able to provide, for a fee, proper installation, inspection and/or maintenance of the product

3.7.2 The instruction manual that is supplied with each unit shall outline in detail the field procedures for installing and repairing the units. The manual shall be reviewed by the certifying body for completeness and ease of comprehension prior to testing.

3.7.3 The manual should include instructions for system start up including purging and how nitrogen concentration should be monitor/measured.

3.7.4 The manual shall include instructions and frequency for conditioning equipment maintenance.

3.7.5 The manual shall include instructions and frequency for other maintenance of the equipment contained in the nitrogen generator (lubrication, filter changes, oil changes, etc).

3.7.6 The manual shall include instructions for maintaining the separator mechanism, including ordering information for replacement membrane cartridges or adsorption material. The manual shall include the proper replacement interval for membrane cartridges or adsorption material.

3.7.7 If the nitrogen generator is not supplied with a compressor, the manual shall contain the requirements for compressed air including air quality, minimum pressure and volume that must be supplied to the nitrogen generator.

3.7 Calibration

Each piece of equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage. The certificate shall indicate that the calibration was performed against working standards whose calibration is certified as traceable to the National Institute of Standards and Technology (NIST) or traceable to other acceptable reference standards and certified by an ISO/IEC 17025, "*General Requirements for the Competence of Testing and Calibration Laboratories"*, calibration laboratory. The test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date.

The calibration of new equipment is also required. Documentation indicating either the date of purchase or date of shipment, equipment description, and model and serial number is required for identification. The period from the time the equipment was put into service to the date of testing must be within an interval that does not require the equipment to be calibrated as determined on the basis of the parameters mentioned above. The new test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date.

3.8 Test Facilities

If review of all required information indicates suitability for testing, representative samples of the seismic sway brace equipment shall be made available. The range of products, and testing orientations will be specified by the testing laboratory. If testing cannot be completed at the testing laboratory, the manufacturer shall provide facilities and all properly calibrated instrumentation required to perform these tests. Alternatively, a mutually agreeable 3rd party laboratory may be used provided that this facility has the ability to perform the tests as described herein, and can satisfy the requirements for calibration for the equipment. For testing not conducted at a testing laboratory, a representative of the testing laboratory shall witness all the tests and shall receive copies of the data collected during testing, and calibration certificates of the equipment used.

3.9 Tolerances

Tolerances on units of measure shall be as described in Appendix B, unless otherwise specified.

4. PERFORMANCE REQUIREMENTS

4.1 Examination

4.1.1 Requirement

The nitrogen generators shall conform to the manufacturer's drawings and specifications and to the requirements of this standard.

4.1.2 Test/Verification

Sample nitrogen generators shall be examined and compared to drawings and specifications. It shall be verified that the samples conform to the physical and structural requirements described in Section 3, General Requirements.

4.2 Bypass Mode Capacity

4.2.1 Requirement

The Bypass capacity shall be the amount of compressed air at 40 psi that can be produced in 30 minutes in bypass mode. This capacity shall be listed in the report as an equivalent volume of the sprinkler system (in gallons/liters).

4.2.2 Test/Verification

Start and run the nitrogen generator in bypass mode. Connect the output of the generator to a pressure vessel with a volume of at least 10 percent of the bypass capacity. Record initial pressure in the vessel (atmospheric pressure) and measure the time to increase the pressure in the vessel to 40 psi (275 kPa).

This test shall be recorded as successful if the time (in minutes) to increase the pressure in the vessel, T_{meas} is less than or equal to T_{req} in the following formula:

$$T_{req} \leq 30 \text{ x (Volume of pressure vessel)/(Bypass Capacity)}$$

4.3 Nitrogen Generation Capacity

4.3.1 Requirement

The unit shall be capable of producing nitrogen at a concentration of at least 98%. If higher purity is claimed by the manufacturer, that purity shall be used in this test.

4.3.2 Test/ Verification

The nitrogen generator shall be placed in an environmental chamber at 77°F (25°C) and 50% relative humidity. The unit shall draw supply air from this chamber. The output of the nitrogen generator shall be independently vented to outside the chamber.

Start and run the nitrogen generator and pipe the output through a flow meter to atmosphere. Allow the system to stabilize by running for a minimum of 1 minute. After the stabilization period, measure the output flow, concentration of nitrogen in the output stream and pressure. Record the flow for a minimum of 10 minutes. The nitrogen concentration shall be a minimum of the manufacturer's stated purity level (minimum 98%) for the entire duration of the test.

Record the nitrogen purity level and the flow rate of nitrogen produced.

4.4 Service Assessment

4.4.1 Requirement

Using the manufacturer's instructions, perform periodic parts replacement and/or maintenance procedures on typical portions of the device, using spare parts supplied by the manufacturer. Maintenance shall be possible without specialized training and using only commercially available tools or tools supplied with the unit.

4.4.2 Test/ Verification

Check safety valves, replace membrane/adsorbent material, replace filters, and service other parts of the nitrogen generator, using the manufacturer's supplied instructions. Oil changes are not deemed to be a necessary portion of this program. All components requiring periodic replacement and/or maintenance shall be changed or installed satisfactorily, in accordance with the supplied instructions.

4.5 Pressure Integrity

4.5.1 Requirement

The components of the nitrogen generator shall withstand pressure equal to or greater than two times the design pressure of that portion of the nitrogen generator for a period of 5 minutes without leakage or rupture. Components may be tested individually or in subassemblies of like pressure rating. Safety relief valves and other relief mechanisms may be removed prior to this test if necessary.

4.5.2 Test/Verification

The components of one sample of each type of nitrogen generator shall be subjected to a pressure integrity test. Test pressure for each component or test assembly of components shall be two times the design pressure of that portion of the nitrogen generator. Gaskets and seals may be reinforced if necessary during this test. Pressure relief valves and materials may be removed for this test. Pressure shall be maintained for 5 minutes without leakage or rupture. Tests may be conducted with either air or water.

4.6 System Durability

4.6.1 Requirement

The entire nitrogen generator shall be designed to operate reliably for 50 days without maintenance.

4.6.2 Test/Verification

Connect the output of the generator to a regulator. Set the regulator to 40 psi (275 kPa). Nitrogen shall be discharged from the outlet of the regulator through a solenoid valve. The solenoid valve shall be cycled so that the Nitrogen Generator compressor runs approximately 50% of the time, with the duration of the cycles acceptable to the manufacturer. If the system includes a nitrogen storage tank a continuous discharge for the tank may be used in place of the solenoid. The discharge rate shall be set so the compressor operates approximately 50% of the time.

The system shall be run for 50 days. At the conclusion of this test, no mechanical failure, nor any appreciable change in operating characteristics of the air compressor section or the nitrogen separator section, shall have occurred. The system shall still generate the stated purity of nitrogen.

4.7 Control Panel Cycling (dual tower systems only)

4.7.1 Requirement

The control panel shall be designed to operate reliably for 25,000 cycles.

4.7.2 Test/Verification

A sample device shall be subjected to 25,000 cycles of operation, not including the compressor and electric motor. Inlet pressure to the nitrogen separating section shall be supplied by the laboratory air supply. The control panel shall be supplied with AC power to the control circuitry to simulate a continuously running motor. Outlet pressure piping shall be vented through a solenoid. Outlet pressure shall be set to the system pressure. Nitrogen shall be discharged through the solenoid valve for 30 seconds, and then held for 30 seconds. This shall be considered one cycle. At the conclusion of this test, no mechanical failure, nor any appreciable change in operating characteristics of the air compressor section or the nitrogen separator section, shall have occurred.

4.8 Dielectric Strength

4.8.1 Requirement

Electrical components shall withstand application of twice their rated voltage plus 1000 volts between all terminals provided for external connections and ground for a duration of 1 minute. This requirement is intended to be applied only to AC power wiring. Any low voltage DC equipment or controls may be disconnected for the test.

4.8.2 Test/Verification

Voltage shall be applied between each terminal and ground. Components subjected to the Dielectric Strength test shall continue to function normally after the test.

This test may be waived at the testing engineer's discretion if there are no significant electrical components in the unit.

4.9 Additional Tests

Additional tests may be required, depending on design features, results of any tests, material application, or to verify the integrity and reliability of the nitrogen generator, at the discretion of the testing laboratory.

Unexplainable failures shall not be permitted. A re-test shall only be acceptable at the discretion of the testing laboratory and with adequate technical justification of the conditions and reasons for failure.

5. REPORTING REQUIREMENTS

The information outlined below represents the minimum requirements for reporting for a test program for seismic sway brace components. It is strongly encouraged that the requester and the test laboratory reach agreement on the test method to be used, the data to be recorded, and the reporting to be issued at the conclusion of the testing prior to any testing being performed.

5.1 Final Report

5.1.1 At the conclusion of a test program for the nitrogen generator(s) the data shall be collected and organized into a final report that describes the following:

- Products tested in the evaluation
- Tests conducted for each product
- Test method and data collected for each test
- Calibration of equipment
- Signature and date of review

5.1.2 Considering the amount of raw data that can be created during a project, it is envisioned that the final reporting may also include a supporting document wherein the actual raw data is kept in order to increase the usefulness of the final report. This should be agreed between the requester and the testing laboratory prior to the start of any testing.

5.2 Samples

5.2.1 Prior to the start of testing, the requester and the test laboratory shall reach an agreement on the scope of samples to be included within the test program. Changes to the samples included within the program shall only be possible via written communication between the requester and test laboratory.

5.3 Test Method

5.3.1 All testing shall be performed using a documented test procedure which outlines the equipment to be used, orientation of the part under test, the data to be collected, and the level of analysis to be performed.

5.4 Calibration of Equipment

Each piece of equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage. A copy of the calibration certificate for each piece of test equipment shall be incorporated into the final report or supporting documents. The certificates shall indicate that the calibration was performed against working standards whose calibration is certified as traceable to the National Institute of Standards and Technology (NIST) or traceable to other acceptable reference standards and certified by an ISO/IEC 17025 accredited calibration laboratory. The test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date. A copy of the service accreditation certificate as an ISO/IEC 17025, "General Requirements for the Competence of Testing and Calibration Laboratories" shall be required with the measurement equipment calibration.

5.5 Review and Signatures

The review of the final report and supporting documentation shall be agreed upon between the requester and the test laboratory at the start of the program. This will outline the nature of the review and responsibilities of the signatory.

APPENDIX A: Units of Measurement

LENGTH: in. - “inches”; (mm - “millimeters”)
mm = in. x 25.4

ft - “feet”; (m - “meters”)
m = ft x 0.3048

AREA: $in.^2$ - “square inches”; (mm^2 - “square millimeters”)
$mm^2 = in.^2 \times 6.4516 \times 10^2$

ft^2 - “square feet”; (m^2 - “square meters”)
$m^2 = ft^2 \times 0.0929$

MASS: lb - “pounds”; (kg - “kilograms”)
kg = lb x 0.454

PRESSURE: psi - “pounds per square inch”; (bar - “bar”)
kPa = psi x 6.895

bar - “bar”; (kPa - “kilopascals”)
bar = kPa x 0.01
bar = psi x 0.06895

TEMPERATURE: F - “degrees Fahrenheit”; (C - “degrees Celsius”)
C = (F - 32) x 0.556

LIQUID: gal. - “gallons”; (L - “liters”)
L = gal. x 3.785

L - “liters”; (dm^3 - “cubic decimeters”)
$L = dm^3$

FLOW RATE: gal./min. - “gallons per minute”; (L/min. - “liters per minute”)
L/min. = gal./min. x 3.785

FLOW VELOCITY: ft/s – “feet per second”; (m/s - “meters per second”)
m/s = ft/s x 0.3048

HUMIDITY: % = percent

DEW POINT: F - “degrees Fahrenheit”; (C - “degrees Celsius”)
C = (F - 32) x 0.556

APPENDIX B: Tolerances

Unless otherwise stated, the following tolerances shall apply:

Angle	**± 2°**
Frequency (Hz)	**± 5 percent of value**
Length	**± 2 percent of value**
Volume	**± 1 percent of value**
Pressure	**± 0.1 psi (690 Pa)**
Air Flow	**± 1 percent of value**
Dew Point	**± 1 percent of value**
Nitrogen Percentage	**- 0.1 percent**
Humidity	**± 2 percent of value**
Temperature	**± 2°F (1°C)**
Time	**+ 5/–0 seconds**
	+0.1/–0 minutes

Unless stated otherwise, all tests shall be carried out at a room (ambient) temperature of 68 ± 9°F (20 ± 5°C).