

ASME N511-2007

Revision of N511-2007 (R2013)

In-Service Testing of Nuclear Air Treatment, Heating, Ventilating, and Air-Conditioning Systems

May 2017 Draft

AN AMERICAN NATIONAL STANDARD



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Mechanical Engineers**

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**The American Society of
Mechanical Engineers**

Three Park Avenue • New York, NY 10016

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FOREWORD

This Standard covers the requirements for in-service testing of nuclear safety-related air treatment, heating, ventilating, and air conditioning systems in nuclear facilities that are designed, built, and acceptance tested in accordance with ASME AG-1.

This Standard provides a basis for the development of test programs, in-service test procedures, and corrective action requirements.

In 1971, what is now the Committee on Nuclear Air and Gas Treatment was organized as ANSI N45.8 to develop standards for high-reliability, air-cleaning equipment for nuclear facilities and corresponding tests to confirm performance of the equipment. Two standards, N509 and N510, were published in 1975 and 1976, and updated in 2002 and 2007, respectively. In 1976, under the accredited organization rules, the Committee was reorganized as the ASME Committee on Nuclear Air and Gas Treatment. The scope of responsibility was broadened to include the development of codes and standards for design, fabrication, inspection, and testing of air-cleaning and conditioning components and appurtenances, as well as air-cleaning components used in engineering safety systems in nuclear facilities. The current assignment is to produce code documents and maintain ASME N509 and N510, and develop and maintain ASME N511.

Suggestions for improvement gained in the use of this Standard will be welcomed. They should be sent to the Secretary, Committee on Nuclear Air and Gas Treatment, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016.

This Standard was approved by the ASME Committee on Nuclear Air and Gas Treatment and the ASME Board of Nuclear Codes and Standards, and was subsequently approved as an American National Standard by the American National Standards Institute on October 30, 2007.

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IN-SERVICE TESTING OF NUCLEAR AIR TREATMENT, HEATING, VENTILATING, AND AIR-CONDITIONING SYSTEMS

1 INTRODUCTION

1.1 Scope

This Standard covers the requirements for in-service testing of nuclear safety-related air treatment, heating, ventilating, and air-conditioning systems in nuclear facilities.

1.2 Purpose

The purpose of this Standard is to provide requirements for in-service testing, the results of which are used to verify that the nuclear air treatment, heating, ventilating, and air-conditioning systems perform their intended function.

1.3 Applicability

This Standard applies to the in-service testing of nuclear air treatment, heating, ventilating, and air-conditioning systems that have been designed, built, and acceptance tested in accordance with ASME AG-1. Sections of this Standard may be used for technical guidance when testing air treatment, heating, ventilating, and air-conditioning systems designed and built to other standards.

1.4 Use of This Standard

This Standard provides a basis for the development of test programs and does not include acceptance criteria, except where the results of one test influence the performance of other tests. Based on the system design and its function(s), the owner shall develop a test program and acceptance criteria.

Nonmandatory Appendices A through C provide additional information and guidance.

1.5 Definitions

The definitions provided in this section supplement those listed in ASME AG-1, Article AA-1000.

abnormal incident: any event or condition that may adversely affect the function of the nuclear air treatment, heating, ventilating, and air-conditioning systems.

acceptance test: a test made upon completion of fabrication, installation, repair, or modification of a unit, component, or part to verify to the user or owner that the item meets specified requirements.

adsorbent: a solid having the ability to concentrate other substances on its surface.

adsorber: a device or vessel containing adsorbent.

adsorber bank or *filter bank*: one or more filters or adsorbers secured in a single mounting frame, or one or more side by side panels containing poured or packed air treatment media, confined within the perimeter of a duct, plenum, or vault cross section, sometimes referred to as a stage.

aerosol: a stable suspension of particles, solid or liquid, in air.

challenge: to expose a filter, adsorber, or other air treatment device to an aerosol or gas of known characteristics, under specified conditions, for the purpose of testing.

challenge aerosol: an aerosol used for in-place leak testing of installed HEPA filter systems.

NOTE: The polydispersed aerosol used for in-place leak testing of systems differs in size from the 0.3 μm monodisperse DOP aerosol used for efficiency testing of individual HEPA filters by manufacturers. For potential substitutes for DOP, reference ASME AG-1, Article TA-2000.

challenge gas: a gas of known characteristics used for in-place testing of adsorbers.

HEPA filter (high-efficiency particulate air filter): a disposable, extended media, dry type filter enclosed in a rigid casing that exhibits a minimum efficiency of 99.97% when tested with an essentially monodisperse 0.3 μm test aerosol.

in-service test: a test to determine the operational readiness of a system or component.

pressure, maximum operating: the maximum pressure the system components will be subjected to while performing their function, including the allowable pressure during abnormal operating conditions, that will not physically damage the system or component (e.g., sudden closure of dampers or registers).

pressure, operating: the pressure that corresponds to the normal design operating mode of the system. This pressure is less than or equal to the maximum operating pressure.

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pressure, structural capability: the pressure, including transients, that verifies the component or system can be safely operated without permanent distortion.

reference value: one or more test parameters that are measured, observed, or determined when the equipment or system is known to be operating acceptably within its design basis limits.

system: an assembly of components, including associated instruments and controls, required to perform the function of a nuclear air treatment, heating, ventilating, and air-conditioning system.

test boundary: the physical limits of the component, system, or device being subjected to a specified test.

test canister: a specially designed sample holder containing adsorbent for laboratory tests that can be removed from an adsorber bank, without disturbing the remainder of the adsorber, to provide representative samples for laboratory testing.

test program: a documented plan for in-service testing based upon system design specifications and functional requirements, including required tests, test frequency, detailed procedures, and acceptance criteria.

2 REFERENCES

The following references supplement this Standard and are a part of it to the extent indicated in the text. The issue date of the referenced document noted below shall be in effect. If no date is listed, the latest edition and addenda are applicable.

ANS 3.1-1999, Selection, Qualification, and Training of Nuclear Power Plant Personnel

Publisher: American Nuclear Society (ANS), 555 North Kensington Avenue, LaGrange Park, IL 60526

ASME AG-1, Code on Nuclear Air and Gas Treatment

Publisher: The American Society of Mechanical Engineers (ASME), Three Park Avenue, New York, NY 10016-5990; Order Department: 22 Law Drive, P.O. Box 2300, Fairfield, NJ 07007-2300

ASTM D 3803-89, Standard Test Method for Nuclear Grade Activated Carbon

Publisher: ASTM International (ASTM), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

HVAC Systems Testing, Adjusting, and Balancing, 1983

Publisher: Sheet Metal and Air Conditioning Contractors' National Association (SMACNA), 4201 Lafayette Center Drive, Chantilly, VA 20151-1209

Industrial Ventilation: A Manual of Recommended Practice, 24th Edition

Publisher: American Conference of Government Industrial Hygienists (ACGIH), 1330 Kemper Meadow Drive, Cincinnati, OH 45240

National Standard of Total System Balance, 1989

Publisher: Associated Air Balance Council (AABC), 1518 K Street, NW, Washington, DC 20005

Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems, 1998

Publisher: National Environmental Balancing Bureau (NEBB), 8575 Grovemont Circle, Gaithersburg, MD 20877

3 GENERAL INSPECTION AND TEST REQUIREMENTS

All inspections and tests shall be conducted in accordance with the requirements within this Standard and the specific requirements of sections 6 and 8. Activities discussed in this Standard may involve the use of hazardous materials, operations, and equipment. This Standard does not purport to address all of the safety requirements associated with their use. The owner's test program shall establish appropriate safety and health practices and determine the applicability of regulatory requirements.

3.1 Test Instruments

A calibration program shall be established in accordance with ASME NQA-1 requirements. All permanent and temporary test instruments used in the conduct of tests required by this Standard shall be in calibration. Instrument accuracy shall meet or exceed the requirements of Table 1.

3.1.1 Range Requirements. The full-scale range of instruments shall be limited as necessary to ensure that the readings are within the accuracy requirements of Table 1.

3.1.2 Instrument Fluctuation. Symmetrical damping devices or averaging techniques may be used to reduce random signal fluctuations. Hydraulic instruments may be damped by using gage snubbers or throttling valves in instrument lines.

3.1.3 Evaluation Following Test Instrument Loss, Damage, or Calibration Failure. When a test instrument is lost, damaged, or otherwise fails to meet the requirements of Table 1 during calibration, all test results obtained using the instrument shall be evaluated, dating back to the time of the previous calibration. If the evaluation does not confirm that the instrument met the acceptance criteria for the test(s) in question, the test(s) shall be repeated with calibrated instruments.

pressure, structural capability: the pressure, including transients, that verifies the component or system can be safely operated without permanent distortion.

reference value: one or more test parameters that are measured, observed, or determined when the equipment or system is known to be operating acceptably within its design basis limits.

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Table 1 Instrument Accuracy Requirements

Measurement	Range	Accuracy [Note (1)]
Pressure	> 1 psig [> 7 kPa (gage)]	±2%
Pressure	From 1 in. wg to 1 psig [0.25 kPa to 7 kPa (gage)]	±0.1 in. wg (± 0.025 kPa)
Pressure	From 0.1 in. wg to 1 in. wg [25 Pa to 250 Pa (gage)]	±0.01 in. wg (± 2.5 Pa)
Temperature	Variable	±2°F (± 1°C)
Temperature [Note (2)]	Variable	±0.5°F (± 0.25°C)
Vibration	Variable	(Per para. 3.1.6.1)
Flow	Variable	±5%
Velocity (airflow)	Variable	±3%
Speed	Variable	±2%
Time	Variable	±1 sec
Electrical voltage	Variable	±1%
Electrical resistance	Variable	±1%
Challenge aerosol	1 to 10 ⁵	±2%
Challenge gas	1 to 10 ⁵	±2%

NOTES:

- (1) References as percent of full scale unless otherwise noted.
 (2) Required for pressure testing in Mandatory Appendix II and hydronic heating and cooling performance testing.

3.1.4 Specific Instrument Accuracy Requirements

3.1.4.1 Vibration Instrument. Vibration instrument accuracy shall be at least ±10%. The minimum frequency response range of the vibration-measuring instrument shall be approximately one-third of the minimum shaft speed. For rotating components, the maximum frequency response range shall be at least two times the rotational shaft speed of the component being measured. For reciprocating components, the maximum frequency response range shall be at least two times the speed of the rotating element, times the number of unique planes occupied by a piston throw.

3.1.4.2 Challenge Aerosol-Measuring Instrument.

The challenge aerosol-measuring instrument shall be verified to have a linear range of at least 10⁵ times the minimum detectable quantity of the instrument.

3.1.4.3 Challenge Gas-Measuring Instrument.

The challenge gas-measuring instrument shall be verified to be capable of distinguishing challenge gas from background and measuring challenge gas over a linear range of at least 10⁵ times the minimum detectable quantity of the instrument.

3.2 Reference Values

3.2.1 Establishment of Reference Values. Reference values are determined during acceptance testing (ASME AG-1, Article TA-4000), when the equipment or system

is proven to be operating within the acceptable limits of the design specification. Operating tests and inspections specified in ASME AG-1, Article TA-4000 are performed under conditions readily reproducible during subsequent in-service tests to allow for direct comparison of test results. All test results and associated analyses are included in the test procedure documentation.

3.2.2 Reestablishment of Reference Values Following Component Replacement, Repair, or Modification. Following component replacement, repair, or modification requiring disassembly, an evaluation shall be conducted to determine the effect on current reference values. Whenever the evaluation indicates any of the reference values have been affected, new reference values shall be established in accordance with para. 3.2.1 or the previous reference values reverified. Evaluation of the new reference values shall verify that the component conforms to the acceptance criteria prior to accepting it as fully operational. The evaluation to determine the effect on reference values shall be documented.

3.3 Inspection and Test Requirements

The owner's test program shall define system test boundaries and evaluate system performance with respect to system functional requirements. The following categories of tests shall be implemented as applicable and in accordance with this section:

Table 2 In-Service Test Intervals

Interval	Test Frequency	Symbol
Monthly	Once per 31 days	M
Quarterly	Once per 92 days	Q
Yearly	Once per 366 days	Y
Biennial	Once per 2-year period	2Y
10 years	Once per 10-year period	10Y

- (a) periodic in-service tests (section 5)
- (b) tests following an abnormal incident (section 7)
- (c) tests following component replacement, repair, or modification (para. 3.2.2)

3.3.1 Inspection and Test Parameters. Parameters that need to be observed, calculated, and recorded in order to meet the requirements of this Standard shall be identified for each system.

3.3.2 System Operating Conditions. Operating conditions required for in-service testing shall be determined for each system.

3.3.3 Procedure Requirements. The owner shall be responsible for the development and implementation of written test procedures that meet the requirements of this Standard. Each equipment test section consists of common (section 4) and in-service (section 5) test requirements and acceptance criteria that apply to each of the systems. The owner shall document which requirements are applicable (see Mandatory Appendices I through IV for development guidance).

3.3.4 In-Service Tests. In-service tests shall be conducted at intervals not to exceed those specified in section 5 or the owner's test program, whichever is most limiting. In-service test intervals are maximum intervals allowed by this Standard and should not be used as default intervals in the absence of system-specific evaluations. Specific system test intervals should be determined on the basis of system design use. In-service test intervals are defined in Table 2.

4 COMMON TESTS

Tests as specified in paras. 4.1 through 4.3 shall also be used in section 5 where applicable.

4.1 Visual Inspection

Visual inspections shall be conducted in accordance with ASME AG-1, Article AA-5000 and the applicable portions of Mandatory Appendix I. The in-service visual inspections listed in section 5 shall verify that no unacceptable damage or degradation, which could impair function, has occurred to the equipment or system.

4.2 Pressure Boundary Tests

Pressure boundary tests consist of leak tests for ducts and housings, including fan and damper housings.

Table 3 Fan In-Service Tests

Test	Measure	Observe	Interval
Visual inspection	...	X	Q
Leak test	X	...	10Y
Mechanical run test	X	...	Q
Flow rate test	X	...	2Y
Static pressure test	X	...	2Y
Rotational speed test	X	...	2Y
Vibration test	X	...	Q

These leak tests shall be conducted using either the pressure decay or constant pressure method to verify that the leak rate for the duct or housing does not exceed the allowable limits established for the system. Testing shall be conducted in accordance with Mandatory Appendix II. Leak testing performed to satisfy ASME AG-1, Sections SA (ducts) and HA (housings) may be used to meet these test requirements when the test method is compatible with Mandatory Appendix II.

4.3 Vibration Test

Vibration measurements shall be taken on the accessible motor, fan, compressor, and pump bearing housings in at least two different orthogonal planes approximately perpendicular to the line of the rotating shaft. When the bearing housing is not accessible, the frame of the component may be used if it will be representative of bearing housing vibration. When portable vibration instruments are used, reference points shall be clearly identified on the component being measured to permit duplication in both location and plane.

5 IN-SERVICE TEST REQUIREMENTS

5.1 General

In-service tests shall be conducted at the required time intervals after the completion of the field acceptance tests outlined in ASME AG-1, Article TA-4000.

5.2 Fan Tests

This section provides the in-service test requirements for fans and related accessories. Integrated system testing shall be conducted in accordance with para. 5.10.

5.2.1 Test Requirements. In-service tests listed in Table 3 shall be conducted at the specified interval and test results verified to be within the acceptance limits of the owner's test program and section 6 and compared with the reference values obtained in acceptance tests in ASME AG-1, section TA-4100.

5.2.2 Visual Inspection. A visual inspection of the fan and associated components shall be conducted in accordance with para. 4.1 and Mandatory Appendix I (section I-2).

Table 2 In-Service Test Intervals

Interval	Test Frequency	Symbol
Monthly	Once per 31 days	M
Quarterly	Once per 92 days	Q
Yearly	Once per 366 days	Y
Biennial	Once per 2-year period	2Y
10 years	Once per 10-year period	10Y

- (a) periodic in-service tests (section 5)
- (b) tests following an abnormal incident (section 7)
- (c) tests following component replacement, repair, or modification (para. 3.2.2)

3.3.1 Inspection and Test Parameters. Parameters that need to be observed, calculated, and recorded in order to meet the requirements of this Standard shall be identified for each system.

3.3.2 System Operating Conditions. Operating conditions required for in-service testing shall be determined for each system.

3.3.3 Procedure Requirements. The owner shall be responsible for the development and implementation of written test procedures that meet the requirements of this Standard. Each equipment test section consists of common (section 4) and in-service (section 5) test requirements and acceptance criteria that apply to each of the systems. The owner shall document which requirements are applicable (see Mandatory Appendices I through IV for development guidance).

3.3.4 In-Service Tests. In-service tests shall be conducted at intervals not to exceed those specified in section 5 or the owner's test program, whichever is most limiting. In-service test intervals are maximum intervals allowed by this Standard and should not be used as default intervals in the absence of system-specific evaluations. Specific system test intervals should be determined on the basis of system design use. In-service test intervals are defined in Table 2.

4 COMMON TESTS

Tests as specified in paras. 4.1 through 4.3 shall also be used in section 5 where applicable.

4.1 Visual Inspection

Visual inspections shall be conducted in accordance with ASME AG-1, Article AA-5000 and the applicable portions of Mandatory Appendix I. The in-service visual inspections listed in section 5 shall verify that no unacceptable damage or degradation, which could impair function, has occurred to the equipment or system.

4.2 Pressure Boundary Tests

Pressure boundary tests consist of leak tests for ducts and housings, including fan and damper housings.

Table 3 Fan In-Service Tests

Test	Measure	Observe	Interval
Visual inspection	...	X	Q
Leak test	X	...	10Y
Mechanical run test	X	...	Q
Flow rate test	X	...	2Y
Static pressure test	X	...	2Y
Rotational speed test	X	...	2Y
Vibration test	X	...	Q

These leak tests shall be conducted using either the pressure decay or constant pressure method to verify that the leak rate for the duct or housing does not exceed the allowable limits established for the system. Testing shall be conducted in accordance with Mandatory Appendix II. Leak testing performed to satisfy ASME AG-1, Sections SA (ducts) and HA (housings) may be used to meet these test requirements when the test method is compatible with Mandatory Appendix II.

4.3 Vibration Test

Vibration measurements shall be taken on the accessible motor, fan, compressor, and pump bearing housings in at least two different orthogonal planes approximately perpendicular to the line of the rotating shaft. When the bearing housing is not accessible, the frame of the component may be used if it will be representative of bearing housing vibration. When portable vibration instruments are used, reference points shall be clearly identified on the component being measured to permit duplication in both location and plane.

5 IN-SERVICE TEST REQUIREMENTS

5.1 General

In-service tests shall be conducted at the required time intervals after the completion of the field acceptance tests outlined in ASME AG-1, Article TA-4000.

5.2 Fan Tests

This section provides the in-service test requirements for fans and related accessories. Integrated system testing shall be conducted in accordance with para. 5.10.

5.2.1 Test Requirements. In-service tests listed in Table 3 shall be conducted at the specified interval and test results verified to be within the acceptance limits of the owner's test program and section 6 and compared with the reference values obtained in acceptance tests in ASME AG-1, section TA-4100.

5.2.2 Visual Inspection. A visual inspection of the fan and associated components shall be conducted in accordance with para. 4.1 and Mandatory Appendix I (section I-2).



Insert 1 – Paragraph 1.5 Definitions

acceptable preconditioning: the alteration, variation, manipulation or adjustment of the physical condition of a component before in-service testing for the purpose of protecting personnel or equipment or to meet the manufacturer's recommendations. This may include routine and scheduled maintenance for maintaining optimum equipment and system performance. Preconditioning for purposes of personnel protection or equipment preservation should outweigh the benefits gained by testing only in the as-found condition. This preconditioning may be based on the equipment manufacturer's recommendations or an industry-wide operating experience to enhance equipment and personnel safety. This preconditioning should have been evaluated and documented in advance of the in-service test.

Insert 2 – Paragraph 1.5 Definitions

as-found condition: the condition of a component between in-service tests without preconditioning.

Insert 3 – Paragraph 1.5 definitions

Ppreconditioning: the modification, manipulation or adjustment of a component performed just prior to in-service tests that would affect the results of the in-service test. This may include activities such as cycling, cleaning, lubricating, agitating or other specific maintenance or operational activities that may be performed prior to or during in-service testing that could affect the ability to determine component degradation. This excludes normal scheduled routine maintenance to keep optimum component performance.

Insert 4 – Paragraph 3.3 Inspection and Test Requirements**As-Found Conditions and Ppreconditioning**

Components shall be tested in the as-found condition whenever possible. Preconditioning shall not be performed unless an evaluation is made prior to in-service testing. See the definitions for preconditioning and acceptable preconditioning.

Insert 5 – Paragraph 1.5 Definitions

unacceptable preconditioning - Any activity performed prior to or during an in-service test which alters one or more measured parameter, such that it results in acceptable test results. This could include activities such as cycling, cleaning, lubricating, agitating, or other specific activities performed prior to or during an in-service test that could mask degradation. The impact may depend on the design of the component. For example, stem lubrication has essentially no impact on a motor operated damper; however it may influence the test result of an air operated damper.

Table 4 Damper In-Service Tests

Test	Measure	Observe	Interval
Visual inspection	...	X	2Y
Leak test	X	...	2Y
Position indication test	...	X	2Y
Exercise test	...	X	2Y
Flow control test	...	X	2Y
Static timing test	X	...	2Y
Fire damper test	...	X	2Y
Dynamic time test	X	...	2Y
Interlock test	...	X	2Y

5.2.3 Pressure Boundary Leak Test. When a fan housing is part of the system pressure boundary, a pressure boundary leak test shall be conducted to verify the leak tightness of the fan housing, shaft seal, and attached interfaces in accordance with para. 4.2 and Mandatory Appendix II. The fan housing, shaft seal, and attached interfaces may be tested concurrent with the duct and housing leak test specified in para. 5.4.3.1.

5.2.4 System Functional Tests. Paragraphs 5.2.4.1 through 5.2.4.5 shall be conducted in the same time frame.

5.2.4.1 Mechanical Run Test. The fan shall be operated at the design flow rate for at least 15 min and stable system operation (no surging) verified.

5.2.4.2 Flow Rate Test. The fan flow rate shall be measured. Recommended procedures are contained in Industrial Ventilation (ACGIH) or equivalent.

5.2.4.3 Static Pressure Test. The fan inlet and outlet static pressure and velocity pressure shall be measured and the overall fan static pressure determined.

5.2.4.4 Rotational Speed Test. Direct drive configurations may be tested at the fan or motor. When a fan does not have a direct drive coupling to the motor, the rotational speed of the fan shaft shall be measured.

5.2.4.5 Vibration Test. The vibration of each fan and motor bearing shall be measured in accordance with para. 4.3.

5.3 Damper In-Service Tests

This section provides the in-service test requirements for dampers and related accessories. Integrated system testing shall be conducted in accordance with para. 5.10.

5.3.1 In-Service Test Requirements. In-service tests listed in Table 4 shall be conducted at the specified interval and test results verified to be within the acceptance limits of the owner's test program and section 6 and be compared with the reference values obtained in the acceptance tests in ASME AG-1, section TA-4200.

5.3.2 Visual Inspection. A visual inspection of the dampers and associated components shall be conducted in accordance with para. 4.1 and Mandatory Appendix I (section I-3).

5.3.3 Pressure Boundary Leak Test, Damper Seat.

When dampers have seat leak rate limits, a dynamic pressure boundary leak test shall be conducted in the direction the damper is expected to function, in accordance with para. 4.2 and Mandatory Appendix II. Seat leakage shall be tested by blanking off or otherwise isolating a duct section upstream of the damper. The leak test shall be performed with the damper cycled closed using its normal closing mechanism (exclusive of any additional assistance).

5.3.4 Component Functional Tests. Component functional tests shall verify that the damper is operational prior to conducting the system functional tests specified in para. 5.3.5.

5.3.4.1 Position Indication Test. Dampers having remote position indicators shall be observed during operation to verify that the damper position corresponds to the remote indicator.

5.3.4.2 Exercise Test. Power-operated dampers shall be fully cycled using a control switch or other actuating device to verify operation. Manual dampers, which have a shut off function, shall be fully cycled to verify operation. Fire dampers shall be tested in accordance with para. 5.3.5.2.

5.3.4.3 Static Timing Test. Power-operated dampers that are required to operate within a specified time limit shall be tested by measuring the time to fully open or close (as required by the owner's test program).

5.3.5 System Functional Tests

5.3.5.1 Flow Control Test. Power-operated dampers that control airflow shall be observed under throttled flow conditions to verify freedom of movement and stable operation.

5.3.5.2 Fire Damper Test. Fire dampers shall be tested, using a normal or simulated actuation signal, to verify activation under design flow.

5.3.5.3 Dynamic Timing Test. Isolation dampers having a required actuation response time shall be tested to the fully open or closed position (as required by the owner's test program) under design flow rate conditions.

5.3.5.4 Interlock Test. Dampers that have an opening or closing function interlocked with other components (e.g., fan, other dampers, etc.) shall be tested to verify interlock action.

5.4 Duct and Housing In-Service Tests

This section provides the in-service test requirements for ducts and housings.

Table 5 Duct and Housing In-Service Tests

Test	Measure	Observe	Interval
Visual inspection	...	X	2Y [Note (1)]
Leak test	X	...	10Y

NOTE:

- (1) Loop seal water level in duct or housing drain lines shall be maintained to ensure the integrity of the system pressure boundary at all times. Monthly or more frequent inspection of the water level in the loop seal may be required, depending on the system design.

5.4.1 In-Service Test Requirements. In-service tests listed in Table 5 shall be conducted at the specified interval and test results verified to be within the acceptance limits of the owner's test program and section 6. Test results shall be compared with the reference values obtained in the acceptance tests in ASME AG-1, section TA-4300.

5.4.2 Visual Inspection. A visual inspection of the ducts, housings, and associated attachments shall be conducted in accordance with para. 4.1 and Mandatory Appendix I (section I-4).

5.4.3 Pressure Boundary Leak Test. A pressure boundary leak test shall be conducted on filter housings and applicable ductwork in accordance with para. 4.2 and Mandatory Appendix II.

5.5 Refrigeration Equipment In-Service Tests

This section provides the in-service test requirements for refrigeration equipment. Integrated system testing shall be conducted in accordance with para. 5.10.

5.5.1 In-Service Test Requirements. In-service tests listed in Table 6 shall be conducted at the specified interval and test results verified to be within the acceptance limits of the owner's test program and section 6. Test results shall be compared with the reference values obtained in the acceptance tests in ASME AG-1, section TA-4400.

5.5.2 Visual Inspection. A visual inspection of the refrigeration equipment components shall be conducted in accordance with para. 4.1 and Mandatory Appendix I (section I-5).

5.5.3 Pressure Boundary Tests

5.5.3.1 Refrigerant Piping and Coils. The refrigerant system shall be monitored under normal operating conditions to verify no unacceptable refrigerant leaks in excess of the limits specified in the applicable sections of ASME AG-1 and the owner's test program.

5.5.3.2 Hydronic Piping and Coils. Hydronic piping and coils shall be observed to verify no unacceptable fluid leaks. Testing shall be conducted by inspecting

Table 6 Refrigeration Equipment In-Service Tests

Test	Measure	Observe	Interval
Visual inspection	...	X	Q
Leak tests	...	X	Q
Valve position indication test	...	X	2Y
Valve exercise test	...	X	2Y
Valve timing test	X	...	Q
Flow control valve test	...	X	Q
Mechanical run test	...	X	Q
Performance test	X	...	Q
Vibration test	X	...	Q
Rotational speed test	X	...	2Y

the fluid system, under normal operating pressure, for evidence of leaks in excess of the limits specified in the applicable sections of ASME AG-1 and the owner's test program.

5.5.4 Component Functional Tests

5.5.4.1 Fans. Fans shall be tested in accordance with para. 5.2.

5.5.4.2 Valve Position Indication Test. Valves with position indicators shall be observed during valve full-stroke operation to verify that the valve position corresponds to the remote indication.

5.5.4.3 Valve Exercise Test. Power-operated valves shall be fully stroked using their remote control switch or other actuation device to verify operation. Manual valves shall be fully stroked to verify freedom of movement.

5.5.4.4 Valve Timing Test. Power-operated valves that are required to operate within a specified time limit shall be tested by measuring the stroke time.

5.5.5 System Functional Tests

5.5.5.1 Flow Control Valve Test. Power-operated valves, controlled by flow instrumentation, shall be observed under throttled flow conditions to verify freedom of movement and stable operation.

5.5.5.2 Mechanical Run Test. The refrigeration compressor shall be operated with the system operating in the normal heat load range for at least 15 min and stable system operation verified.

5.5.5.3 Performance Test. The refrigeration compressor inlet and outlet pressure and temperature shall be measured with the refrigeration equipment operating within its design load range.

5.5.5.4 Vibration Test. The vibration on accessible motor, fan, compressor, and pump-bearing housings in the refrigeration system shall be measured in accordance with para. 4.3.

Table 7 Conditioning Equipment In-Service Tests

Test	Measure	Observe	Interval
Visual inspection	...	X	Q
Leak test	...	X	Q
Valve performance tests	...	X	2Y
Mechanical run test	...	X	Q
Performance test	X	...	2Y
Rotational speed test	X	...	2Y
Vibration test	X	...	Q
Electric heater performance test	X	...	2Y
Hydronic heating and cooling performance test	X	...	2Y

5.5.5.5 Rotational Speed Test. For refrigerant compressors that have variable speed drives, or that do not otherwise have direct drive operations, the rotational speed of the compressor shaft shall be measured (not required for hermetically sealed compressors).

5.6 Conditioning Equipment In-Service Tests

This section provides the in-service test requirements for conditioning equipment. Integrated system testing shall be conducted in accordance with para. 5.10.

5.6.1 In-Service Test Requirements. In-service tests listed in Table 7 shall be conducted at the specified interval and test results verified to be within the acceptance limits of the owner's test program, section 6, and compared with the reference values obtained in the acceptance tests in ASME AG-1, section TA-4500.

5.6.2 Visual Inspection. A visual inspection of the conditioning equipment components shall be conducted in accordance with para. 4.1 and Mandatory Appendix I (section I-6).

5.6.3 Pressure Boundary Leak Test, Hydronic Piping and Coils. With the conditioning system at normal operating pressure, hydronic piping, coils, and pressure vessels shall be observed to verify no unacceptable fluid leaks in excess of the limits specified in the applicable sections of ASME AG-1 and the owner's test program.

5.6.4 Component Functional Tests

5.6.4.1 Fans. Fans shall be tested in accordance with para. 5.2.

5.6.4.2 Refrigeration. Refrigeration components shall be tested in accordance with para. 5.5.

5.6.4.3 Valve Performance. Conditioning system valves shall be tested in accordance with paras. 5.5.4.1 through 5.5.4.3.

5.6.5 System Functional Tests

5.6.5.1 Hydronic System Flow Balance Verification Test. A verification of the hydronic system flow balance

shall be conducted (refer to Nonmandatory Appendix C for guidance on scope and verification methods).

5.6.5.2 Flow Control Valve Test. Power-operated valves, controlled by flow instrumentation, shall be observed under throttled flow conditions to verify freedom of movement, stable operation, and ability to maintain the required flow rate.

5.6.5.3 Mechanical Run Test. The conditioning system pumps shall be operated, at the reference flow rate, for at least 15 min and stable system operation verified.

5.6.5.4 Performance Test. With the conditioning system pump operating at the reference flow rate, pump differential pressure and flow rate shall be measured.

5.6.5.5 Rotational Speed Test. Direct drive configurations may be tested at the motor or shaft. For conditioning system pumps that have variable speed drives, or that do not otherwise have direct drive operations, the rotational speed of the pump shaft shall be measured.

5.6.5.6 Vibration Test. The vibration of each bearing on the pump and associated motor in the conditioning system shall be measured in accordance with para. 4.3.

5.6.5.7 Electric Heater Performance Test. With design flow rate through the heater bank, the electrical supply voltage, amperage, phase balance, and differential temperature shall be measured.

5.6.5.8 Hydronic Heating and Cooling Performance Test. With the conditioning system operating at design air and hydronic flow rate, at the available heat load conditions, the air side flow, differential pressure and temperature, and the hydronic side flow, differential temperature and pressure, shall be measured.

5.7 Moisture Separator, Prefilter, HEPA Filter Bank In-Service Tests

This section provides the in-service test requirements for installed moisture separator, prefilter, and HEPA filter banks.

Table 8 Moisture Separator, Prefilter, HEPA Filter Bank In-Service Tests

Test	Measure	Observe	Interval
Visual inspection	...	X	2Y
Differential pressure test	X	...	M
In-place leak test [Note (1)]	X	...	2Y [Note (2)]

NOTES:

- (1) In-place leak tests are not required on systems used for 100% recirculation (e.g., reactor containment cleanup units), unless the atmospheric cleanup rate is time dependent.
- (2) Or after complete or partial filter bank replacement.

5.7.1 In-Service Test Requirements. In-service tests listed in Table 8 shall be conducted at the specified interval or after complete or partial bank replacement. Test results are to be verified to be within the acceptance limits of the owner's test program and section 6 and compared with the reference values obtained in the acceptance tests in ASME AG-1, section TA-4600.

5.7.2 Visual Inspection. A visual inspection of the installed moisture separator, prefilter, and HEPA filter banks shall be conducted in accordance with para. 4.1 and Mandatory Appendix I (section I-7).

5.7.3 System Functional Tests

5.7.3.1 Differential Pressure Test. With the system operating at design flow rate ($\pm 10\%$), the differential pressure across each moisture separator, prefilter, and HEPA filter bank shall be measured.

5.7.3.2 In-Place Leak Test. With the system operating at design flow rate ($\pm 10\%$), the challenge aerosol leak rate of each HEPA filter bank shall be measured in accordance with Mandatory Appendix III.

5.8 Type II and Type III Adsorber Bank In-Service Tests

This section provides the in-service test requirements for installed Type II and Type III adsorber banks.

5.8.1 In-Service Test Requirements. In-service tests listed in Table 9 shall be conducted at the specified interval and verified to be within the acceptance limits of the owner's test program, section 6, and compared with the reference values obtained in the acceptance tests in ASME AG-1, section TA-4700.

5.8.2 Visual Inspection. A visual inspection of the Type II and Type III adsorber banks shall be conducted in accordance with para. 4.1 and Mandatory Appendix I (section I-8).

5.8.3 System Functional Tests

5.8.3.1 Differential Pressure Test. With the system operating at design flow rate ($\pm 10\%$), the differential pressure across each adsorber bank shall be measured.

Table 9 Type II and Type III Adsorber Bank In-Service Tests

Test	Measure	Observe	Interval
Visual inspection	...	X	2Y
Differential pressure test	X	...	M
In-place leak test [Note (1)]	X	...	2Y [Note (2)]
Electric heater performance test	X	...	2Y
Laboratory test of adsorbent media	X	...	2Y

NOTES:

- (1) In-place leak tests are not required on systems used for 100% recirculation (e.g., reactor containment cleanup units), unless the atmospheric cleanup rate is time dependent.
- (2) Or after complete or partial adsorber bank replacement.

5.8.3.2 In-Place Leak Test. With the system operating at design flow rate ($\pm 10\%$), the challenge gas leak rate of each adsorber bank shall be measured in accordance with Mandatory Appendix IV.

5.8.3.3 Electric Heater Performance Test. With design air flow ($\pm 10\%$) through each heater bank, the electrical supply voltage, amperage, phase balance of each heater circuit, and differential temperature and air flow across the heater coil shall be measured.

5.9 Adsorbent In-Service Tests

This section provides the in-service laboratory test requirements for radioactive iodine penetration of the adsorbent bed.

5.9.1 In-Service Test Requirements. In-service laboratory tests shall be conducted, using representative samples of adsorbent, at least every 2 years or 720 hr¹ of accumulated service time, whichever is sooner. This test measures the penetration of radioiodine through adsorbent. Laboratory test results shall be verified to be within the acceptance limits of the owner's test program. Sample locations shall be selected to ensure samples are representative of the overall condition of the adsorbent in the adsorber bank. If the entire bank of adsorbent is being replaced, an in-service laboratory test is not required.

5.9.2 Laboratory Analysis. A laboratory analysis of the adsorbent shall be conducted in accordance with ASTM D 3803-89 to measure the ability of the adsorbent to remove radioiodine. Test bed depth used in the laboratory test shall be the same as the nominal adsorber depth in the adsorber bank being tested. The laboratory test should be performed at a face velocity of 40 ft/min, unless the actual system face velocity is greater than 44 ft/min. Otherwise, the test shall be conducted at the actual face velocity.

¹ A documented history of adsorbent degradation may be used in the evaluation of the design specification or technical specification to establish a longer adsorbent sample interval.

Samples shall be representative of the adsorbent in the bank and drawn from the bank test canisters or from the bank itself.

An in-place leak test of the bank shall be conducted following sample removal in accordance with para. 5.8, unless it can be demonstrated that the removal of the sample does not create a potential leak path around or through the adsorber bank.

5.10 Integrated System Tests

5.10.1 In-Service Test Requirements. Each system shall be tested to verify that the functional performance within the range of design operating conditions is achieved. Integrated system tests shall be conducted to challenge all integrated control functions, including interlocks, computer logic, and manual or automatic actuation circuits (damper position changes, fan starts and stops, compressor and pump starts or stops, valve position changes, heater energization or de-energization). These actuations can be from a number of different sources, including radiation, temperature, chlorine, and pressure sensors; manual controls; and emergency safeguard signals. Sensor operation shall be verified in addition to control circuitry. Integrated system testing shall verify that the intended design function of the system is achieved in accordance with the owner's test program. The maximum test interval for integrated system tests shall be 10 years. However, the frequency may need to be shorter based upon evaluations of the system's function.

5.10.2 HEPA Filter Bank and Adsorber Bank Integrated System Test Requirements. All potential HEPA filter bank and adsorber bank bypass flow paths, including housing bypass ducts and associated dampers, shall be challenged to verify that leak rates are within the owner's test program. Bypass flow paths may be challenged during the in-place leak testing, specified in paras. 5.7.3.2 and 5.8.3.2, by ensuring that the challenge aerosol or gas injection and sample ports encompass all potential bypass leak paths. If a potential bypass flow path is not challenged during these in place tests, a separate test shall be performed, using the methods outlined in Mandatory Appendix III or IV, to verify that the HEPA filter banks or adsorber banks are not being bypassed in excess of the limits specified in the owner's test program.

NOTE: Some bypass leak paths may not be measurable using Mandatory Appendix III or IV. Use of other innovative testing methods may be required.

5.11 Air System Flow Balance Verification Test

A verification of the system airflow balance shall be conducted. Recommended procedures include SMACNA, NEBB, ACGIH, AABC, or equivalent (see Nonmandatory Appendix C for guidance on scope and

verification methods). The maximum interval for air system flow verification testing shall be 10 years.

6 ACCEPTANCE CRITERIA

Results of tests described in section 5 shall be subject to the acceptance criteria in section 6 and the owner's test program. Acceptance criteria are specified in section 5 only when they affect the quality of other tests. When test results do not meet the applicable acceptance criteria, the corrective actions required by section 8 shall be initiated. In-service test results shall be compared with the acceptance test reference values. Comparison should include a trend analysis designed to predict degradation rates of the components under test. Projected degradation rates that indicate probable loss of intended design function prior to the next scheduled in-service test should require corrective action prior to the predicted loss of intended design function in accordance with section 8.

6.1 Visual Inspection

Inspection results are acceptable when there are no indications of improper installation, physical damage, structural distress, or degradation that would impair the ability of the equipment or system to perform its intended function.

6.2 Pressure Boundary Tests

Pressure boundary test results are acceptable when there are no leaks in excess of the limits specified in the applicable sections of ASME AG-1 and the owner's test program.

6.3 Functional Tests

Functional test results are acceptable when they meet the requirements of the applicable sections of ASME AG-1 and the owner's test program.

7 TESTING FOLLOWING AN ABNORMAL INCIDENT

Following an abnormal incident in which the system has been challenged, the applicable acceptance tests in ASME AG-1, Article TA-4000 shall be conducted to verify that the system is fully operational. This requirement shall apply only to those components that may have been affected by the incident. An evaluation shall be conducted and documented to determine the extent of the required actions to be initiated.

8 CORRECTIVE ACTION REQUIREMENTS

Corrective action is required when test results do not meet the acceptance criteria specified. For equipment that is replaced, modified, or repaired, such that the reference values change, a new set of reference values shall be obtained in accordance with the requirements of

para. 3.2.2 and ASME AG-1, Article TA-4000. Additional guidance for corrective actions is included in Nonmandatory Appendix A.

9 QUALITY ASSURANCE

9.1 General

In-service testing of nuclear air treatment, heating, ventilating, and air-conditioning systems shall be conducted in accordance with a documented quality assurance program meeting the requirements of ASME NQA-1.

9.2 Personnel

Tests shall be conducted by personnel who have demonstrated competence as evidenced by documented experience and training. Personnel shall be qualified in accordance with ASME NQA-1 or ANS 3.1.

9.3 Documentation

In-service test procedures shall document the test results specified in section 5 of this Standard and include a record of test failures with subsequent corrective actions and analysis of test data trends. These records shall be maintained for the life of the facility.

9.3.1 Procedures. Written test procedures shall be used to document the in-service testing performed and the test results obtained in accordance with section 5 of this Standard.

9.3.2 Reports. A written report shall be provided to document the in-service testing performed in accordance with section 5 of this Standard. The report shall contain, as a minimum, the following:

(a) the system name, test/inspection procedure(s) used, date of test results, and the test performer's printed name and signature

(b) identification of instruments, equipment, tools, and documents to the extent that they, or their equivalent, can be identified for future examinations

(c) observations and dimensional checks specified by the respective test data and any reports developed during the inspection and testing

(d) conclusions and recommendations by visual examinations and testing personnel

(e) reference to previous reports if this report is for reinspection and testing

(f) test configuration and system operating conditions

(g) test data and results

MANDATORY APPENDIX I

VISUAL INSPECTION CHECKLIST

I-1 GENERAL

A specific inspection checklist for each component in the system shall be included in the in-service test procedures. This Mandatory Appendix lists typical items for each component to be visually inspected in section 5 (in-service tests), if applicable to the installed equipment. The inspection shall be conducted in accordance with para. 4.1.

I-2 FAN INSPECTION CHECKLIST

- (a) housing and duct interface
- (b) fan impellers
- (c) fan drives and guards/covers
- (d) fan inlet and outlet connections
- (e) interference with moving parts
- (f) fan shaft seal
- (g) drive adjustment and condition
- (h) lubricant levels
- (i) supports and attachments
- (j) bolting and fasteners
- (k) instrumentation
- (l) electrical connections
- (m) control system components
- (n) pneumatic connections
- (o) provisions to access for testing and maintenance

I-3 DAMPER INSPECTION CHECKLIST

- (a) housing and duct interface
- (b) actuator linkage, motor, and controller
- (c) interference with moving parts
- (d) damper shaft seal
- (e) blade edge seals and damper seat
- (f) limit switches
- (g) supports and attachments
- (h) bolting and fasteners
- (i) instrumentation
- (j) electrical connections
- (k) pneumatic connections
- (l) provisions to access for testing and maintenance

I-4 DUCT, HOUSING, AND MOUNTING FRAME INSPECTION CHECKLIST

- (a) housing and duct connections (no caulking on ducts, housings, and mounting frames associated with nuclear air treatment systems)

- (b) access door seals and gaskets
- (c) access door latches
- (d) housing internal access ladders and platforms
- (e) sample and injection ports, location, and caps
- (f) supports and attachments
- (g) bolting and fasteners
- (h) instrumentation and connections
- (i) electrical connections
- (j) housing/duct penetration seals
- (k) loop seals (water level) and drain connections
- (l) lighting conduits and socket housing seals (flush mounted)
- (m) HEPA filter/adsorber mounting frame continuous seal welds
- (n) mounting frame penetrations seal welded
- (o) mounting frame seating surface (weld spatter, flatness, scratches)
- (p) sample canister installation
- (q) mounting frame clamping devices
- (r) provisions to access for testing and maintenance
- (s) lighting for test and maintenance available

I-5 REFRIGERATION EQUIPMENT INSPECTION CHECKLIST

- (a) housing or duct interface with refrigeration equipment
- (b) fan, pump, compressor belt, and coupling guards
- (c) interferences with moving parts
- (d) drive adjustment and conditions
- (e) fluid leaks
- (f) lubricant levels
- (g) supports and attachments
- (h) bolting and fasteners
- (i) instrumentation
- (j) electrical connections
- (k) control system components
- (l) pneumatic connections and tubing (no crimping)
- (m) provisions to access for testing and maintenance

I-6 CONDITIONING EQUIPMENT INSPECTION CHECKLIST

- (a) housing or duct interface with conditioning equipment
- (b) drive and coupling guards
- (c) interferences with moving parts

- (d) drive adjustment and condition
- (e) fluid leaks
- (f) lubricant levels
- (g) supports and attachments
- (h) bolting and fasteners
- (i) instrumentation
- (j) electrical connections
- (k) control system components
- (l) pneumatic connections and tubing (no crimping)
- (m) drains and spray nozzles not plugged
- (n) provisions to access for testing and maintenance

I-7 MOISTURE SEPARATOR BANK, PREFILTER BANK, AND HEPA FILTER BANK INSPECTION CHECKLIST

- (a) moisture separator media, frame, clamps, and gaskets
- (b) moisture separator water collection system and drains
- (c) prefilter media, frame, clamps, and gaskets/seals
- (d) HEPA filter media, frame, clamps, and gaskets/seals

- (e) sealant or caulking (none allowed)
- (f) moisture separator, prefilter, and HEPA filter orientation (vertical)
- (g) bolting and fasteners
- (h) provisions to access for testing and maintenance

I-8 TYPE II AND TYPE III ADSORBER BANK INSPECTION CHECKLIST

- (a) Type II media, frame, screen, clamps, and gaskets
- (b) sealant or caulking (none allowed)
- (c) Type III media, screens, and frame
- (d) test canisters
- (e) bulk loading equipment
- (f) fire protection system piping, nozzles, and instrumentation
- (g) bolting and fasteners
- (h) provisions to access for testing and maintenance

I-9 ACCEPTANCE CRITERIA

The acceptance criteria for these inspections shall be in accordance with section 6 and the owner's test program.

MANDATORY APPENDIX II

DUCT AND HOUSING LEAK TEST PROCEDURE

II-1 GENERAL

This procedure is used to test the leak tightness of the ducts and housings, including installed fan housings, damper housings, and fan and damper shaft seals.

II-2 SUMMARY OF METHOD

Ducts and housings that form the pressure boundary of the system shall be leak tested with air using one of the methods listed in this procedure. Either method may be used and will produce a similar test result. The constant pressure method is useful for testing small volumes and is conducted at the maximum operating pressure for the system. The pressure decay method is useful in testing large volumes and is conducted by pressurizing to 1.25 times the maximum operating pressure, then allowing the pressure to decay for a fixed period of time or until the pressure decreases to 75% of the maximum operating pressure, whichever occurs first. Fans, dampers, and other components that are part of the pressure boundary shall be installed and tested with the pressure boundary to verify interface connection leak tightness. If the measured leak rate is in excess of the acceptance criteria, the leaks shall be located by one of the methods listed in this procedure. After leaks are repaired, the duct and housing shall be retested to verify leak tightness.

NOTE: This test procedure is written as if the operating pressure were positive, but it would be identical for negative pressure systems with appropriate change in signs used in the data collection and calculations.

II-3 PREREQUISITES

Construction, modifications, and repairs affecting the test boundary shall be complete and the inlet and discharge openings of the duct or housing sealed before the test is started. All electrical, piping, and instrument connections shall be complete, and all permanent seals shall be installed before the test is started. For pressure decay testing, the volume of the pressure test boundary must be determined.

II-4 TEST EQUIPMENT

- (a) pressurization source (pneumatic, test fan with flow control, etc.)
- (b) covers to seal test boundaries
- (c) clock or timer

- (d) pressure-indicating device
- (e) flowmeter or totalizing gas volume meter (constant pressure method)
- (f) temperature-indicating device
- (g) bubble solution for detecting air leaks (bubble method)
- (h) optional portable electronic sound detection equipment (audible leak method)
- (i) barometer

II-5 PROCEDURE

II-6 CONSTANT PRESSURE TEST

- (a) Connect the pressurization source to the duct or housing.
- (b) Connect the flow meter or totalizing gas volume meter between the pressurization source and housing (downstream of the throttling valve, if used).
- (c) Install temperature- and pressure-indicating devices so that they will indicate representative temperature and pressure inside the duct or housing being tested.
- (d) Seal test boundaries and close access doors in the normal manner. Do not use temporary sealant, duct tape, or similar temporary materials except for sealing the temporary blank-off panels.
- (e) Start the pressurization source and operate it until the maximum operating pressure is achieved. Maintain pressure constant with the flow control device until temperature remains constant within $\pm 0.5^\circ\text{F}$ (0.25°C) for a minimum of 10 min. Record the initial stabilized pressure, temperature, and barometric pressure.
- (f) Measure the flow rate of the air being added to or removed from the duct or housing while maintaining the maximum operating pressure within ± 0.1 in. wg [0.025 kPa (gage)]. When using the flow meter, record flow readings once a minute for a 5-min continuous period, and average the readings to calculate the measured leak rate. When using a totalizing gas volume meter, measure the total volume of air for a 10-min continuous period, and divide the measured volume by time (10 min) to calculate the measured leak rate. Record final pressure, temperature, and barometric pressure.
- (g) Convert the final calculated leak rate to standard cubic feet per minute (cubic meters per second) in accordance with the method illustrated in Industrial Ventilation (ACGIH) (see references in section 2).

II-7 PRESSURE DECAY TEST

(a) Connect the pressurization source (with a leak tight shutoff valve) to the duct or housing.

(b) Install the temperature- and pressure-indicating devices where they will indicate the representative temperature and pressure inside the duct or housing being tested.

(c) Seal test boundaries and close access doors in the normal manner. Do not use temporary sealants, duct tape, or similar temporary materials except for sealing the temporary blank-off panels.

(d) Start the pressurization source and operate until the pressure is 1.25 times the maximum operating pressure (but not to exceed the structural capability pressure). Maintain this pressure constant with a flow control device until temperature remains constant within $\pm 0.5^\circ\text{F}$ (0.25°C) for a minimum of 10 min. Close shutoff valve.

NOTE: If the structural capability pressure for the duct or housing is less than 1.25 times the maximum operating pressure, the initial and final test pressure shall be calculated as follows to achieve an average test pressure equal to the maximum operating pressure:

$$P_f = (0.80 \times OP_{\max}) + [(1.25 \times OP_{\max}) - SCP]$$

$$P_i = (OP_{\max} - P_f) + OP_{\max}$$

where

OP_{\max} = maximum operating pressure

P_f = final test pressure

P_i = initial test pressure

SCP = structural capability pressure

(e) Record the initial time, pressure, temperature, and barometric pressure.

(f) Record pressure readings once a minute until pressure decays to 75% of the maximum operating pressure or for a minimum of 15 min [see Note in (d) above].

(g) Record final time, pressure, temperature, and barometric pressure.

(h) Calculate leak rate from the following equation in U.S. customary units:

$$Q_{\text{avg}} = \left(\frac{P_i}{T_i} - \frac{P_f}{T_f} \right) \left(\frac{V}{R \times \Delta t \times 0.075} \right)$$

For SI units, see the following equation:

$$Q_{\text{avg}} = \left(\frac{P_i}{T_i} - \frac{P_f}{T_f} \right) \left(\frac{V}{R \times \Delta t \times 60 \times 1.201} \right)$$

where

P_f = final pressure within test boundary, lb/ft² ABS [Pa (absolute)]

P_i = initial pressure within test boundary, lb/ft² ABS [Pa (absolute)]

Q_{avg} = average leak rate, ft³/min (L/s)
[air density is 0.075 lb/ft³ (1.201 kg/m³)]

R = gas constant for air
= 53.35 ft-lb/lb-°R (0.286 kJ/kg-K)

T_f = absolute temperature at end of test, °R (K)

T_i = absolute temperature at start of test, °R (K)

V = volume within test boundary, ft³ (m³)

Δt = time difference, min
= $t_f - t_i$

II-8 ACCEPTANCE CRITERIA

Pressure boundary test results are acceptable when there are no leaks in excess of the limits specified in the applicable sections of ASME AG-1 and the owner's test program. If the calculated leak rate exceeds the acceptance criteria specified in the owner's test program, locate leaks in accordance with one of the techniques outlined in section II-9 or II-10.

II-9 BUBBLE LEAK LOCATION METHOD

(a) Pressurize the test boundary to the maximum operating pressure for the system.

(b) With the test boundary under continuous pressure, apply bubble solution to areas to be tested. Identify places where bubbles are found, and perform corrective actions.

(c) Following corrective actions, retest in accordance with section II-6 or II-7.

II-10 AUDIBLE LEAK LOCATION METHOD

(a) Pressurize the test boundary to the maximum operating pressure for the system.

(b) With the test boundary continuously pressurized, locate audible leaks (electronic sound detection equipment optional), and perform corrective actions.

(c) Following corrective action, retest in accordance with section II-6 or II-7.

MANDATORY APPENDIX III

HEPA FILTER BANK IN-PLACE LEAK TEST PROCEDURE

III-1 GENERAL

This procedure is used to leak test HEPA filter banks.

III-2 SUMMARY OF METHOD

The system is operated at design flow rate. Challenge aerosol is injected upstream of each bank through the qualified injection ports. The concentration of the challenge aerosol is measured upstream and downstream of the HEPA filter bank. The ratio of the downstream and upstream concentration represents the HEPA filter bank leak rate.

III-3 PREREQUISITES

- (a) Visual inspection of components.
- (b) Airflow capacity shall be verified in accordance with para. 5.2.4.2.
- (c) The injection and sample locations shall be qualified to provide uniform air-aerosol mixing in accordance with ASME AG-1, Appendix TA-V.

III-4 TEST EQUIPMENT

- (a) challenge aerosol generator
- (b) challenge aerosol measuring instrument
- (c) challenge aerosol (e.g., DOP aerosol) for in-place testing leak testing of installed HEPA filter systems shall be a polydispersed liquid aerosol having an approximate light scattering droplet size distribution as follows:

- (1) 99% less than 3 μm diameter
- (2) 50% less than 0.7 μm diameter
- (3) 10% less than 0.4 μm diameter

NOTE: Sample line length should be minimized to reduce sample response time, and the lengths of the lines should be approximately equal.

III-5 PROCEDURE

- (a) Connect challenge aerosol generator to the injection port.
- (b) Place the challenge aerosol-measuring instrument sample probes upstream and downstream of the bank to be tested.
- (c) Start the system, and verify stable flow rate within $\pm 10\%$ of design flow rate.
- (d) Measure the upstream and downstream aerosol background concentration. The preinjection background levels shall be stable to ensure correct instrument response and shall not interfere with the detector's ability to detect leaks in excess of the maximum allowed by the acceptance criteria.
- (e) Start the challenge aerosol injection.
- (f) Record the upstream and downstream concentrations. Repeat until at least three of the readings are stable.
- (g) Stop the injection.
- (h) Using the final set of readings meeting the stability and tolerance criteria, calculate the bank leak rate using the following equation:

$$L = 100 \left(\frac{C_d}{C_u} \right)$$

where

- C_d = downstream concentration
- C_u = upstream concentration
- L = percent of leak

III-6 ACCEPTANCE CRITERIA

The acceptance criteria for these inspections shall be in accordance with section 6 and the owner's test program.

MANDATORY APPENDIX IV

ADSORBER BANK IN-PLACE LEAK TEST PROCEDURE

IV-1 GENERAL

This procedure is used to leak test adsorber banks.

IV-2 SUMMARY OF METHOD

The system is operated at design flow rate. Challenge gas is injected upstream of each bank through the injection port. The concentration of challenge gas is measured upstream and downstream of the bank. The ratio of the downstream and upstream concentrations represents the bank leak rate.

IV-3 PREREQUISITES

(a) Visual inspection of the components. (If samples of adsorbent are to be taken for laboratory testing, it is recommended to remove such samples at this time.)

(b) Airflow capacity shall be verified in accordance with para. 5.2.4.2.

(c) The injection port shall be qualified to provide uniform air-aerosol mixing in accordance with ASME AG-1, Appendix TA-V.

IV-4 TEST EQUIPMENT

- (a) challenge gas generator
- (b) challenge gas-measuring instrument

IV-5 PROCEDURE

(a) Connect challenge gas generator to the injection port.

(b) Place the challenge gas-measuring instrument sample probes upstream and downstream of the bank to be tested.

(c) Start the system, and verify stable flow rate and within $\pm 10\%$ of design flow rate.

(d) Measure the upstream and downstream challenge gas background concentration. The preinjection background levels shall be stable to ensure correct instrument response and shall not interfere with the detector's ability to detect challenge gas leaks less than the maximum allowed by the acceptance criteria.

(e) Start the challenge gas injection.

(f) Record the upstream and downstream concentrations, as rapidly as instrument response time allows, until sufficient data have been recorded to allow calculation of adsorber bank leak rate. Care must be taken to obtain sufficient readings quickly after injection.

(g) Terminate challenge gas injection.

(h) Using the upstream and downstream concentration data, calculate the adsorber bank leak rate using the following equation:

$$L = 100 \left(\frac{C_d}{C_u} \right)$$

where

C_d = downstream concentration

C_u = upstream concentration

L = percent of leak

IV-6 ACCEPTANCE CRITERIA

The acceptance criteria for these inspections shall be in accordance with section 6 and the owner's test program.

NONMANDATORY APPENDIX A CORRECTIVE ACTION GUIDANCE

Corrective action may consist of replacement, repair, modification, maintenance, or analysis to demonstrate that the equipment will fulfill its design function. A revised set of reference values, as described in para. 3.2, should be established after the corrective action has been taken.

Results of a failed test should not be resolved simply by a successful repetition of the test. A successful repetition of the test should be preceded by corrective action.

If the cause of the test failure cannot be determined by inspection or analysis, the corrective action may consist of recalibration of test instruments and subsequent retesting. If it is determined that the test failure is due to an equipment malfunction, instead of difficulties with the test equipment, or test procedure, the equipment should be declared unavailable for service until the specific cause has been determined and the condition corrected.

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NONMANDATORY APPENDIX B CHALLENGE GAS SUBSTITUTE SELECTION CRITERIA

Alternative test agents (challenge gas) may be used to perform in-place testing of adsorbers, as required in Mandatory Appendix IV, when their selection is based upon meeting the following characteristics:

(a) The test agent gives similar in-place leak test results as one of the following: R-11, R-12, R-112, or R-112a.

(b) The test agent has similar retention times on activated carbons, at the same concentration levels, as one of the following: R-11, R-12, R-112, or R-112a.

(c) The test agent has similar lower detection limit sensitivity and precision in the concentration range of

use as one of the following: R-11, R-12, R-112, or R-112a.

(d) The test agent exhibits chemical and radiological stability under the test conditions.

(e) The test agent causes no degradation of the carbon and its impregnant(s) or of other nuclear air treatment system components under the test conditions.

(f) If the alternative test agent is toxic, then it shall be listed in the National Institute for Occupational Safety and Health (NIOSH) Registry of Toxic Effects of Chemical Substances (RETECS), formerly known as the Environmental Protection Agency's "Toxic Substance Control Act" (TSCA) inventory for commercial use.

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NONMANDATORY APPENDIX C

TEST PROGRAM DEVELOPMENT GUIDANCE

C-1 OVERVIEW

The scope of the periodic in-service test program for nuclear air treatment, heating, ventilating, and air conditioning systems should be developed commensurate with the safety significance of the system performance function(s). The overall depth of the performance-monitoring effort should be flexible, with various tests being added, modified, or deleted as results and industry experience warrant. This Nonmandatory Appendix provides guidance in developing a test program that will meet the requirements of this Standard.

C-2 DEFINITIONS

The following definitions are applicable to this Nonmandatory Appendix:

analyzed system configuration: the alignment and condition (on or off) of various components, hand switches, controls, valves, piping, etc., that have been analyzed as being capable of accomplishing a specific system function.

analyzed system performance: the predicted performance as determined in the appropriate analysis (safety, system, or component analysis) or the acceptable limit as defined in the Technical Specification Basis. This value is in the conservative direction when related to the design limit, with the difference between the two defining the analysis margin.

design basis: that information which identifies the specific functions to be performed by a structure, system, or component of a facility and the specific values or range of values chosen for controlling parameters as reference bounds for the design. These values may be restraints derived from generally accepted "state-of-the-art" practices for achieving functional goals or requirements derived from analysis (based on calculation and/or experiment) of the effects of a postulated accident for which the structure, system, or component must meet its functional goals (REF: 10 CFR 50.2).

parameters: the variables or measurable qualities of a system or component that are used to define acceptable operation or can be restricted to ensure that performance remains within design limits.

system performance function: the goal or task that the system is required to accomplish or support.

Examples of system performance functions, which might be applicable to nuclear air treatment, heating, ventilating, and air conditioning systems, include the following:

- (a) provide a habitable environment (temperature, humidity, filtration, ventilation) for facility personnel
- (b) provide an acceptable environment (temperature, humidity, ventilation) to support equipment operability and environmental qualification requirements
- (c) prevent the uncontrolled release of airborne radioactivity and limit offsite dose in accordance with 10 CFR 50 Appendix I, 10 CFR 20, and 10 CFR 100

C-3 TEST PROGRAM DEVELOPMENT

The owner should perform a detailed review of all design basis documentation applicable to each system. Subsequent to this review, a Test Basis Document should be prepared for each nuclear air treatment, heating, ventilating, and air conditioning system in the facility to identify the following:

- (a) system performance function(s).
- (b) analyzed system configuration for each identified performance function.
- (c) the critical performance parameters that will define acceptable system operation for each performance function.
- (d) the parameter design limits. These are the design or analysis limits which govern the system performance and bound the system.

NOTE: The Nuclear Management and Resources Council, Inc. (NUMARC) sponsored document "Design Basis Document Guidelines," NUMARC 90-12, October 1990 and USNRC NUREG-1397, "An Assessment of Design Control Practices and Design Reconstitution Programs in the Nuclear Power Industry," February 1991 can provide further detail on methods for determining the various design basis functions.

C-4 AIR/HYDRONIC SYSTEM BALANCE VERIFICATION GUIDANCE

Under the scope of the Preoperational Test Program, all nuclear safety related air treatment, heating, ventilating, and air conditioning systems are tested, adjusted, and balanced to the requirements of ASME AG-1, Section TA. It is not the intent of this Standard to mandate the reperformance of the initial testing, adjusting, and balancing program. This Standard, however, does

Table C-1 Performance Parameters and Parameter Design Limits

Performance Function	Performance Parameters	Parameter Design Limit
C-5.1(a) and (b)	Heat Removal	850,000 Btuh
	Total system airflow	30,000 SCFM (min.)
	Air temperature at coil outlet	60°F (max.)
	Chilled water flow to coil	114 GPM (min.)
	Chilled water supply temperature	45°F (max.)
	Control room ambient air temperature	80°F (max.)
C-5.1(c)	Radiation Protection	
	Outside airflow (pressurization)	400 SCFM (min.)
	Outside airflow	900 SCFM (max.)
	HEPA filter bypass leakage	1% (max.)
	Adsorber bypass leakage	1% (max.)
	Adsorbent methyl iodide removal efficiency	99% (min.)
	Humidity control at adsorber	70% (max.)
	Control room complex pressure	+0.25 in. wg (relative to all adjacent areas)
	Isolation damper leakage	Bubbletight at 15 in. wg
	Isolation damper closure time	25 sec (max.)
	Filter unit total pressure drop	8 in. wg (max.)

require a periodic verification that the degree of air/hydronic system balance necessary to achieve the safety related functions of the system(s) has been maintained.

The key to determining the scope and methodology for periodic system air/hydronic balance verification is the proper initial identification of the critical safety function(s) of the system and determination of the performance parameters required to be measured and compared with previously established reference values. The goal of the monitoring effort is to provide reasonable assurance that the system performance functions are being achieved.

C-5 SAMPLE TEST PROGRAM

Given a sample Control Room Complex Emergency HVAC System, consisting of a fan, ductwork, dampers, chilled water cooling coils, nuclear air filtration unit (electric preheater, prefilter, HEPA filters, adsorber), controls, etc., the System Test Basis Document might be structured as follows:

C-5.1 System Performance Functions

(a) Provide a habitable environment for control room complex personnel in the event of a design basis accident.

(b) Maintain the control room complex environment to ensure equipment operability.

(c) Limit radiological dose to control room complex personnel in accordance with GDC-19 requirements.

C-5.2 Analyzed System Configuration

To achieve Performance Functions in paras. C-5.1(a) through (c), one Essential Air Filtration unit in service, normal ventilation system isolated, and an essential chilled water system in service.

C-5.3 Critical Performance Parameters and Parameter Design Limits

For critical performance parameters and parameter design limits, see Table C-1.

Based upon the identified critical performance parameters for the sample Control Room Complex Emergency HVAC System, the periodic in-service test program would be appropriate as shown in Table C-2.

Table C-2 Periodic In-Service Test Programs

Test Section	Test Description	Test Applicable to System?	Test Frequency
5.2	Fans	Yes	...
5.2.2	Visual Inspection	Yes	Q
5.2.3	Pressure Boundary Leak Test	Yes	10Y
5.2.4.1	Mechanical Run Test	Yes	Q
5.2.4.2	Flow Rate Test	Yes	2Y
5.2.4.3	Static Pressure Test	Yes	2Y
5.2.4.4	Rotational Speed Test	Yes	2Y
5.2.4.5	Vibration Test	Yes	Q
5.3	Dampers	Yes	...
5.3.2	Visual Inspection	Yes	2Y
5.3.3	Leak Test, Damper Seat	Yes	2Y
5.3.4.1	Position Indication Test	Yes	2Y
5.3.4.2	Exercise Test	Yes	2Y
5.3.4.3	Static Timing Test	Yes	Q
5.3.5.1	Flow Control Test	Yes	2Y
5.3.5.2	Fire Damper Test	Yes	2Y
5.3.5.3	Dynamic Timing Test	Yes	2Y
5.3.5.4	Interlock Test	Yes	2Y
5.4	Duct and Housing	Yes	...
5.4.2	Visual Inspection	Yes	2Y
5.4.3	Leak Test	Yes	10Y
5.5	Refrigeration Equipment	Note (1)	...
5.5.2	Visual Inspection	...	...
5.5.3.1	Leak Test, Refrigerant Piping and Coils	...	...
5.5.3.2	Leak Test, Hydronic Piping and Coils	...	...
5.5.4.1	Fans	...	...
5.5.4.2	Valve Position Indication Test	...	...
5.5.4.3	Valve Exercise Test	...	...
5.5.5.1	Flow Control Valve Test	...	...
5.5.5.2	Mechanical Run Test	...	...
5.5.5.3	Performance Test	...	...
5.5.5.4	Vibration Test	...	...
5.5.5.5	Rotational Speed Test	...	...
5.6	Conditioning Equipment	Note (2)	...
5.6.2	Visual Inspection	...	...
5.6.3	Leak Test, Hydronic Piping and Coils	...	...
5.6.4	Component Functional Tests	...	...
5.6.5.1	Hydronic System Flow Balance Verification Test	...	...
5.6.5.2	Flow Control Valve Test	...	...
5.6.5.3	Mechanical Run Test	...	...
5.6.5.4	Performance Test	...	...
5.6.5.5	Rotational Speed Test	...	...
5.6.5.6	Vibration Test	...	...
5.6.5.7	Electric Heater Performance Test	...	...
5.6.5.8	Hydronic Heating and Cooling Performance Test	Yes	2Y
5.7	Moisture Separator, Prefilter, HEPA Filter Bank	...	...
5.7.2	Visual Inspection	Yes	2Y
5.7.3.1	Differential Pressure Test	Yes	M
5.7.3.2	In-Place Leak Test	Yes	2Y

Table C-2 Periodic In-Service Test Programs (Cont'd)

Test Section	Test Description	Test Applicable to System?	Test Frequency
5.8	Type II and Type III Adsorber Bank	...	...
5.8.2	Visual Inspection	Yes	2Y
5.8.3.1	Differential Pressure Test	Yes	M
5.8.3.2	In-Place Leak Test	Yes	2Y
5.8.3.3	Electric Heater Performance Test	Yes	2Y
5.9	Adsorbent		
5.9.2	Laboratory Analysis	Yes	2Y [Note (3)]
5.10.1	In-Service Test Requirements	Note (4)	...
5.10.2	HEPA Filter Bank and Adsorber Bank Integrated System Test	Yes	2Y
5.11	Air System Flow Balance Verification Test	Yes	10Y

NOTES:

- (1) Refrigeration equipment is scoped and tested with the Essential Chilled Water System.
- (2) Conditioning equipment, with the exception of the control room complex Essential Cooling Coil, is scoped and tested with the Essential Chilled Water System.
- (3) Laboratory analysis of the adsorbent is required at least every 2 years or 720 hr of accumulated service time, whichever is sooner.
- (4) Measurements for control room complex pressure and ambient room temperature are incorporated into para. 5.10, Integrated System Tests.

NONMANDATORY APPENDIX D

ADSORBER BANK IN-PLACE LEAK TEST PROCEDURE USING PULSE MODE INJECTION WITH CONTINUOUS MONITORS

D-1 GENERAL

This procedure is used to leak test adsorber banks, using continuously monitoring test instruments and pulse injections.

D-2 SUMMARY OF METHOD

The system is operated at design flow rate. The challenge gas is injected upstream of the adsorber bank for a predetermined time interval to achieve adequate challenge concentration. The challenge peak concentration is monitored, upstream and downstream of the bank with the tracer gas detectors and, if required, on a multichannel data recorder. Mechanical leakage is determined from the ratio of downstream concentration to upstream concentration for each pulse mode injection. The averages of the mechanical leaks of the pulses are reported.

D-3 PREREQUISITES

(a) Visual inspection of the components. (If samples of adsorbent are to be taken for laboratory testing, it is recommended to remove such samples at this time.)

(b) Airflow capacity is verified in accordance with paragraph 5.2.4.2.

(c) The injection port is qualified to provide uniform air-aerosol mixing in accordance with ASME AG-1, Appendix TA-V.

D-4 TEST EQUIPMENT

- (a) Challenge gas generator
- (b) Challenge gas constant monitoring instrument(s).
- (c) Multichannel data recorder, if required

D-5 PROCEDURE

(a) Connect challenge gas generator to the injection port.

(b) Place the challenge gas constant monitoring instrument sample probes upstream and downstream of the bank to be tested.

(c) Connect the multichannel data recorder to the upstream and downstream continuous monitoring instruments, if required.

(d) Start the system, and verify stable flow rate to be within $\pm 10\%$ of design flow rate.

(e) Measure the upstream and downstream background concentrations.

(f) If the preinjection background levels interfere, take actions required to reduce background concentrations to an acceptable level before proceeding. Such actions may include identification and mitigation at the source, such as degreasing, painting, refrigeration equipment maintenance activities. In the absence of point of source releases, run the system until background levels reach an acceptable level.

(g) Inject challenge gas for 10-20 seconds (as required). Adjust the generator and injection time to produce as a minimum, the predetermined minimum upstream concentration peak that is within the linear range of the detector.

(h) Monitor both the upstream and downstream readings, read and record the peak upstream and downstream concentration readings. If the downstream detector peaks at the same time as the upstream detector, the ratio of the peak values detected should be used for calculation of leakage.

If the two detectors do not peak at the same time, (i.e., the downstream detector peaks at some time after the peak on the upstream detector) this may indicate challenge gas breakthrough and / or desorption. If this occurs, the use of the

optional multichannel data recorder may help in discriminating between a possible mechanical leak and breakthrough or desorption.

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(i) After the initial pulse, allow adequate time for the upstream concentration to decrease and stabilize prior to each additional pulse. If necessary, re-zero the detectors between pulses. Repeat injections at least three more times and record the upstream and corresponding downstream concentration readings.

(j) Using the upstream and downstream concentration data, calculate the adsorber bank leak rate using the following equations:

$$L = 100 \left(\frac{C_d}{C_u} \right)$$

Where

C_d = downstream concentration

C_u = upstream concentration

L = percent of leak

D-6 Acceptance Criteria

The acceptance criteria for these inspections shall be in accordance with Section 6 and the owner's test program.

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Guidance for the Use of a Multichannel Data Recorder to Determine Bank Leakage During Pulse Testing of an Adsorber Bank

The application of a multichannel data recorder is optional when there is no need to distinguish a leak from either desorption or breakthrough; but it is recommended to plot the variations in test agent concentration with time for individual pulse tests and to compare the trace for any resulting leak to that of the leak-identifying upstream concentration.

The use of a data recorder is required when it is difficult to determine whether a leak is present, prior to rapid desorption, or quick breakthrough of the test agent through the carbon bed.

Figures 1 and 2 illustrate how the data recorder may be used to determine whether a leak is present under conditions involving quick breakthrough.

Figure 1:
Traces of Challenge Gas Concentration for Pulse Test That Demonstrates No Leak and Quick Breakthrough

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