ASME AG-1–2009
(Revision of ASME AG-1–2003)

Code on Nuclear Air and Gas Treatment

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

ASME
SETTING THE STANDARD

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The 2009 edition of this Code is being issued with an automatic addenda subscription service. The use of addenda allows revisions made in response to public review comments or committee actions to be published as necessary. The next edition of this Code is scheduled for publication in 2012.

ASME issues written replies to inquiries concerning interpretation of technical aspects of this Code. Periodically certain acitons of the ASME Committee on Nuclear Air and Gas Treatment may be published as Cases. Cases and interpretations are published on the ASME Web site under the Committee Pages at http://cstools.asme.org as they are issued.

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(A detailed Contents precedes each AG-1 Section.)

FOREWORD

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In 1971, the ANSI N45.8 Committee was organized to develop standards for high reliability air cleaning equipment for nuclear facilities and corresponding tests to confirm performance of the equipment. Two standards, ASME N509 and ASME N510, were published in 1975 and 1976.

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 increased to include the development of codes and standards for design, fabrication, inspection, and testing of air cleaning and conditioning components and appurtenances used in safety-related systems in nuclear facilities. ASME AG-1 is the new Code resulting from the increased scope.

This Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction activities. Construction, as used in this Foreword, is an all-inclusive term relating to material, design, fabrication, inspection, testing, and certification. The Code does not address all aspects of these activities and those not specifically addressed may be considered. The Code is neither a handbook nor a replacement for education, experience, and the use of engineering judgment. The phrase "engineering judgment" refers to technical judgments made by knowledgeable designers experienced in the application of the Code. Engineering judgments must be consistent with Code philosophy and such judgments shall never be used to overrule mandatory requirements or specific prohibitions of the Code. The user is cautioned to carefully review these Code requirements for suitability to specific applications other than nuclear power and nuclear fuel cycle facilities.

The Code requirements established by the Committee shall not be interpreted as approving, recommending, or endorsing any proprietary design.

The Committee on Nuclear Air and Gas Treatment meets regularly to consider revisions of the Code requirements, new Code requirements as dictated by technological development, Code Cases, and requests for interpretations. Only the Committee on Nuclear Air and Gas Treatment has the authority to provide official interpretations of this Code. Requests for revisions, new Code requirements, Code Cases, or interpretations shall be addressed to the Secretary in writing and shall give full particulars in order to receive consideration and action. (See Mandatory Appendix covering preparation of technical inquiries.)

The first edition of this Code was approved by the American National Standards Institute (ANSI) on April 30, 1985, and issued on February 28, 1986. This seventh edition was approved by ANSI on June 15, 2009.

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ORGANIZATION OF ASME AG-1

1. GENERAL

The ASME Code on Nuclear Air and Gas Treatment consists of Divisions I through IV. All Divisions are broken down into Sections designated by two capital letters. Each Division is made up as follows:

Division I: General Requirements
- Section AA: Common Articles

Division II: Ventilation Air Cleaning and Ventilation Air Conditioning
- Section BA: Fans and Blowers
- Section DA: Dampers and Louvers
- Section SA: Ductwork
- Section HA: Housings
- Section RA: Refrigeration Equipment
- Section CA: Conditioning Equipment
- Section FA: Moisture Separators
- Section FB: Medium Efficiency Filters
- Section FC: HEPA Filters
- Section FD: Type II Adsorber Cells
- Section FE: Type III Adsorbers
- Section FF: Adsorbent Media
- Section FG: Mounting Frames, CONAGT Air-Cleaning Equipment, Nuclear Safety-Related Equipment
- Section FH: Other Adsorbers
- Section FI: Metal Media Filters
- Section FJ: Low Efficiency Filters
- Section FK: Special Round and Duct-Connected HEPA Filters
- Section FL: Sand Filters
- Section FM: High Strength HEPA Filters
- Section IA: Instrumentation and Controls

Division III: Process Gas Treatment
- Section GA: Pressure Vessels, Piping, Heat Exchangers, and Valves
- Section GB: Noble Gas Hold-Up Equipment
- Section GC: Compressors
- Section GD: Other Radionuclide Equipment
- Section GE: Hydrogen Recombiners
- Section GF: Gas Sampling

Division IV: Testing Procedures
- Section TA: Field Testing of Air Treatment Systems
- Section TB: Field Testing of Gas-Processing Systems

2. SECTIONS

Sections are divided into articles, subarticles, paragraphs, and, where necessary, subparagraphs and subsubparagraphs.

3. ARTICLES

Articles are designated by the application letters indicated above for the sections, followed by Arabic numbers in units of 1000, such as BA-1000 or RA-2000. Where possible, articles dealing with the same topics are given the same number in each section in accordance with the following:

Article Number	Title
1000	Introduction
2000	Referenced Documents
3000	Materials
4000	Structural Design
5000	Inspection and Testing
6000	Fabrication, Joining, Welding, Brazing, Protective Coating, and Installation
7000	Packaging, Shipping, Receiving, Storage, and Handling
8000	Quality Assurance
9000	Nameplates and Stamping

The numbering of articles and the material contained in the articles may not, however, be consecutive. Because the complete outline may cover phases not applicable to a particular section or article, the rules have been prepared with some gaps in the numbering.

4. SUBARTICLES

Subarticles are numbered in units of 100, such as BA-1100 or RA-1200.

5. SUBSUBARTICLES

Subsubarticles are numbered in units of 10, such as BA-2130, and generally have no text. When a number such as BA-1110 is followed by text, it is considered a paragraph.

6. PARAGRAPHS

Paragraphs are numbered in units of 1, such as BA-2131 or RA-2132.

7. SUBPARAGRAPHS

Subparagraphs, when they are major subdivisions of a paragraph, are designated by adding a decimal followed by one or more digits to the paragraph number, such as BA-1111.1 or RA-1111.2. When they are minor subdivisions of a paragraph, subparagraphs may be designated by lowercase letters in parentheses, such as BA-1111(a) or RA-1111(b).

8. SUBSUBPARAGRAPHS

Subsubparagraphs are designated by adding lower case letters in parentheses to major subparagraph numbers, such as BA-1111.1(a) or RA-1111(b). When further subdivisions of minor subparagraphs are necessary, subsubparagraphs are designated by adding Arabic numerals in parentheses to the subparagraph designation, such as BA-1111(a)(1) or RA-1111(a)(2).

9. APPENDICES

Appendices pertaining to each section appear at the end of each section and are designated with the section prefix. Nonmandatory appendices are designated by letters of the alphabet, and mandatory appendices are designated by Roman numerals. Metric appendices carry the same designators as customary appendices, with the prefix "M."

ASME AG-1–2009
SUMMARY OF CHANGES

Following approval by the ASME Committee on Nuclear Air and Gas Treatment (CONAGT) and ASME, and after public review, ASME AG-1–2009 was approved by the American National Standards Institute on June 15, 2009.

ASME AG-1–2009 consists of AG-1–2003, ASME AG-1a–2004, and ASME AG-1b–2007; editorial changes, revisions, and corrections; as well as the following changes identified by a margin note, **(09)**.

Page	*Location*	*Change*
x	Organization of ASME AG-1	Updated
9, 10	Article AA-2000	Revised in its entirety
35–38	AA-6500	Revised in its entirety
92, 93	BA-1100	Revised
	BA-1110	Revised to include testing and quality assurance
	BA-1130	(1) Definitions of *axial fans*, *fans*, *fan arrangement number*, *inlet bell*, and *orientation* revised (2) Definitions of *design speed*, *maximum speed*, and *operating speed* added
94	Article BA-2000	Revised in its entirety
95	Article BA-3000	Revised in its entirety
98–103	Article BA-4000	Revised in its entirety
104	BA-5111	First sentence revised
105	BA-5141	Revised
	BA-5142	References to BA-4142 revised to BA-4141
	BA-5210	Revised
106	Article BA-6000	(1) First sentence revised (2) BA-6200 added
107	Article BA-7000	Revised in its entirety
108	Article BA-8000	Revised in its entirety
109	Article BA-9000	New BA-9100 added, and all subsequent paragraphs redesignated
110	Nonmandatory Appendix BA-A	(1) Parenthetical note below heading deleted (2) Last word in BA-A-1300 revised
112, 113	Table BA-B-1000	Revised

Page	*Location*	*Change*
116	Article DA-1000	First paragraph revised to delete the word "minimum"
117	DA-1330	Definition of *single-blade damper* revised
118	DA-1380	Definition of *fire damper construction* revised
119	Article DA-2000	Revised in its entirety
121, 122	Table DA-3110	Revised and general note added
124	DA-4120(p)	Added
126	DA-4232	Revised
129	DA-4323	Reading of 25 lb revised to 40 lb
131	DA-5100	Reference to DA-4140 revised to DA-4130
134	Article DA-7000	Reference to ANSI/ASME NQA-2 revised to ASME NQA-1
201	HA-3111	Parentheses removed from the term "galvanized"
202	Table HA-3110	ASTM A 167 line under "Plate, Sheet, and Strip" deleted
287	Table CA-3230	ASTM A 167 line under "Plate, Sheet, and Strip" deleted
288	Table CA-3310	ASTM A 167 line under "Plate, Sheet, and Strip" deleted
289	Table CA-3410	ASTM A 167 line under "Plate, Sheet, and Strip" deleted
327	Article FA-1000	Revised in its entirety
328	Article FA-2000	Revised in its entirety
329	Article FA-3000	Revised in its entirety
330	Article FA-4000	Revised in its entirety
333, 334	Article FA-5000	Revised in its entirety
335	Article FA-6000	Revised in its entirety
336	Article FA-7000	Revised in its entirety
337	Article FA-8000	Revised in its entirety
338	Article FA-9000	Revised in its entirety
339	Nonmandatory Appendix FA-A	(1) Designator revised from FA-B (former Nonmandatory Appendix FA-A deleted) (2) Table FA-A-1000 revised
354	Article FC-1000	Revised in its entirety
355	Article FC-2000	Revised in its entirety
356, 357	Article FC-3000	Revised in its entirety
358	Article FC-4000	Revised in its entirety
364	Article FC-5000	Revised in its entirety
367	Article FC-6000	Revised in its entirety
368	Article FC-7000	Revised

Page	*Location*	*Change*
369	Article FC-8200	Revised in its entirety
370	Article FC-9000	Revised in its entirety
372	Article FC-I-2000	Revised in its entirety
373, 374	Article FC-I-3000	Revised in its entirety
375, 376	Article FC-I-4000	Revised in its entirety
377, 378	Article FC-I-5000	Revised and redesignated as Article FC-I-6000, and new Article FC-I-5000 added
379	Table FC-A-1000	Revised
400	Article FE-2000	Listing of ASTM A 167 deleted
401	FE-3140(a)	Listing of ASTM A 167 deleted
517	Section FL	Added (in course of preparation)
	Section FM	Added (in course of preparation)
523	Table IA-3100	ASTM A 167 line under "Plate, Sheet, and Strip" deleted
548	TA-1120	Last sentence revised
	TA-1130	(1) Definitions of *challenge aerosol*, *in-service test*, and *test canister* revised (2) Definition of *habitability envelope* added (3) Definition of *acceptance test* deleted
550	Article TA-2000	Revised in its entirety
551–554	Article TA-3000	Revised in its entirety
555, 556	Article TA-4000	Revised in its entirety
567	Article TA-5000	First sentence revised
568	TA-6200	Last sentence revised
	TA-6310	"Written" deleted from first sentence
	TA-6320	Subparagraph (b) inserted, and all subsequent subparagraphs redesignated
569, 570	Mandatory Appendix TA-I	Revised in its entirety
573	Article TA-II-3000	Subparagraph (c) revised
575	Article TA-II-5000	Revised
576	TA-III-1100	Value of 80% revised to 75%
577	Article TA-III-2000	Last sentence revised
578	Article TA-III-3000	Subparagraphs (c), (d), and (e) revised
579	TA-III-4100	Subparagraphs (e) and (g) revised
	TA-III-4200	Revised
580	TA-III-4300	Revised
581	TA-IV-1100	Revised
582	Article TA-IV-2000	Revised
583	Article TA-IV-3000	"Pitot" capitalized

Page	*Location*	*Change*
584	Article TA-IV-4000	Revised
585	Article TA-V-1000	Revised
586	Article TA-V-2000	Sentence added
588	Article TA-V-4000	Revised in its entirety
589	TA-VI-1100	Revised
591	Article TA-VI-3000(c)	Revised in its entirety
592	Article TA-VI-4000(b)	Revised in its entirety
593	TA-VII-1100	First sentence revised
594	Article TA-VII-2000	Sentence added
595	Article TA-VII-3000	Subparagraph (c) deleted
596	Article TA-VII-4000	Revised in its entirety
603	Article TA-A-3000(c)	Revised
604	Article TA-A-4000(d)	Revised
606	Nonmandatory Appendix TA-C	Revised

SPECIAL NOTE:
The Interpretations to ASME AG-1 are included in this edition as a separate section for the user's convenience.

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Division I
General Requirements

SECTION AA
COMMON ARTICLES

Figures

Tables

Nonmandatory Appendices

ARTICLE AA-1000
INTRODUCTION

AA-1100 SCOPE

This Code provides requirements for the performance, design, construction, acceptance testing, and quality assurance of equipment used as components in nuclear safety-related air and gas treatment systems in nuclear facilities.

AA-1110 PURPOSE

The purpose of this Code is to ensure that equipment used in nuclear facilities for nuclear safety-related air and gas treatment systems is acceptable in all aspects of performance, design, construction, and testing.

AA-1120 APPLICABILITY

This Code applies only to individual components in a system. This Code does not cover any functional system design requirements or sizing of complete systems, or any operating characteristics of these systems. The responsibility for meeting each requirement of this Code shall be assigned to the Owner or assigned designee.

AA-1130 DEFINITIONS AND TERMS

Each Code section shall delineate the definitions and terms unique to that section. Definitions that have common application are listed in this section.

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.

active component: any component that must perform a mechanical motion or change of state during the course of accomplishing a nuclear safety-related function.

air density: 0.075 lb/ft^3 (1.201 kg/m^3) for standard air. This corresponds to air at a pressure of 29.92 in. Hg (760 mm Hg) at a temperature of 69.8°F (21°C) with a specific volume of 13.33 ft^3/lb (0.832 m^3/kg).

airflow (ACFM, SCFM, ACMS, SCMS): expressed in terms of CFM (cubic feet of air per minute). ACFM is a cubic foot of air with a density at actual existing conditions. SCFM (standard CFM) is a cubic foot of air with a standard density. ACMS and SCMS correspondingly apply to cubic meters per second under actual and standard conditions.

allowable deflection (d_{all}): the deflection resulting from each of the component loading conditions defined in AA-4212.

allowable stress value (S): the maximum stress limit to be used in the design.

assembly: two or more devices sharing a common mounting or supporting structure.

broadband response spectrum: a response spectrum that describes the motion indicating that multiple frequency excitation predominates.

Certificate of Compliance: a written statement, signed by a qualified party, attesting that the items or services are in accordance with specified requirements and accompanied by additional information to substantiate the statement.

Certificate of Conformance: a written statement, signed by a qualified party, certifying that items or services comply with specific requirements.

clean air system: an air cleaning system that is designed to maintain a definite level of air cleanliness within an enclosed working area.

component: a constituent of any referenced item. For example, an adsorber is a component of an air cleaning unit. An air cleaning unit and ducts are components of the air cleaning system.

component conditions: operating conditions of a component referred to as Service Level A, Service Level B, Service Level C, or Service Level D.

contained space: a building, building space, room, cell, glove box, or other enclosed volume in which air supply and exhaust are controlled.

contaminated exhaust system: an air cleaning system that is designed to remove harmful or potentially harmful particulates, mists, or gases from the air or gas exhausted from a contained space or process.

contaminated space: any enclosed or outdoor space with actual or potential airborne concentrations of hazardous or radioactive materials that may cause one or both of the following:

(*a*) unacceptable damage or dose to personnel and equipment occupying the space

(*b*) contamination of other spaces

contamination: any unwanted material in the air or on surfaces. For the purpose of this Code, contamination is usually assumed to be hazardous or radioactive.

contamination zone: an isolated area that is or that could become contaminated and that is designed to facilitate decontamination.

Contractor: any organization under contract for furnishing items or services to an organization operating in compliance with this Code. It includes the terms Vendor, supplier, subcontractor, and Fabricator, and subtier levels of these where appropriate, but excludes Material Suppliers and Material Manufacturers.

decibel (dB): a numerical expression of the relative loudness of a sound, which is a dimensionless quantity, used to express a level in logarithmic terms of the ratio of a quantity to a reference for sound pressure, which is 0.0002 dyne/cm^2, and for sound power that reference is 10^{-12} W.

decontamination: the removal of contamination from the air or surfaces.

design specification: a concise document defining technical requirements in sufficient detail to form the basis for a product, material, or process that indicates, when appropriate, the procedure or means that determines whether or not the given requirements are satisfied. The design specification includes requirements for performance and testing.

design working pressure: the maximum allowable working pressure for which a specific part of a system is designed.

device: an item, component, or accessory that is used in connection with, or as an auxiliary to, other items of equipment.

driver: a prime mover that produces rotational power input to the driven equipment. For the purpose of this Code, the term driver will be understood to be an AC induction motor. Other types of drivers are not covered by this section of the Code.

duct: an air or gas path enclosure.

effective width: a reduced width of plate that is effective in carrying loads after the local buckling stress has been exceeded. These effective plate regions are adjacent to stiffeners, or at corners where two or more joined plates stiffen one another. Forty to fifty plate thicknesses are normally considered as effective in acting with the stiffeners.

Engineer: as used in this document, the Engineer is the individual or organization designated by the Owner to be responsible for the original design or modification to the original design of air and gas treatment systems, and is responsible for determining the performance parameters for the system.

Engineered Safety Feature (ESF): a nuclear air treatment system, HVAC system, gas processing system, or a component that serves to control and limit the consequences of releases of energy and radioactivity in the event of occurrences as described in ANSI/ANS 51.1 and 52.1.

equipment: all HVAC components including ductwork, housings, plenums, fans, cleaning and refrigeration devices, dampers, and structural supports.

Fabricator: as used in this Code, this term refers to the organization that assembles, forms, or constructs components for use in air or gas treatment systems for the owner or his designee. Fabricators receive materials for fabrication from a Material Supplier and Material Manufacturer.

floor acceleration: the acceleration of a particular building floor (or equipment mounting) resulting from the motion of a given earthquake. The maximum floor acceleration is obtained from the floor response spectrum as the acceleration at high frequencies (in excess of 33 Hz) and is sometimes referred to as the ZPA (zero period acceleration).

full-load heat run: a test to determine the driver temperature rise. The driver must be run at full load until the driver temperature stabilizes. Driver winding temperatures are then taken, or resistance of the windings is taken and the temperature calculated.

ground acceleration: the acceleration of the ground resulting from the motion of a given earthquake. The maximum ground acceleration is obtained from the ground response spectrum as the acceleration at high frequencies (in excess of 33 Hz).

harsh environment: an adverse environment caused by a postulated design accident event that results in more severe environmental conditions than would normally be expected had the accident event not occurred.

hold points: pre-established critical steps in manufacturing and testing that require the Manufacturer to advise the QAR (quality assurance representative) before proceeding further with the work, subject to the approval of the work up to that point by the QAR. The Manufacturer shall not proceed with the work past the hold point except by written agreement from the purchaser or authorized agent.

housing: a duct section that contains one or more components, each of which may be used for moving, cleaning, heating, cooling, humidifying, or dehumidifying the air or gas stream.

interspace: any space other than the contaminated space or the protected space where the air cleaning system or parts may be located. The interspace may be considered contaminated if its concentration of airborne contamination is higher than the concentration inside that part of the air cleaning system located within the interspace. The interspace may be considered clean if its concentration of airborne contamination is lower than the concentration inside the part of the air cleaning system located within the interspace.

leak tightness: the condition of a component, unit, or system where leakage through the pressure boundary is less than a specified value at a specified differential pressure.

low cycle fatigue: a progressive fracture or cumulative fatigue of a material that may occur in less than 1000 cycles due to a localized stress concentration.

Manufacturer's qualified standard or material: a standard or material used by a particular manufacturer that, by reasons of design or manufacturability, is not identifiable to an industry recognized standard. Where this type of standard or material is used, proof of acceptability will be demonstrated by the Manufacturer's design calculations or tests.

Material Manufacturer: as used in this Code, this term refers to an organization that certifies that metallic or nonmetallic material furnished is in compliance with requirements of the basic material specifications. In addition, the Material Manufacturer supervises and directly controls one or more of the operations that affect the material properties required by the material specification, and verifies the satisfactory completion of all the requirements of the material specification performed prior to that certification.

Material Supplier: as used in this Code, this term refers to an organization that supplies metallic or nonmetallic material produced and certified by Material Manufacturers, but does not perform any operations that affect the material properties required by the material specification.

maximum deflection value ($d_{max.}$)*:* the maximum deflection, including equipment tolerances, that can be sustained without impairing system function.

narrow band response spectrum: a response spectrum that describes the motion indicating that a single frequency excitation predominates.

natural frequency: the frequency at which a linear–elastic structure will tend to vibrate once it has been set into motion. A structure can possess many natural frequencies. The lowest of these is called the fundamental natural frequency. Each natural frequency is associated with a mode shape of deformation.

nonsafety-related equipment: equipment that is not required to perform safety-related functions.

Nuclear Air Treatment System (NATS): A system designed to remove radioactive gaseous and particulate contaminants from a near-atmospheric pressure gas: stream without significantly altering the physical properties of the inert carrier gases. Such a system contains one or both of the high efficiency gas cleaning components referred to as HEPA filters and impregnated carbon (or inorganic silver-containing) adsorbers. These items are usually accompanied by one or more auxiliary air treatment components such as prefilters, afterfilters, heaters, coils, and moisture separators. Accessories such as dampers, ducts, plenums, and fans are included when they are within or are a part of a defined pressure boundary.

nuclear power plant operating modes: plant operations during any of the five conditions described in Section 3.0 of ANSI/ANS 51.1 and ANSI/ANS 52.1.

nuclear power plant process systems: systems that are integral parts of a nuclear power plant, comprising components that may be provided to perform a specific function for normal operation of the plant, mitigation of the consequences of design basis events or accidents, or safe shutdown of the plant following a design basis event or accident.

nuclear safety function: a term applying to any component, system, or structure performing a nuclear safety function that is necessary to ensure

(*a*) the integrity of the reactor coolant pressure boundary or primary coolant boundary

(*b*) the capability to shut down the reactor and maintain it in a safe shutdown condition

(*c*) the capability to prevent or mitigate the consequences of plant conditions that could result in potential offsite exposures that are comparable to the guideline exposures of 10 CFR 100.

nuclear safety related: a term applying to one of the following

(*a*) structures, systems, or components designed to perform a nuclear safety function

(*b*) drawings, specifications or procedures, analyses, and other documents used to determine or describe parameters affecting structures, systems, or components that are designed to perform a nuclear safety function

(*c*) services to design, purchase, fabricate, handle, ship, store, clean, erect, install, test, operate, maintain, repair, refuel, and modify structures, systems, or components that are designed to perform a nuclear safety function

octave: the interval between any two frequencies having the ratio 2:1.

operating basis earthquake (OBE): the earthquake that, considering the regional and local geology and seismology and specific characteristic of local subsurface material, could reasonably be expected to affect the plant site during the operating life of the plant. It is that earthquake which produces the vibratory ground motion for which those nuclear safety-related features of the plant necessary for subsequent operation without undue risk to the health and safety of the public are designed to remain functional.

Owner: the organization legally responsible for the construction and/or operation of a nuclear facility including but not limited to one who has applied for, or who has been granted, a construction permit or operating license by the regulatory authority having lawful jurisdiction.

performance test: a test made on an individual production item or lot of a product to verify its performance in accordance with specified requirements.

periodic maintenance: regularly scheduled equipment upkeep.

plenum: a section of duct in the air flow path that has a sufficient cross-sectional area and depth to cause substantial reduction in flow velocities. The plenum may contain flow adjustment devices and may collect and distribute several air or gas streams.

protected space: any enclosed or outdoor space that has its concentrations of airborne toxic or radioactive materials limited to acceptable levels by action of a cleaning system.

quality control administration: the management and documentation that ensures that the specified quality control examination is performed.

quality control examination: the comparison of the physical, chemical, or other characteristics of a material, component, part, or appurtenance to specified acceptance standards.

resonance: a structural response to a dynamic input, characterized by vibration of the structure at its natural frequency.

required response spectrum (RRS): the response spectrum issued by the user or his agent as part of his specification for proof testing, or artificially created to cover future applications. The RRS constitutes a requirement to be met.

response spectrum: a plot of the maximum response of single degree of freedom bodies, at a damping value expressed at a percent of critical damping of different natural frequencies, when these bodies are rigidly mounted on the surface of interest (that is, on the ground for the ground response spectrum or on the floor for the floor response spectrum) when that surface is subjected to the motion of a given earthquake as modified by an intervening structure.

safe shutdown earthquake (SSE): the earthquake that is based upon evaluation of the maximum earthquake potential considering regional and local geology and seismology and specific characteristics of local subsurface material. It is the earthquake that produces the maximum vibratory ground motion for which nuclear safety-related structures, systems, and components are designed to perform their nuclear safety function.

safety-related equipment: equipment for air and gas treatment systems or equipment that is essential to *(a)* the capability to shut down the reactor and maintain it in a safe shutdown condition

(b) the capability to prevent or mitigate the consequences of accidents that could result in offsite exposures in excess of the limits stated in 10 CFR 100

seismic/nonsafety-related equipment: equipment that is not required to perform a safety function during or following plant Service Level B, C, or D, but that must retain its structural integrity so as not to damage, degrade, or interfere with the performance of safety functions by any safety-related equipment or components.

service factor: the allowable loading above the nameplate rating at which the driver may be operated without exceeding the designated temperature rise of the driver. Service factor denotes the safety margin built into a driver.

shutdown: the procedure of making a reactor subcritical or the state of a reactor in a subcritical condition.

single failure: a random occurrence that results in loss of capability of a component to perform its intended nuclear safety function. Multiple failures resulting from a single occurrence are considered to be a single failure.

NOTE: Fluid and electrical systems are considered to be designed against single failure if neither a single failure of any active component [assuming passive components function properly) nor a single failure of any passive component (assuming active components function properly] result in a loss of the capability of the system to perform its safety function.

sound: an alteration in pressure, stress, particle displacement, and particle velocity, which is propagated in an elastic material, or the superposition of such propagated alternations.

sound power: the total energy radiated by a source per unit of time.

sound power level (L_w): the amount of power radiated from a noise source relative to a reference power level. In decibels, it is 10 times the logarithm to the base 10 of the ratio of the acoustic power in watts to the reference power. The reference power is 10^{-12} W.

$$L = 10 \log W / 10^{-12}$$

stiffeners: internal or external members used to reinforce duct, housing, and plenums, which may be used to transmit loads and reactions to supports.

structural analysis report: a document which, through the use of applicable and recognized mathematical techniques, verifies that the equipment under consideration possesses sufficient structural integrity to withstand the specified combination of normal, abnormal, and design basis event loads. Acceptance criteria shall be defined by the design specification.

structures and supports: the entire range of the structural elements used that fill either or both functions of carrying the weight of components or providing them with structural stability. The term includes hangers, which are generally considered to be those elements that carry the weight from above with the supporting members being mainly in tension. Likewise, the term includes supports that carry the weight from below with the supporting members being mainly in compression. The term also includes spring-loaded sway braces, snubbers, and other devices used to provide structural stability during any of the specified operating conditions.

test response spectrum (TRS): the response that is constructed using analysis or derived using spectrum analysis equipment based on the actual motion of the test machine.

total enclosed, air over (TEAO): a driver intended for cooling by a minimum flow of air over the driver.

water gage: the measure of pressure expressed as height of water column in inches or millimeters.

witness points: operations in manufacturing and testing that require the Manufacturer to advise the QAR before proceeding further so that the subsequent operation may be witnessed by the QAR.

ARTICLE AA-2000 REFERENCED DOCUMENTS (09)

Each Code section shall delineate the referenced documents applicable to that section. References applicable to Section AA, or that have common application are listed in this section. Unless otherwise shown or noted, the latest edition and addenda are applicable.

10 CFR, Code of Federal Regulations, Title 10; Energy, Parts 0 to 199

Publisher: Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-9325

ANSI/ABMA 9-1990 (R2000), Load Ratings and Fatigue Life for Ball Bearings

ANSI/ABMA 11-1990 (R1999), Load Ratings and Fatigue Life for Roller Bearings

Publisher: American National Standards Institute (ANSI), 25 West 43rd Street, New York, NY 10036

ASME B31.1, Power Piping

ASME NQA-1, Quality Assurance Program Requirements for Nuclear Facility Applications

Boiler and Pressure Vessel Code ("the ASME Code")
- Section II, Material Specifications
- Section III, Nuclear Power Plant Components
- Section V, Nondestructive Examination
- Section IX, Welding and Brazing Qualifications

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

ASNT SNT TC 1A-2001, Recommended Practice No. SNT-TC 1A

Publisher: American Society for Nondestructive Testing (ASNT), 1711 Arlingate Lane, P.O. Box 28518, Columbus, OH 43228-0518

ASTM A 370A-2007, Standard Test Methods and Definitions for Mechanical Testing of Steel Products

ASTM A 380-2006, Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems

ASTM D 3843-2000, Standard Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities

ASTM D 4227-2005, Standard Practice for Qualification of Coating Applicators for Application of Coatings to Concrete Surfaces

ASTM D 4228-2005, Standard Practice for Qualification of Coating Applicators for Application of Coatings to Steel Surfaces

ASTM D 4537A-2004, Standard Guide for Establishing Procedures to Qualify and Certify Personnel Performing Coating Work Inspection in Nuclear Facilities

ASTM D 5161A-2004, Standard Guide for Specifiying Inspection Requirements for Coating and Lining Work (Metal Substrates)

ASTM E 165-2002, Standard Test Method for Liquid Penetrant Examination

Manual of Coating Work for Light-Water Nuclear Power Plant Primary Containment and Other Safety-Related Facilities, Chapter 8, First Edition, 1979

Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

AWS A2.4-2007, Standard Symbols for Welding, Brazing, and Nondestructive Examination

AWS A3.0-2001, Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying

AWS A5.8/A5.8M-2004, Specifications for Filler Metals for Brazing and Braze Welding

AWS C1.1/C1.1M-2000 (R2006), Recommended Practice for Resistance Welding

AWS C3.3-2002, Recommended Practices for Design, Manufacture, and Examination of Critical Brazed Components

AWS D1.1/D1.1M-2006, Structural Welding Code—Steel—20th Edition

AWS D1.3-1998, Structural Welding Code—Sheet Steel

AWS D9.1/D9.1M-2006, Sheet Metal Welding Code

AWS Z49.1-2005, Safety in Welding, Cutting and Allied Processes

Publisher: American Welding Society (AWS), 550 NW LeJeune Road, Miami, FL 33126

IEEE 323-2003, Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations

IEEE 334-2006, Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations

IEEE 344-2004, Recommended Practice for Seismic Qualifications of Class 1E Equipment for Nuclear Power Generating Stations

IEEE 112-2004, Standard Test Procedures for Polyphase Induction Motors and Generators

Publisher: Institute of Electrical and Electronics Engineers (IEEE), 445 Hoes Lane, Piscataway, NJ 08854

Manual of Steel Construction, Thirteenth Edition

Publisher: American Institute of Steel Construction (AISC), One East Wacker Drive, Suite 700, Chicago, IL 60601-1802

NCIG-01, Visual Weld Acceptance Criteria for the Structural Welding at Nuclear Power Plants, Revision 2

NCIG-03, Training Manual for Inspectors of Structural Welds at Nuclear Power Plants Using the Acceptance Criteria of NCIG-01, Revision 1

Publisher: Nuclear Construction Issues Group (NCIG)

NEMA MG-1-2006, Motors and Generators

Publisher: National Electrical Manufacturers Association (NEMA), 1300 North 17th Street, Rosslyn, VA 22209

SSPC-SP10, Near-White Metal Blast Cleaning

Publisher: The Society for Protective Coatings (SSPC), 40 24th Street, Pittsburgh, PA 15222-4656

ARTICLE AA-3000
MATERIALS

Each section of this Code delineates material requirements applicable to that section. In addition, the materials listed in Section III of the ASME Boiler Pressure Vessel Code (hereafter referred to as the ASME Code) are acceptable materials.

The ASME or ASTM numbers for acceptable materials designate a chemical composition and a material thickness limit. A grade designation is usually required to determine the minimum strength of the material. If the specific grade material has an assigned minimum yield and tensile strength, these values shall be used for design purposes. If values have not been established and assigned, then tests in accordance with the procedures outlined in ASTM A 370 shall be performed to obtain these values. Results of mill-certified tests performed as above designating these values shall be calculated by the procedures in Article AA-4000.

ARTICLE AA-4000
STRUCTURAL DESIGN

AA-4100 SCOPE

This article contains the minimum requirements for structural design of equipment for which this Code is applicable. Nonmandatory Appendices AA-A through AA-D contain guidance on implementing these rules.

AA-4110 ENVIRONMENTAL QUALIFICATION

Electrical equipment shall be qualified to meet the environmental conditions specified for the equipment in Divisions II and III of this Code.

AA-4200 DESIGN CRITERIA

This subarticle contains the load, stress, deflection, and other criteria for the design of equipment. Verification of equipment design shall be based on calculations or tests, or a combination of both.

AA-4210 LOAD CRITERIA

All loads as specified in the design specification or the applicable equipment section of this Code shall be taken into account in designing equipment and shall include, but not be limited to, the loads listed in AA-4211.

AA-4211 Loads

additional dynamic loads (ADL): loads resulting from system excitation due to structural motion caused by safety relief-valve actuation and other hydrodynamic loads due to design basis accident (DBA), small pipe break accident (SBA), and intermediate pipe break accident (IBA); also, liquid slosh in tanks and vessels and mechanical shock loads.

constraint of free end displacement loads (T): loads caused by constraint of free end displacement that results from thermal or other movements.

dead weight (DW): the weight of equipment or ductwork including supports, stiffeners, insulation, all internally or externally mounted components or accessories, and any contained fluids.

design pressure differential (DPD): dynamic pressure loads resulting from a DBA, IBA, or SBA.

design wind (W): loads due to design hurricane, design tornado, or other abnormal meteorological condition that could occur infrequently.

external loads (EL): applied loads caused by attached piping, accessories, or other equipment.

fluid momentum loads (FML): loads other than those listed here, such as the momentum and pressure forces due to fluid flow.

live loads (L): loads occurring during construction and maintenance and loads due to snow, ponded water, and ice.

normal loads (N): loads consisting of normal operating pressure differential, system operating pressure transients, dead weight, external loads, and inertia loads.

$$N = \text{NOPD} + \text{SOPT} + \text{DW} + \text{EL} + \text{FML}$$

normal operating pressure differential (NOPD): the maximum positive or negative pressure differential that may occur during normal plant operation, including plant startup and test conditions; included are pressures resulting from normal airflow and damper or valve closure.

seismic loads: loads that are the result of either an operating basis earthquake (OBE) or safe shutdown earthquake (SSE). Both orthogonal components of the horizontal seismic excitation are applied simultaneously

TABLE AA-4212
LOAD CONDITIONS

Component Service Level	Load Combination
A	$N + T$ $N + L$
B	$N + W + T$ and N + OBE + T + ADL
C [Note (1)]	$N + W + T$ and N + SSE + ADL
D	N + DPD + SSE + ADL

GENERAL NOTES:
(a) Constraint of free end displacement loads, external loads, additional dynamic loads, and fluid momentum loads are associated with the service level of concern and are not, in general, the same for all service levels.
(b) If particular equipment design criteria require additional load combinations, those requirements shall be stated in the equipment design specification.

NOTE:
(1) The SSE loading in Service Level C may be replaced with the OBE loading if component operability is required during or after a seismic event and operability can be assured by test or analysis.

with the vertical seismic loading. These seismic forces are applied in the directions that produce worst-case stresses and deflections.

system operational pressure transient (SOPT): overpressure transient loads due to events such as rapid damper, plenum or housing door, and valve closure, or other normal loads that result in a short duration pressure differential.

AA-4212 Load Combinations

The load combinations to be considered for equipment design are given in Table AA-4212.

AA-4213 Service Conditions

The equipment design specification or the applicable equipment section of this Code shall identify the loads and shall designate the appropriate design and service limits for design of equipment systems. The design and service loads shall be established considering all plant and system operating conditions anticipated or postulated to occur during the intended service life of the equipment systems.

AA-4214 Design and Service Limits

AA-4214.1 Design Limits. The limits for design loading are designated as design limits.

AA-4214.2 Service Limits. The equipment design specification may designate service limits as defined in (a) through (d) below.

(a) Level A Service Limits. Level A service limits are those sets of limits that must be satisfied for all loads identified in the equipment design specification to which the equipment may be subjected in the performance of its specified normal service function.

(b) Level B Service Limits. Level B service limits are those sets of limits that must be satisfied for all loads identified in the equipment design specification for which these service limits are designated. Equipment must withstand load combinations specified for Level B service limits without damage that would require repair.

(c) Level C Service Limits. Level C service limits are those sets of limits that must be satisfied for all loads identified in the equipment design specification for which these service limits are designated. These sets of limits permit large deformations in areas of structural discontinuity.

(d) Level D Service Limits. Level D service limits are those sets of limits that must be satisfied for all loads identified in the equipment design specification for which these service limits are designated. These sets of limits permit gross and general deformations with some consequent loss of dimensional stability and permit damage requiring repair, which may require removal of the component from service.

AA-4220 STRESS CRITERIA

AA-4221 Stress Limits

The maximum normal stress limits for the service levels defined in AA-4212 are stipulated in AA-4320 and in AA-4330.

AA-4230 DEFLECTION CRITERIA

AA-4231 Deflection Limits

The maximum deflection d_{max}, including all equipment tolerances, that may be sustained so that equipment function is not impaired shall be determined. This maximum deflection may be defined in the equipment design specification or the applicable equipment section of this Code. Alternatively, it may be determined by analysis or test, or both. The allowable deflections for the load combinations of AA-4212 are as shown in Table AA-4231.

TABLE AA-4231
DEFLECTION LIMITS

Service Level	Deflection Limit
A [Note (1)]	$d_{all} \leq 0.6\ d_{max}$
B [Note (1)]	$d_{all} \leq 0.6\ d_{max}$
C [Note (2)]	$d_{all} \leq 0.9\ d_{max}$
D [Note (2)]	$d_{all} \leq 0.9\ d_{max}$

GENERAL NOTES:
(a) If particular equipment design criteria require more restrictive limits on deflections, those requirements will be stated in the applicable equipment section of this Code.
(b) Deflections shall be limited to prevent transmission of excessive load to other components such as filter frames, coils, bearings, and access doors.

NOTES:
(1) Deflections shall be limited to values that prevent buckling in primary load carrying elements.
(2) Deflections shall be limited to values as described in AA-4323.

AA-4240 OTHER CRITERIA

AA-4241 Vibration Isolation

Types of vibration isolation devices and their efficiencies shall be as specified in the equipment design specification or the applicable equipment section of this Code. Vibration isolation devices shall be designed with adequate restraints to resist the loads generated under any service level.

AA-4242 Provisions for Relative Movement

Consideration shall be given to the relative motion between equipment systems and their supporting elements, as this will affect ability to function. When clearances or travel ranges, or both, are required to accommodate movements of equipment systems and their supporting elements, sufficient design margins shall be introduced to allow for fabrication and installation tolerances.

AA-4243 Structural Attachments

Structural attachments may be of either the integral or nonintegral type, as defined in AA-4243.1 and AA-4243.2.

AA-4243.1 Integral Attachments

(a) Integral attachments are those fabricated as an integral part of the equipment. Consideration shall be given to local stresses induced in equipment by integral attachments.

(b) Integral attachments used as part of an assembly for the support or guiding of the equipment may be welded directly to the equipment, provided the design is adequate for all applicable service conditions and load combinations set forth in AA-4212 and the requirements of AA-6300 are met.

AA-4243.2 Nonintegral Attachments. Nonintegral attachments are those that are bolted, pinned, clamped to, or bear on the equipment. Consideration shall be given to the mechanical connection and local stresses induced in the equipment by nonintegral attachments.

AA-4300 DESIGN OF EQUIPMENT SYSTEMS AND THEIR SUPPORTING ELEMENTS

AA-4310 GENERAL REQUIREMENTS

AA-4311 Acceptability

The requirements for acceptability of the design of equipment systems and their supports are given in AA-4311.1 through AA-4311.3.

AA-4311.1 The design shall be such that the allowable stresses will not exceed the limits given in this subarticle. Design stress values S, yield strength S_y, and ultimate strength S_u are given in Article AA-3000 references. These values form the basis for determining allowable stress, depending on analysis type.

AA-4311.2 For self-limiting loads under Service Level D, localized material yielding is permitted, provided that yielding does not form a mechanism that would result in collapse of the structure.

AA-4311.3 For configurations where compressive stresses occur, critical buckling shall be considered.

AA-4312 Basis for Determining Stresses in Design by Analysis

The theory of failure for combining stresses for the design of equipment systems and their supporting elements used in the rules of this subarticle is the maximum stress theory. In the maximum stress theory, the controlling stresses are the membrane and bending stresses.

AA-4312.1 Plate- and Shell-Type Components: Analysis Procedures. The analysis procedures for plate- and shell-type systems shall be in accordance with the rules of AA-4320. Consideration shall be given to the governing mode of failure. Several analyses that might include, but are not necessarily limited to, the following, may be required to determine the limiting case:

(a) elastic analysis based on maximum stress theory
(b) elastic analysis based on maximum deflection
(c) elastic analysis based on allowable buckling stress (see AA-4323)

AA-4312.2 Linear-Type Systems and Supports: Analysis Procedures. Elastic analysis based on maximum stress theory in accordance with the rules of AA-4330 shall be used for the design of linear-type systems.

AA-4312.3 Applicability of Mathematical Analysis. The design procedure that may be used shall be either analysis or test, or a combination, and is dependent upon the nature of the structural system under consideration. The choice shall be based on the practicality of the method for the type, size, shape, and complexity of the equipment, and the reliability of the conclusions. The analysis method is not recommended for complex equipment that cannot be modeled to correctly describe the static and dynamic structural characteristics of the equipment. Furthermore, analysis without testing may be acceptable only if structural integrity alone can ensure the design intended function. If mathematical analysis is inadequate for all or part of the design verification, a suitable test program shall be implemented in accordance with the rules of AA-4350.

AA-4313 Terms Related to Design by Analysis

The terms used in the design of equipment systems and their supports are shown in AA-4313.1 through AA-4313.11.

AA-4313.1 Gross Structural Discontinuity. Gross structural discontinuity is a geometric or material discontinuity that affects the stress or strain distribution throughout the entire thickness of the member. Gross discontinuity-type stresses are those portions of the actual stress distributions that produce net bending and membrane force resultants when integrated through the thickness. Examples of gross structural discontinuities are junctions between parts of different diameters or thicknesses, and flange-to-shell junctions.

AA-4313.2 Normal Stress. Normal stress is the component of stress normal to the plane of reference, also referred to as the direct stress. Usually the distribution of normal stress is not uniform throughout the thickness of a part. Therefore, the normal stress is considered to be made up of two components, one of which is uniformly distributed and equal to the average value of stress across the thickness under consideration, and the other of which varies from this average value with the location across the thickness.

AA-4313.3 Membrane Stress. Membrane stress is the component of normal stress that is uniformly distributed and equal to the average of stress across the thickness of the section under consideration.

AA-4313.4 Bending Stress. Bending stress is the variable component of normal stress described in AA-4313.2. The variation may or may not be linear across the thickness.

AA-4313.5 Shear Stress. Shear stress is the component of stress tangent to the plane of reference.

AA-4313.6 Primary Stress. Primary stress is any normal stress or a shear stress developed by an imposed loading that is necessary to satisfy the laws of equilibrium of external and internal forces and moments. The basic characteristic of a primary stress is that it is not self-limiting. Primary stresses that considerably exceed the yield strength will result in failure or, at least, in gross distortion. A general primary membrane stress is one that is so distributed in the structure that no redistribution of load occurs as a result of yielding. An example of primary stress is general membrane stress in a circular cylindrical shell due to distributed live loads.

AA-4313.7 Secondary Stress. Secondary stress is a normal stress or a shear stress developed by the constraint of adjacent material or by self-constraint of the structure. The basic characteristic of a secondary stress is that it is self-limiting. Local yielding and minor distortions can satisfy the conditions that cause the stress to occur, and failure from one application of the stress is not to be expected. An example of secondary stress is bending stress at a gross structural discontinuity.

AA-4313.8 Peak Stress. A peak stress includes an increment added to primary or secondary stresses by a stress riser, such as a notch.

AA-4313.9 Free End Displacement. Free end displacement consists of the relative motions that would occur between an attachment and connected structure or equipment if the two members were separated. Examples of such motions are those that would occur because of relative thermal expansion of ductwork, piping, equipment, and equipment supports, or because of movements imposed upon the equipment by sources other than the piping.

AA-4313.10 Limit Analysis. Limit analysis is a method used to compute the maximum load or combination of loads a structure made of ideally plastic (non-strain hardening) material can carry. Among the methods used in limit analysis is a technique that assumes elastic, perfectly plastic, material behavior, and a constant level of moment or force in those redundant structural elements in which the level of membrane yield, plastic hinge formation, or critical buckling load in the member has been reached. Any increase in load must be accompanied by a stable primary structure until a failure

TABLE AA-4321
PLATE- AND SHELL-TYPE COMPONENTS: PRIMARY STRESS ALLOWABLES

Service Level	Stress Category: General Membrane σ_1 [Note (1)]	Stress Category: Membrane and Bending $\sigma_1 + \sigma_2$ [Note (2)]
A	1.0 S [Note (3)]	1.5 S
B	1.0 S	1.5 S
C	1.2 S	1.8 S
D	Lesser of 1.5 S or 0.4S_u [Note (3)]	Lesser of 2.25 S or 0.6 S_u

NOTES:
(1) General membrane stress σ_1 is the average membrane stress across the solid section, excluding discontinuities and concentrations.
(2) Bending stress σ_2 is the linearly varying portion of stress across the solid section under consideration, excluding effects of discontinuities and concentrations.
(3) S = design stress
S_u = ultimate stress
See Article AA-3000 references.

mechanism defined by the lower bound theorem of limit analysis is reached in the primary structure.

AA-4313.11 Collapse Load: Lower Bound. The collapse load is the load at which deformations of an ideally plastic structure increase without bound. If, for a given load, any system of stresses can be found that everywhere satisfies equilibrium and nowhere exceeds the material yield strength, the load is at or below the collapse load. This is the lower bound theorem of limit analysis, which permits calculation of a lower bound to the collapse load.

AA-4320 DESIGN VERIFICATION OF PLATE- AND SHELL-TYPE COMPONENTS AND THEIR SUPPORTING ELEMENTS

AA-4321 Stress Analysis

A detailed stress analysis of all major structural plate- and shell-type components and their supporting elements shall be prepared in sufficient detail to show that each of the stress limitations of Table AA-4321 is satisfied when the component and its supporting elements are subjected to the load combinations of AA-4212.

AA-4322 Stress Limits

AA-4322.1 Design Loads. The maximum normal stress limits are satisfied for the design loading combinations as stipulated in AA-4212, or as stated in the equipment design specification if the requirements of eqs. (1) and (2) are met (see AA-4322.2 for service limits associated with the service levels of AA-4212).

$$\sigma_1 \leq 1.0S \quad (1)$$

$$\sigma_1 + \sigma_2 \leq 1.5S \quad (2)$$

where

S = design stress value from Article AA-3000 references

σ_1 = membrane stress

σ_2 = bending stress

AA-4322.2 Service Limits. The maximum normal stress limits for Service Levels A through D are as stipulated below.

(a) Level A Service Limits. Level A service limits are satisfied for the service conditions of AA-4214.2(a) for which these limits are designated in the equipment design specification if the requirements of eqs. (1) and (2) are met.

(b) Level B Service Limits. Level B service limits are satisfied for the service conditions of AA-4214.2(b) for which these limits are designated in the equipment design specification if the requirements of eqs. (1) and (2) are met.

(c) Level C Service Limits. Level C service limits are satisfied for the service conditions of AA-4214.2(c) for which these limits are designated in the design specification if the requirements of eqs. (1) and (2) are not exceeded by more than 20%.

(d) Level D Service Limits. Level D service limits are satisfied for the service conditions of AA-4214.2(d) for which these limits are designated in the equipment design specification if the requirements of eqs. (3) and (4) are met.

$$\sigma_1 \leq \text{lesser of } 1.5S \text{ or } 0.4S_u \quad (3)$$

$$\sigma_1 + \sigma_2 \leq \text{lesser of } 2.25S \text{ or } 0.6S_u \quad (4)$$

TABLE AA-4323
LINEAR-TYPE SYSTEMS: PRIMARY STRESS ALLOWABLES

Service Level	Stress Category: General Load Induced Stress	Stress Category: Stress From Constraint of Free End Displacements
A	$\bar{S}$ [Note (1)]	$3\bar{S}$
B	$\bar{S}$	$3\bar{S}$
C [Note (2)]	$1.5\,\bar{S}$	NA
D [Note (2)]	$\dfrac{1.2\,S_y}{F_t}(\bar{S})$ not to exceed $\dfrac{0.7\,S_u}{F_t}(\bar{S})$	NA

GENERAL NOTE: NA = not applicable

NOTES:
(1) $\bar{S}$ refers to the primary allowable stresses developed in the ASME Code, Section III, Division 1, Subsection NF-3322.1 through NF-3322.8.
F_t = allowable tensile stress
S_u = ultimate stress
S_y = yield stress
Values are found in Article AA-3000 references.
(2) Loads shall not exceed 0.67 times the critical buckling load of the primary framing system.

where

S_u = specified minimum ultimate tensile strength of material found in Article AA-3000 references.

Other terms are as defined in AA-4322.1.

AA-4323 Buckling and Stress Limits Set by Buckling Stress Criteria

The allowable deflection due to compressive loads shall be limited to prevent postbuckling failure in the plate. Buckling stresses shall be verified against Service Level D allowable values of Table AA-4323.

AA-4323.1 Local Yielding and Buckling. The maximum stress for the load-carrying capacity of plates shall be based on the postbuckling behavior of the plate.

(a) When buckling governs, deflections shall be computed based on effective width concept.

(b) When local yielding governs, deflections shall be computed based on the average or reduced section.

AA-4323.2 Lateral Buckling. Critical lateral buckling stresses shall be computed based on moment resisting capacity.

AA-4323.3 Flexural Buckling. Maximum stresses shall be computed based on stability considerations.

AA-4323.4 Torsional Buckling. Maximum shear stresses shall be computed based on the torsional capacity of the section.

AA-4330 DESIGN VERIFICATION OF LINEAR-TYPE SYSTEMS BY ANALYSIS

AA-4331 Stress Analysis

A detailed stress analysis of all major linear-type equipment shall be prepared in sufficient detail to show that each of the stress limitations of AA-4332 is satisfied when the equipment is subjected to the load combinations of AA-4212.

AA-4332 Stress Limits

AA-4332.1 Design Level A and Level B Limits. Design Level A and Level B limits are identical and are given in the ASME Code, Section III, Division 1 Subsection NF. The allowable stress for the combined mechanical loads and effects that result from constraint of free end displacements (see AA-4313.6), but not thermal or peak stresses, shall be limited to three times the stress limits of the ASME Code, Section III, Division 1 Subsection NF.

AA-4332.2 Level C Limits. The stress values for Level C limits may be increased by 50% over the values given in the ASME Code, Section III, Division 1 Subsection NF. Constrained free end displacement and differential support motion effects need not be considered. Primary stresses shall not exceed 0.67 times the critical buckling strength of the primary framing system. In such analysis, local instabilities, such as compression, flange, and web buckling shall be evaluated. In addition, overall buckling in compression members shall be evaluated.

AA-4332.3 Level D Limits. If the equipment design specification specifies service loads for which Level D limits are designated, the following rules shall be used in evaluating them independently of all other design and service loadings:

(a) The allowable stresses presented in the ASME Code, Section III, Division 1 Subsection NF, may be increased by a factor of 1.2 (S_y/F_t), but not to exceed a factor of 0.7 (S_u/F_t), where S_y is the specified minimum yield strength of the material, F_t is the allowable tensile stress, and S_u is the ultimate tensile stress.

(b) Primary stresses shall not exceed 0.67 times the critical buckling strength of the primary framing system. In such analysis, local instabilities such as compression, flange, and web buckling shall be evaluated. In addition, overall buckling in compression members shall also be evaluated.

AA-4340 FUNCTIONABILITY REQUIREMENTS

The stress limits specified by this Code do not ensure that the equipment will be able to perform the required safety function. Functionability is ensured by following the rules stipulated below.

AA-4341 Functionability of Mechanical Systems

The methods of AA-4341.1, AA-4341.2, or AA-4341.3 shall be used to ensure operability of mechanical systems and their supporting elements.

AA-4341.1 The Service Levels C and D stress limits of AA-4322 and AA-4332 shall be reduced to the Levels B and C stress limits, respectively.

AA-4341.2 The deflections at all critical locations shall be calculated and ensured to be within the allowable values in AA-4230. These critical locations shall be given in the applicable equipment section of this Code or by the equipment design specification, or by both. Furthermore, for equipment where buckling is of concern, deflection checks shall be performed for the component or support load condition as specified in AA-4323.

AA-4341.3 The functionability of the equipment shall be verified experimentally.

AA-4342 Functionability of Electrical Systems

Operability of electrical systems and their supporting elements shall be ensured using the method outlined in AA-4350.

AA-4350 DESIGN VERIFICATION BY TESTING

AA-4351 General

Design verification by testing shall be in accordance with the rules of this subarticle. Seismic tests are to be performed by subjecting the equipment to vibratory motion that conservatively simulates that postulated at the equipment mounting during the OBE and an SSE. In addition, other loads that may occur concurrently with the seismic event shall be accounted for (see AA-4212). The rules of this subarticle are consistent with and complementary to ANSI/IEEE 344.

AA-4351.1 Equipment Mounting. The equipment to be tested shall be mounted on the test machine in a manner that simulates the intended service mounting. The mounting method shall be the same as that recommended for actual service, which includes the recommended bolt size and configuration, weld pattern, and type. The effect of all attached hardware such as electrical connections, conduit, sensing lines, piping, and ductwork shall be considered. The method of mounting the equipment to the test machine shall be documented and shall include a description of any interposing fixtures and connections. Effect of such fixtures and connections shall be evaluated if they are only used during qualification and not for inservice mounting. Equipment orientation shall be along the major and minor axes for each test condition unless specified otherwise by the equipment design specification or the applicable equipment section of this Code.

AA-4351.2 Equipment Monitoring. Sufficient monitoring equipment shall be used to evaluate the performance of the safety function of the equipment before, during, and after the test. In addition, sufficient vibration monitoring equipment shall be used to allow determination of the applied vibration levels. In addition to the monitoring of the test machine, as many points of the equipment shall be monitored as needed to provide information for evaluating the test results.

AA-4351.3 Exploratory Tests. Exploratory vibration tests required for all qualification tests except multiple frequency tests (see AA-4356) shall be run on equipment to aid in the determination of the test method that will best qualify or determine the dynamic characteristics of the equipment. As per AA-4352, the type of test required to qualify equipment for various applications shall be dependent on the nature and dynamic characteristics of the equipment and the required response spectrum (RRS). If it can be shown that the equipment is not in resonance at any frequency within the frequency range of interest, it shall be considered to act as a rigid body and analyzed or tested accordingly. If there are resonances, one of the various methods of AA-4352 or other justifiable methods shall be used.

The exploratory test shall be in the form of a low level (the level shall be chosen to give a usable signal to noise ratio on the vibration sensing equipment) continuous sinusoidal sweep at a rate no greater than 2 octaves per minute over the frequency range equal to or greater than that to which the equipment is to be qualified. If the configuration of the equipment is such that critical natural frequencies cannot be ascertained due to either the complexity of the equipment or the inaccessibility of critical parts, the exploratory test is not adequate. If the configuration of the equipment is such that critical natural frequencies cannot be ascertained, seismic qualification shall be accomplished by proof testing with a random input motion that shall generate a test response spectrum (TRS) to envelop the RRS. An acceptable alternative shall be to qualify the equipment by a fragility test as described in AA-4351.7.

It must be noted that for certain equipment, due to geometric or material nonlinearities, a low level resonant frequency search may not be a conclusive determinant of equipment resonances. In those cases, a higher level input shall be used and the exploratory tests rerun.

AA-4351.4 Seismic Qualification Tests. Seismic qualification tests designed to show acceptable performance of equipment during and following an SSE shall be preceded by one or more OBE tests. The number of OBE tests shall be given in the equipment design specification and shall be followed by one SSE test. Each minimum test duration shall be given in the equipment design specification.

AA-4351.5 Equipment Loads During Testing. Seismic qualification tests of equipment shall be performed with the equipment subjected to the combined loads identified in AA-4212. These loads shall be simulated and shown to be equal to or greater than those expected. If any load is not included during these tests, justification for the absence of the load shall be provided.

AA-4351.6 Proof Testing. Proof testing is used to qualify equipment for a particular application or to a particular requirement. A proof test requires that the equipment be subjected to one of the tests described in AA-4352 to the particular response spectrum or time history defined for the mounting location of the equipment. An attempt to determine the failure threshold of the equipment need not be made. The equipment shall be tested to the performance requirement of the equipment design specification and need not be tested to its ultimate capability.

AA-4351.7 Fragility Testing. Fragility testing shall be used to qualify the equipment by determining its ultimate capability for performing its safety function. Equipment fragility shall be demonstrated by using sine beat, continuous sine, transient, or multifrequency excitation to random-type waveforms. A measurement of the equipment's fragility level for a particular excitation demonstrates its ultimate capability to perform its safety function while subject to that motion.

AA-4351.8 Device Testing. Devices shall be tested under simulated operating conditions to either the levels dictated by expected service requirements or to their ultimate capability. The devices shall be mounted on the shake table in a manner that dynamically simulates the inservice mounting conditions. If a device is intended to be mounted on a panel, the panel shall be included in the test setup, or the response at the device mounting location shall be monitored in the assembly test (see AA-4351.9), in which case the device shall be mounted directly to the shake table if the inservice excitation can be simulated. Devices shall be tested using the methods described in AA-4352.

AA-4351.9 Assembly Testing. Large complex assemblies shall be tested under simulated operating conditions and monitored for proper functional performance; however, it may not always be practical to simulate all systems simultaneously. It is acceptable, therefore, to test such equipment in an inoperative mode with the actual or simulated devices installed, including any nonsafety-related devices. The test shall determine the vibration response at the device location by either direct measurement at full excitation or by determination of the transfer function from the assembly mounting points to the device mounting point. The resulting vibration response of the device at its location in the assembly shall be less than the vibration to which the device is qualified. The test methods described in AA-4352 shall be used.

AA-4352 Test Methods

Present test methods generally fall into two major categories: proof testing (see AA-4351.6) and fragility testing (see AA-4351.7). The choice of method will depend upon the nature of the equipment and the expected vibration environment. Consideration shall be given to the choice of single axis or multiple axis testing as described in AA-4358.

A proof test seismic simulation waveform shall

(a) produce a TRS that closely envelops the RRS or the applicable portions thereof, using single or multiple frequency input motion

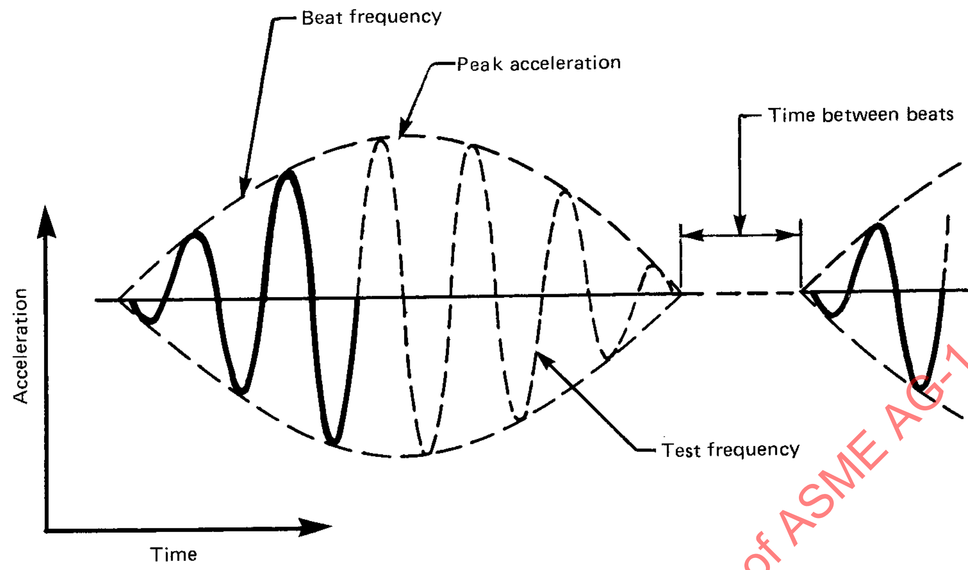
(b) have a peak amplitude equal to or greater than the zero period acceleration (ZPA) of the RRS

(c) have a test duration in accordance with the requirements of AA-4357

AA-4353 Artificially Broadened Required Response Spectra

If single frequency tests are to be conducted to artificially broadened response spectra, tests shall be conducted at frequency intervals on either side of the center frequency of the response spectra. If the center frequency in the broadened area is f_c, testing shall be conducted at this frequency and also at the frequencies $f_c \pm \Delta f_c, f_c \pm 2\Delta f_c, \ldots, f_c \pm n\Delta f_c$, where Δf_c corresponds to a $\frac{1}{6}$ to $\frac{1}{3}$ octave interval, until the entire broadened

FIG. AA-4355.3 SINE BEAT FREQUENCY AND AMPLITUDE



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area has been covered. The TRS generated during each individual test shall have at least the same amplitude as the original narrow-band response spectrum.

AA-4354 Damping Selection

The damping value used in analyzing the test machine motions that generate the TRS shall be the same damping value as that of the RRS.

AA-4355 Single Frequency Tests

If it can be shown that the equipment has no resonances, only one resonance, or distinct resonances that are widely spaced such that the resonance interaction does not reduce the fragility level, single frequency testing may be used to qualify the equipment.

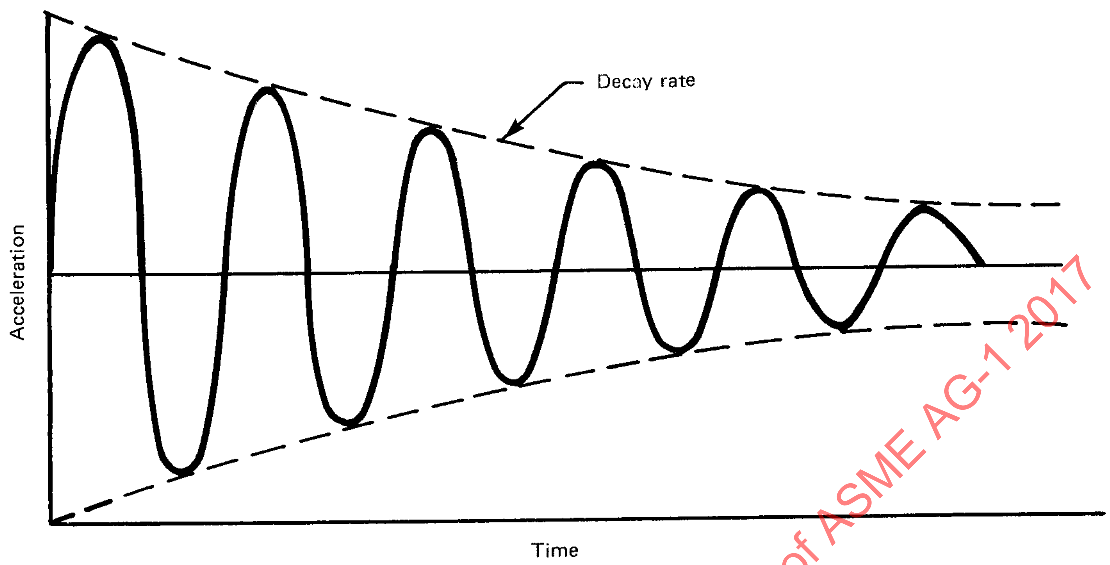
AA-4355.1 Derivation of Test Input Motion. For any input waveform, the shake table motion shall produce a TRS acceleration at the test frequency that is at least equal to that given by the RRS. Additionally, the input motion shall be adjusted to produce a TRS that envelops the RRS at all frequencies, as described in AA-4353. Also, the maximum acceleration of the shake table motion shall be at least equal to the ZPA value of the RRS.

AA-4355.2 Continuous Sine Test. A test at any frequency shall consist of the application of a continuous sinusoidal motion corresponding to the maximum acceleration to which the equipment is to be qualified for the appropriate duration (see AA-4357). The selection of the peak input acceleration and the length of time the test is to be run shall produce at least the maximum response acceleration given in AA-4355.1. The peak input acceleration must be at least equal to the ZPA of the RRS, except at low frequencies where the RRS is below the ZPA for which the value of the RRS must be met (see AA-4358 for requirements on the axial relationships for the test).

AA-4355.3 Sine Beat Test. A test at any frequency shall consist of the application of sine beats of peak acceleration corresponding to that for which the equipment is to be qualified. The sine beats consist of a sinusoid at the frequency and amplitude of interest, as shown in Fig. AA-4355.3. The number of cycles per beat and the peak amplitude of the beat are chosen in accordance with the criteria of AA-4355.1. The peak amplitude of the beat shall at least be equal to the ZPA of the RRS, except at low frequencies where the RRS is below the ZPA for which the value of the RRS must be met.

For a test at any frequency, a series of beats are used to represent low cycle fatigue effects, with a sufficient pause between the beats so that there is no significant superposition of equipment response motion (see AA-4358 for requirements on the axial relationships for the test).

FIG. AA-4355.4 SINE AMPLITUDE DECAY RATE



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AA-4355.4 Decaying Sine Test. A test at any frequency shall consist of the application of decaying sinusoids of peak acceleration corresponding to that for which the equipment is to be qualified. The decaying sinusoids consist of a single frequency of exponentially decaying amplitude, as shown in Fig. AA-4355.4. The peak amplitude and decay rate are chosen to obtain a TRS from the shake table motion that envelops the RRS (see AA-4355.1). The peak amplitude of the sinusoid shall at least be equal to the ZPA of the RRS, except at low frequencies where the RRS is below the ZPA for which the value of the RRS must be met.

For a test at any frequency, a series of decaying sinusoids are used with a sufficient pause between the sinusoids so that there is no significant superposition of equipment response motion. The frequencies of interest are the natural frequencies of the equipment being tested (see AA-4358 for requirements on the axial relationships for the test).

AA-4356 Multiple Frequency Tests

When the seismic ground motion has not been strongly filtered, the floor motion retains the broadband characteristic. In that case, multifrequency testing shall be used for qualification. It is used as a general qualification method as long as the TRS envelops the RRS. Specific input excitation to the test machine shall include a time history motion consisting of random and complex wave shapes.

The test machine input excitation waveforms described in the following subparagraphs shall be employed to test to an RRS level. Other inputs that are not specifically referenced here may also be employed, provided that they envelop the RRS.

AA-4356.1 Derivation of Test Input Motion. For any waveform, the test machine motion must be adjusted so that the TRS envelops the RRS over the frequency range for which the particular test is designed; and, as a minimum, the test machine acceleration must equal the ZPA of the RRS. This comparison must be made using equivalent values of damping. The adjustment of the input motion to produce an envelope spectrum shall be made considering the following factors:

(a) The RRS may have motion amplification over a narrow or broadband of frequencies.

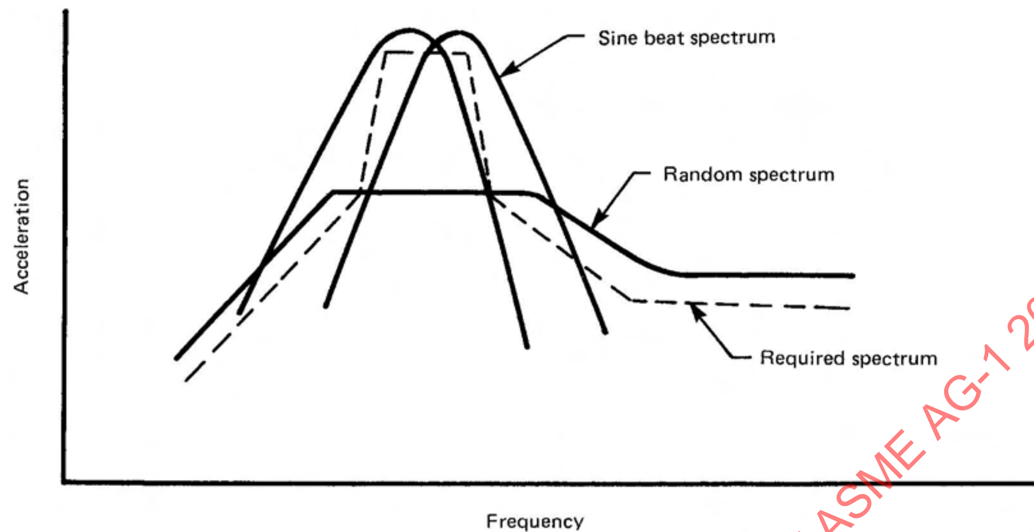
(b) The input excitation waveform may be one of several multiple frequency types.

(c) The equipment being tested may have one of many possible dynamic characteristics.

For assemblies or devices where the dynamic response results from numerous interacting modes, the shake table input excitation must be adjusted so that the TRS envelops the RRS over a frequency range that includes all natural frequencies of the equipment up to the ZPA.

AA-4356.2 Time History Test. A test may be performed by applying to the equipment a specified time history that has been synthesized to simulate the required input to the equipment. It shall be demonstrated that

FIG. AA-4356.4-1 RESPONSE SPECTRUM OF COMPOSITE EXCITATION



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the actual test machine motion was equal to or greater than the required motion.

A time history record may be synthesized to match the RRS using simulation techniques. The duration of the input excitation must be sufficient to simulate the effects of a seismic event. Alternatively, the equipment design specification may contain time history data for use in testing.

AA-4356.3 Random Motion Test. A test shall be performed by applying to the equipment a random excitation, the amplitude of which is controlled in $\frac{1}{3}$ octave or narrower frequency bandwidth filters with individual output gain controls. The excitation shall be controlled to provide a TRS that equals or exceeds the RRS.

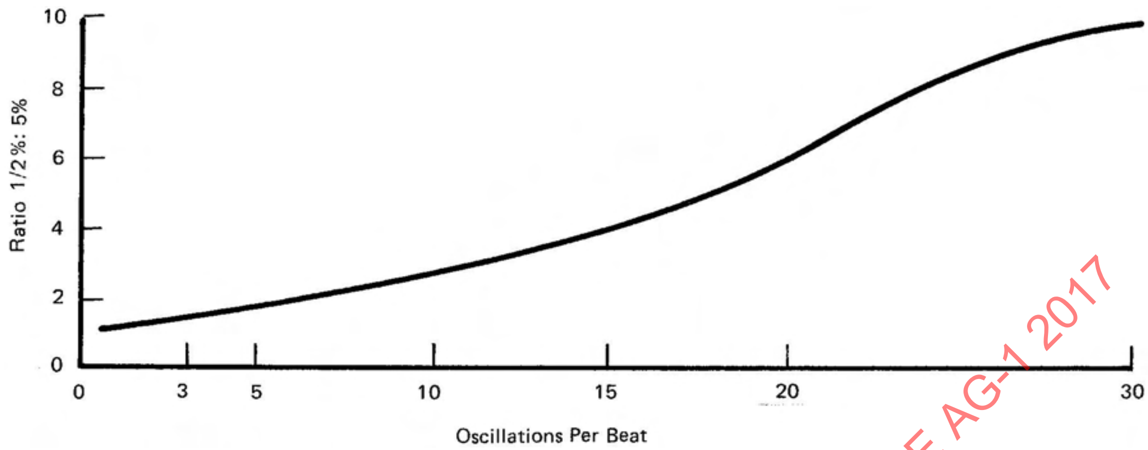
The peak value of the input excitation shall equal or exceed the ZPA of the RRS. The duration of the random excitation shall be as described in AA-4357.

AA-4356.4 Random Motion With Sine Beat Test. To meet an RRS that includes a moderately high peak random excitation, it is acceptable to adjust the random input, as described in AA-4356.3, to equal or exceed as much of the RRS as possible without using a peak input acceleration substantially greater than the ZPA. A sine beat or beats shall be superimposed with random input motion to provide a composite excitation, so that the TRS equals or exceeds the entire RRS over a frequency range that includes the natural frequencies of the equipment up to the ZPA frequency [see Fig. AA-4356.4-1]. The optimum number of oscillations per beat shall be determined from a plot showing the ratio between the $\frac{1}{2}$% and 5% spectrum damping values and the oscillations per beat, as shown in Fig. AA-4356.4-2.

When more than one frequency of sine beats is required to meet the bandwidth of a spectrum, the beats shall be initiated simultaneously. However, if the bandwidth of the peak value of the RRS has been widened to account for uncertainty due to building frequency analysis, the beats shall be applied in sequence or the techniques of AA-4353 shall be applied.

AA-4356.5 Complex Wave Test. This test may be performed by subjecting the equipment to a motion that has been generated by summing a group of sine beats or decaying sinusoids. The frequencies of the component signals shall be spaced at $\frac{1}{3}$ octave or narrower frequency intervals to cover the range required by the RRS. The decaying sinusoids shall have individual decay rate controls covering the range of $\frac{1}{2}$% to 10%. Each frequency must have individual amplitude and phase controls. All frequencies shall be initiated simultaneously with the phase controls set to shape the peak amplitude of the composite waveform. The decay rate shall be varied, and the amplitude of each frequency shall be varied to optimize the fit of the TRS to the RRS. The peak acceleration of the test table during composite waveform excitation shall be greater than or equal to the ZPA of the RRS. The test shall consist

FIG. AA-4356.4-2 OSCILLATIONS PER BEAT



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of several applications of the motion spaced apart in time so that no significant superposition of response motion occurs. The number of applications of the motion must be justified as being representative of the strong motion portion of the SSE. The number of applications shall be such that the total duration of the middle-frequency components equals the duration of the SSE (see AA-4357).

AA-4356.6 Other Tests. The following factors shall be considered to justify the test method employed to qualify equipment:

(a) bandwidth of the RRS compared to that of the TRS and equipment characteristics and responses

(b) duration of the test compared to the defined seismic event

(c) peak acceleration of the test input and the amplification observed

(d) natural modes and frequencies of vibration of the equipment

(e) typical damping of the equipment

(f) fragility levels

(g) total number of cycles and the simulation of fatigue failure

AA-4357 Test Duration

The number of required OBE events per 40-year-plant-life shall be a minimum of five unless stated otherwise in the equipment design specification.

The number of tests run as proof tests (see AA-4351.6) shall have an appropriate input level to fulfill the requirements of AA-4351.4. The OBE tests shall be followed by at least one SSE test. The duration of each test shall at least equal the strong motion portion of the original time history used to obtain the RRS for the SSE and shall be a minimum of 30 sec for a multifrequency test, and a minimum of 15 sec for a single frequency test. Credit may be taken for any test preceding the SSE test if it is shown to be greater than or equal in severity to the required OBEs. Fragility test durations shall at least equal the time duration for the strong motion portion of the SSE in order to properly account for vibration buildup.

AA-4358 Single- and Multiaxis Tests

Single-axis tests are permitted if the tests are designed to reflect conservatively the seismic event at the equipment mounting locations, or if the equipment being tested can be shown to respond independently in each of the three orthogonal axes or otherwise withstand the seismic event at its mounting location. This is the case if equipment axis coupling is zero or very low. For example, if a device is normally mounted on a panel that amplifies motion in one direction, or if a device is restrained to have motion in one direction, single-axis testing of the device is permitted.

If the preceding considerations do not apply, multiaxis testing shall be used. The minimum is biaxial testing with simultaneous inputs in a principal horizontal axis and the vertical axis. Independent random inputs are preferred and, if used, the test shall be performed in two steps with the equipment rotated 90 deg in the horizontal plane for the second step. If independent random inputs are not used (such as with single-frequency tests), four tests shall be run. First, with the inputs in phase; second, with one input 180 deg out of phase; third, with the equipment rotated 90 deg horizontally and the inputs in phase; and fourth, with the same equipment orientation as in the third step but with one input 180 deg out of phase.

AA-4360 DESIGN OF BOLTS

The number and cross-sectional area of bolts required for the load combinations of AA-4212 shall be determined in accordance with the ASME Code, Section III, Division 1 Subsection NF-3324.

AA-4400 DOCUMENTATION REQUIREMENTS

The equipment design verification shall be documented by a certified design verification report (DVR), in accordance with the rules given in this section. This document may be based on one of three types of verification, or a combination of these:

(a) design verification stress report

(b) design verification test report

(c) design verification by comparative evaluation

Factors considered in choosing a particular type of design verification shall be included in the DVR.

AA-4410 CERTIFICATION OF DESIGN VERIFICATION

A certificate of design verification shall be provided with the DVR. This certificate shall include

(a) description and identification of equipment covered by the DVR, including the name of the plant, the plant location, the Owner, location of the equipment in the plant, and its function

(b) statement of compliance with Article AA-4000 and the equipment design specification requirements

(c) date, revision, and report identification number of the analysis or test program

(d) names and signatures of responsible persons performing, reviewing, and approving the design verification

AA-4420 EQUIPMENT DESCRIPTION

The DVR shall include a detailed description of the equipment being qualified. Outline drawings showing equipment interface points, anchor locations, weights, and locations of major components shall be included. In addition, plant specific information such as building location and elevation shall be reported if appropriate. Any appropriate tag numbers and equipment model numbers, where applicable, shall be included.

AA-4430 SAFETY-RELATED FEATURES

AA-4431 Safety-Related Functions

Equipment safety-related functions in all modes of operation shall be fully described in the DVR.

AA-4432 Critical Components

All components critical to the performance of the safety-related functions of the equipment shall be identified in the DVR.

AA-4433 Failure Modes and Evaluation Criteria

For all critical components listed, the potential failure modes being considered in the design shall be described in the DVR. In addition, the evaluation criteria used to verify that the critical components will not enter a failure mode shall be defined in the DVR.

AA-4440 REPORT CONTENT

AA-4441 Design Verification Report

The DVR shall address all items listed in this paragraph:

(a) description of analytical method used

(b) description of mathematical model in sufficient detail to allow reconstruction of the model by referring only to the report content

(c) list of the static loads considered

(d) method of developing dynamic loadings, including

(1) identification of response spectra and damping values used

(2) method of combining modes

(3) method of combining spatial components of dynamic loads

(4) assurance that rigid body motions are included

(e) load combinations considered, including interface loading effects and differential movement of multiple equipment supports

(f) evidence of verification of all computer programs used

(g) justification of methods and assumptions used for manual calculations

(h) results of analyses, including

(1) failure mode analysis.

(2) description of significant mode shapes and natural frequencies.

(3) location and value of maximum stresses.

(4) location and value of maximum deformations.

(5) allowable interface loads.

(6) reaction data at equipment supports; these data may be reported in a summary form only if foundation loads are to be included. Otherwise, detailed listings of individual support reactions for each load case considered shall be included.

(7) summary of maximum anchor bolt or anchor weld stresses compared to allowable limits.

AA-4442 Design Verification Test

The DVR shall address all items listed in this paragraph:

(a) detailed test procedure used for the equipment design verification test (DVT)

(b) identification of the test facility performing the test and the test dates

(c) list of test equipment used and certified calibration records for each

(d) laboratory mounting details for the equipment tested and a comparison of this to inservice mounting; justification for all differences must be addressed

(e) method used to simulate significant inservice interface loads, if applicable

(f) variables to be measured during and after dynamic motion and the accuracy required for each measurement

(g) number, type, and location of each sensor used to measure important equipment function and motion

(h) description of vibration input to the test equipment including

(1) single or multiaxis

(2) single or multifrequency

(3) if multifrequency, type used (sine beat, random)

(i) evidence that all significant modes were adequately excited

(j) evidence that, for multifrequency tests, the test response spectra (TRS) enveloped the required response spectra (RRS)

(k) data showing that the safety-related functions as defined in AA-4431 were not compromised during or after the simulated dynamic loading

(l) results of measurements performed to verify equipment functionability

(m) maximum equipment response (displacement) during most violent tests

(n) maximum reactions at equipment supports (measured or calculated)

(o) list of all anomalies during the DVT and the resolution of each

(p) equipment modifications made during the DVT, if any, and justification for using test data without retesting, or full report of any retesting accomplished

(q) summary of results of DVT and conclusions drawn

AA-4443 Design Verification by Comparative Evaluation Report

If the equipment design being verified has been previously verified to different criteria, or if the equipment design is similar to a design previously verified, it may be acceptable to verify the current design by comparative evaluation.

Whether the basis for design verification is analysis or test, all of the points required by AA-4441 or AA-4442 must be addressed. In addition, any differences between the previous design verification method and the requirements of Article AA-4000 must be identified and justified as conservative. Any differences in equipment design between the previously verified design and the design being considered must also be shown to be conservative.

ARTICLE AA-5000
INSPECTION AND TESTING

AA-5100 GENERAL

AA-5110 SCOPE AND APPLICABILITY

This article contains general requirements for the examination, inspection, and testing of materials and equipment.

The requirements of this article are applicable to the extent they are specifically invoked by other Code sections. Unique requirements are given in each section.

AA-5120 RESPONSIBILITY FOR PROCEDURES

When an inspection or test is required by Article AA-5000 or by any other section, written inspection or testing procedures shall be developed by the parties performing the test or inspection subject to the specific requirements of this Code. The inspection or testing shall be performed by personnel qualified in accordance with Article AA-8000 and with applicable portions of the other sections.

AA-5130 MEASURING AND TEST EQUIPMENT

Control and calibration of measuring and test equipment (M&TE) shall be in accordance with ASME NQA-1, Part I, Requirement 12.

AA-5200 VISUAL INSPECTION

AA-5210 SCOPE

This article contains methods and requirements for visual inspection. The criteria for interpretation of visual inspection are not included in this article, since such criteria are included in the other Code sections.

AA-5220 DESCRIPTION OF METHOD

Visual inspection is generally used to determine such things as surface condition, alignment of mating surfaces, shape, or evidence of leaking.

AA-5221 Direct Visual Examination

Direct visual examination usually may be made when access is sufficient to place the eye within 24 in. (610 mm) of the surface to be inspected and at an angle not less than 30 deg to the surface to be examined. Mirrors may be used to improve the angle of vision, and aids such as a magnifying lens may be used to assist inspections. The specific part, component, vessel, or section thereof shall be illuminated to a minimum of 50 foot-candles (540 lumens/square meter) for general inspection and to a minimum of 100 fc (1080 lx) for the detection or study of small anomalies. Visual inspection personnel shall successfully pass an annual visual examination to ensure natural or corrected near distance acuity so that they are capable of reading standard J-1 letters on standard Jaeger-type test charts for near vision.

AA-5222 Remote Visual Inspection

In some cases, remote visual examination may have to be substituted for direct examination. Remote visual inspection may use visual aids such as mirrors, telescopes, borescopes, fiber optics, cameras, or other instruments. Such systems shall have a resolution capability at least equivalent to that obtainable by direct visual observation.

AA-5230 REQUIREMENTS

When required by the referencing Code section, visual inspections shall be performed.

AA-5240 INSPECTION CHECKLIST

When required by the referencing Code section, a checklist shall be used to plan visual inspections and to verify that the required observations were performed. This checklist shall establish minimum inspection requirements to be followed by the Manufacturer.

AA-5250 REPORTS

When required by another section of this Code, a written report shall be provided and shall contain the following as a minimum:

(a) the inspection procedure used, date of the inspection results, and inspector's signature

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

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

(e) conclusion and recommendation by visual inspection and testing personnel

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

AA-5300 WELDED CONNECTIONS

Examination, inspection, and testing of welds shall be in accordance with Article AA-6000 and other sections of this Code.

AA-5400 BOLTED CONNECTIONS

AA-5410 BEFORE BOLTING

Flange seating surfaces shall be visually examined for cleanliness and acceptable surface finish. Flange faces shall be examined for compliance with tolerances for mutual parallelism and axial alignment, as well as for planarity of each flange.

Gaskets shall be visually examined to ensure conformance with specified dimensional tolerances and freedom from tears, breaks, or other defects.

AA-5420 AFTER BOLTING

Bolts in all bolted connections shall be examined to ensure bolts are in place. A uniform sampling of 25% of all bolts in a bolted connection shall be tested with a calibrated torque wrench.

Torquing requirements shall be established for each bolted connection.

If any bolt in the sample fails to meet torque requirements, all bolts in the connection shall be retorqued.

Gaskets in bolted connections shall be visually examined for uniform compression.

AA-5500 FABRICATION TOLERANCES

Equipment and components shall be examined for conformance to tolerances required by this Code and by the design specification. Refer to other Code sections for specific requirements.

AA-5600 PRESSURE AND LEAK TESTING

Pressure and leak testing of equipment and components shall be performed in accordance with the requirements of this Code. Refer to the other Code sections for specific testing requirements.

AA-5700 PERFORMANCE AND FUNCTIONAL TESTING

Testing shall be performed to ensure that prototype and production equipment possess dynamic and functional characteristics that meet requirements of this Code and of the design specification.

Among the characteristics that may be determined by testing are fluid flow rates and pressures, air filter performance, electrical quantities, bearing operation, rotor balance, and sound power level.

AA-5800 SEISMIC TESTING

Refer to AA-4350 for the requirements of structural design verification by testing.

ARTICLE AA-6000
FABRICATION, JOINING, WELDING, BRAZING, PROTECTIVE COATING, AND INSTALLATION

AA-6100 GENERAL

AA-6110 SCOPE AND APPLICABILITY

This article contains general requirements for the fabrication, joining, welding, brazing, protective coating, and installation of components, parts, and equipment.

The requirements of this article are applicable to the extent they are invoked by the other sections. Unique requirements are given in each Code section.

AA-6120 MATERIALS

AA-6121 Material Selection

Materials to be used in the fabrication of components, parts, and appurtenances shall conform to the requirements of Article 3000 of each Code section.

AA-6122 Material Identification

Materials to be used in the fabrication and installation of components, parts, and appurtenances shall be identified on fabrication and installation plans and specifications as required in Article AA-8000.

AA-6123 Repair of Material With Defects

Material with defects that are discovered or produced during the fabrication and installation processes may be used, provided the defects are repaired in accordance with the requirements of Article AA-8000, and for weld repairs, in accordance with AA-6300.

AA-6130 CONTROL OF FABRICATION AND INSTALLATION PROCESSES

Quality control procedures shall be prepared and maintained current for all fabrication and installation processes in accordance with the requirements of Article AA-8000.

AA-6200 FABRICATION PROCESSES

AA-6210 CUTTING, FORMING, AND BENDING

Material may be cut to shape and size by any means that does not degrade the mechanical or chemical properties of the material below the minimum specified values. The method or methods selected shall not create critical stress areas, such as less than accepted corner radii.

When thermal cutting is used, consideration shall be given to preheating the material.

Forming and bending of pressure-retaining parts that are to meet requirements of Section III or Section VIII of the ASME Code shall conform to the applicable article or articles of the applicable section of this Code.

AA-6220 FORMING TOLERANCES

Forming tolerances shall be defined in the design specification, drawings, and Manufacturer's design documents.

Formed parts outside the tolerances specified after the completion of all forming, assembly, and welding operations shall be rejected. Repairs may be made to formed parts to correct unacceptable tolerances in accordance with AA-6123.

AA-6230 FITTING AND ALIGNING

Parts that are to be assembled or joined by mechanical means (e.g., bolts) or welding shall be fitted, aligned, and when necessary, retained in position during assembly.

Attachments that are welded to the component during construction, but are not incorporated into the final component, such as alignment lugs or straps, tie straps, braces, preheat equipment, and postweld heat treatment equipment, are permitted provided the following requirements are met:

(a) attachment material shall be identified by ASTM or ASME specification number and shall be certified when required by another Code section

(b) the temporary material is compatible for welding to the component material and the attachment and subsequent removal does not reduce the component's structural integrity below the minimum specified value

(c) the welder and welding procedure shall be qualified in accordance with AA-6300

(d) the immediate area around the temporary attachment shall be marked in an acceptable manner so that, after attachment removal, the area can be examined in accordance with the requirements of Article AA-5000

(e) the temporary attachment shall be completely removed by mechanical means such as machining, shearing, clipping, or grinding, or by thermal cutting, in accordance with AA-6210

AA-6240 WELDED JOINTS

Manufacturer's fabrication drawings shall provide complete information regarding location, type, size, and extent of all welds. Field and shop welds shall be clearly identified.

Members to be joined by welding shall be brought into correct alignment when necessary and held in position by bolts, clamps, or temporary weld attachments meeting the requirements of AA-6230, until the welding is completed.

Welding shall conform to the requirements of AA-6300.

AA-6250 MECHANICAL JOINTS

AA-6251 Fasteners and Threaded Joints

Fasteners and threaded joints shall be provided with locking devices or other means to prevent loosening under the vibratory loads expected during system operation. The threads of all bolts or studs shall be engaged for the full length of the thread in the nut unless specified otherwise on Manufacturer's design drawings or specifications. Thread engagement of all bolts and studs shall be as specified on the drawings.

AA-6252 Structural and Pressure Boundary Fasteners

Type, size, and spacing of structural and pressure boundary fasteners shall be selected to meet the maximum stresses anticipated for the worst load combination and shall be documented by calculations.

AA-6253 Thread Lubricants

Any lubricant or compound used in threaded joints shall be acceptable for the service conditions and shall not react unfavorably with any contact material. Contact surfaces within friction-type joints shall be free of oil, paint, lacquer, galvanizing, or other plating.

AA-6254 Removal of Thread Lubricants

All thread lubricants or compounds shall be removed from surfaces that are to be welded.

AA-6255 Bolted Connections

Surfaces of bolted parts in contact with the bolt head and nut shall not have a slope of more than 1:20 with respect to a plane normal to the bolt axis. Where the surface of a high-strength bolted part has a slope of more than 1:20, a beveled washer shall be used to compensate for the lack of parallelism. Bolts loaded in pure shear shall not have threads located in the load bearing part of the shank unless permitted by the design specification or Manufacturer's specification.

AA-6256 Precautions Before Bolting

All parts assembled for bolting shall have contact surfaces free from scale, chips, or other deleterious material. Surfaces and edges to be joined shall be smooth, uniform, and free from fins, tears, cracks, and other defects that would degrade the strength of the joint.

AA-6257 Bolt Tension

All high strength structural bolts shall be tightened to a bolt torque equal to that given in the design specification or Manufacturer's specification. Tightening shall be done by the turn-of-nut method or with properly calibrated wrenches. Bolts tightened by means of a calibrated wrench shall be installed with a hardened washer under the nut or bolt head, whichever is the element turned in tightening. Hardened washers are not required when bolts are tightened by the turn-of-nut method, except that hardened washers are required under the nut and bolt head when the bolts are used to connect material having a specified yield point less than 40.0 ksi (276 MPa).

AA-6258 Locking Devices

Threaded fasteners, except high-strength bolts, shall be provided with locking devices to prevent loosening during service. Elastic stop nuts (when compatible with service temperature), lock nuts, jam nuts, and drilled and wired nuts are all acceptable locking devices. Upset threads may serve as locking devices.

AA-6300 WELDING REQUIREMENTS

AA-6310 GENERAL

(a) Scope. The requirements of AA-6300 apply to the preparation of welding procedure specifications, the qualification of welding procedures, welders, and welding operators for all types of manual and machine welding processes, and to the workmanship, weld quality, and inspection of weldments produced during the manufacture of equipment and components.

The requirements of this subarticle are applicable to the extent they are invoked by the other sections. Unique requirements are given in each section.

(b) Responsibility. Each Manufacturer is responsible for the welding done by its organization and shall conduct the tests required in this Code to qualify the welding procedures used in the construction of the weldments built under this Code, the performance of welders and welding operators who apply these procedures, and the inspections required for workmanship and weld quality verification.

(c) Records. Each Manufacturer shall maintain a record of the results obtained in welding procedure and welder and welding operator performance qualifications. These records shall be certified by the Manufacturer and shall be accessible for review.

(d) Base Metal

(1) Base metals to be joined by welding shall be one or a combination of those listed in Article 3000 of each Code section.

(2) Rust inhibitive coatings, galvanized coatings, or antispatter compounds may remain on the metal to be joined provided the welding procedure is qualified with these materials present.

(e) Filler Metals. Filler metals selected shall be one or a combination of those listed in the ASME Code, Section II, Part C, and shall be compatible with the welding process used and the base metal designated on the Manufacturer's drawings.

(f) Processes. Joining processes under this specification shall include oxyfuel gas welding (OFW), shielded metal-arc welding (SMAW), submerged-arc welding (SAW), gas metal-arc welding (GMAW), flux-cored arc welding (FCAW), gas tungsten-arc welding (GTAW), plasma-arc welding (PAW), resistance welding (RW), stud-arc welding (SW), and carbon-arc welding (CAW).

(g) Terms and Definitions. Terms and definitions shall be interpreted in accordance with ANSI/AWS A3.0.

(h) Symbols. Symbols used on the Manufacturer's drawings shall be in accordance with ANSI/AWS A2.4.

(i) Safety Precautions. Safety precautions shall conform to the latest edition of ANSI/AWS Z49.1.

(j) Standard Units of Measurement. The values stated in U.S. customary units are to be regarded as the standard. The metric (SI) equivalents of U.S. customary units as given are approximate.

(k) Welding Procedure and Performance Qualification:

(1) Qualification of the Manufacturer's welding procedure specifications and welder and welding operator performance shall be in accordance with the requirements of one or more of the following, as defined in each Code section.

(a) ASME Code, Section IX
(b) ANSI/AWS D1.1
(c) ANSI/AWS D9.1
(d) AWS C1.1
(e) AWS C1.3
(f) ANSI/AWS D1.3

(2) Welding of performance qualification test samples shall be performed in accordance with the Manufacturer's qualified welding procedure for the process used.

(3) Welding procedure qualification of coated base metals qualifies the procedure for uncoated base metals, but not vice versa.

(4) Base metal sensitization shall be considered in selecting the welding process and filler metals for welding procedures developed for welding stainless steel.

AA-6320 WORKMANSHIP

AA-6321 Preparation of Base Metal

AA-6321.1 Surfaces and edges to be welded shall be free from fins, tears, cracks, and discontinuities that would adversely affect the quality or strength of the weld. Surfaces to be welded and surfaces adjacent to a weld shall also be free from loose mill scale, slag, rust, moisture, grease, and foreign material that would prevent proper welding. Mill scale that can withstand wire brushing, a thin rust-inhibitive coating, or antispatter compound may remain.

AA-6321.2 Galvanized surfaces need not have the zinc coating removed before welding, provided the welding procedure is qualified with the galvanizing present.

AA-6322 Joint Fit-Up

AA-6322.1 Joints to be welded shall be brought into correct alignment within the tolerances required by the qualified welding procedure.

AA-6322.2 When tack welds are used to assemble the joint for welding and are incorporated into the final weld, they shall be made with electrodes meeting the requirements of the final welds.

AA-6322.3 Tack welds not incorporated into the final welds shall be removed.

AA-6323 Weld Cleaning

AA-6323.1 Where cleaning of base metals is required, it shall be accomplished by wire brushing, grinding, blasting, solvents, or other suitable means that are noninjurious to the material or weld quality.

AA-6323.2 Before welding over previously deposited metal, slag, if present, shall be removed and the weld and adjacent base metal shall be brushed clean. This requirement shall apply not only to successive layers, but also to successive beads and to the crater area when welding is resumed after any interruption.

AA-6323.3 Upon completion, the weld and adjacent areas shall be cleaned of all slag, excessive spatter, soot, dirt, or any residue from welding. Welds shall be left in a condition ready for subsequent inspection.

AA-6324 Weld Quality

AA-6324.1 The sizes and lengths of welds shall be no less than those specified by design requirements and detail drawings.

AA-6324.2 Weld profiles shall be in accordance with the acceptable weld profiles shown in Fig. AA-6324.2.

AA-6324.3 The faces of fillet welds may be slightly convex, flat, or slightly concave, as shown in Fig. AA-6324.2, sketches (a) and (b), with none of the unacceptable profiles shown in sketch (c).

AA-6324.4 Groove welds shall preferably be made with slight or minimum reinforcement except as may be otherwise provided. In the case of butt and corner joints, the reinforcement shall not exceed $^1/_8$ in. (3.2 mm) in height and shall have a gradual transition to the plane of the base metal surface. See Fig. AA-6324.2, sketch (d). They shall be free of the discontinuities shown for butt joints in sketch (e).

AA-6330 INSPECTION AND TESTING OF WELDS

AA-6331 Butt and Fillet Welds

AA-6331.1 Production welds shall be inspected. As a minimum, visual inspection shall be made. Welds that conform to the following criteria shall be acceptable:

(a) fusion: complete fusion is required

(b) penetration: required joint penetration as specified for the application

(c) reinforcement of welds in butt joints: a maximum of 0.125 in. (3.2 mm) face reinforcement and 0.125 in. (3.2 mm) root reinforcement

(d) throat and convexity of fillet welds: a minimum weld leg size, as required on the design drawings, with maximum convexity not to exceed 0.125 in. (3.2 mm)

(e) porosity or slag inclusion: a maximum of three visible pores or slag inclusions, or both, that do not exceed $0.25t$/in. ($0.25t$/25.4 mm) of weld, and a maximum of one visible pore or slag inclusion that does not exceed $0.5t$/in. ($0.25t$/25.4 mm) of weld, where t is the thinner base metal thickness

(f) undercut: no undercut exceeding $0.15t$, where t is 0.125 in. (3.2 mm) or thinner, or exceeding $^1/_{32}$ in. (0.79 mm), where t exceeds 0.125 (3.2 mm)

(g) cracks: no cracks are permitted

AA-6331.2 Completed welds shall be visually inspected for location, size, and length in accordance with the requirements of applicable Manufacturer's drawings and specifications.

AA-6331.3 When specified by the Engineer, the weld acceptance criteria of NCIG-01 may be used in lieu of the criteria of AA-6324 and AA-6331.1 for structures and supports fabricated to the requirements of the AISC specification and AWS D1.1.

AA-6332 Resistance Spot Welds

The diameter of the spot and cross section of the nugget shall be in accordance with the sizes specified on detail drawings and in welding procedure specifications.

AA-6333 Stud Welding

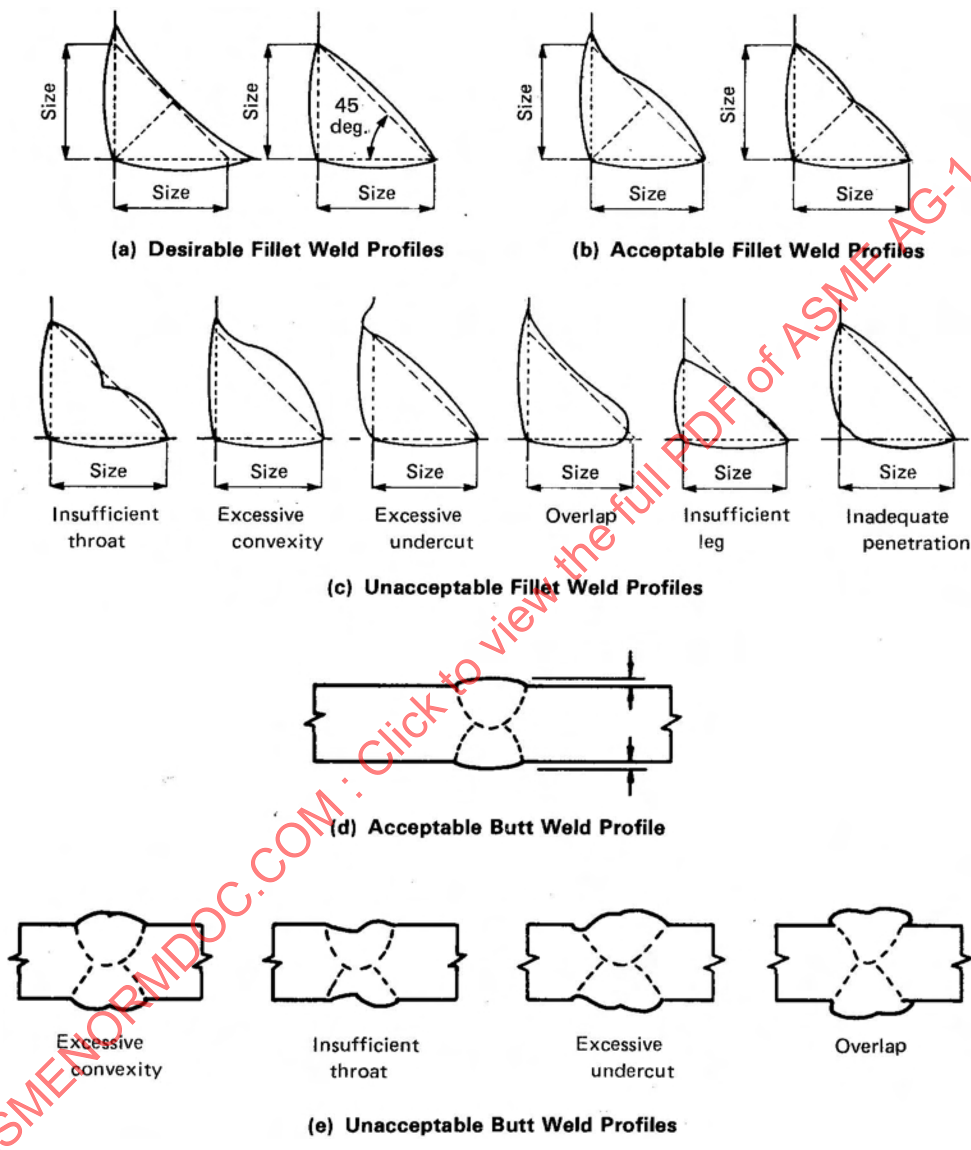
AA-6333.1 The design of studs shall be suitable for arc welding to steel members with automatically timed stud welding equipment. An arc shield shall be furnished for all studs and pins over 10 gage diameter. At the time of welding, the studs shall be free from rust, rust pits, scale, oil, paint, galvanizing, plating, and other deleterious material that would adversely affect the welding operation. After welding, stud ferrules shall be broken free for visual inspection.

AA-6333.2 Stud weld reinforcement shall be as specified by the Manufacturer's drawings and procedure.

AA-6334 Nondestructive Testing (NDT) Methods and Acceptance Criteria

AA-6334.1 When nondestructive testing other than visual inspection is required, it shall be so stated in the Manufacturer's drawings and specifications.

FIG. AA-6324.2 ACCEPTABLE AND UNACCEPTABLE WELD PROFILES



(Courtesy of the American Welding Society)

AA-6334.2 Surface inspection, when required, shall be performed using the dye penetrant method. The standard methods set forth in ASTM E 165 shall be used for dye penetrant inspection, and the acceptance criteria shall be in accordance with AA-6331.

AA-6334.3 For detecting surface or subsurface discontinuities, radiographic or ultrasonic inspection may be used. Radiographic or ultrasonic inspection shall be used only when joint designs require multiple pass welds. The standard methods set forth in Section V of the ASME Code shall be used for inspection and acceptance criteria and shall be in accordance with the following:

(a) no cracks are permitted

(b) not more than three individual discontinuities, with the greatest dimension being less than $\frac{1}{4}$ times the base metal thickness per linear inch (25.4 mm) of weld

AA-6335 Inspector Qualifications

AA-6335.1 Personnel performing visual inspections shall meet the requirements of ASME NQA-1, Part I, Requirement 2 to a Level I capability and be working under the supervision of a Level II or III individual, or shall be Level II or III individuals.

AA-6335.2 Personnel performing nondestructive testing shall be qualified in accordance with SNT-TC-1A. Only individuals qualified for NDT Level I and working under an NDT Level II or III individual, or individuals qualified for NDT Level II or III, may perform nondestructive testing.

AA-6335.3 Personnel performing visual inspections to the requirements of AA-6331.3 shall be trained in accordance with NCIG-03 with regard to the acceptance criteria of NCIG-01.

AA-6336 Repairs

Defects in welds or base metals may be repaired in accordance with the applicable welding code and the applicable equipment section of this Code. Weld repairs shall be performed by qualified welders using qualified procedures and inspected to the original acceptance criteria.

AA-6400 BRAZING

AA-6410 GENERAL

(a) Scope. The requirements of AA-6400 apply to the preparation of brazing procedure specifications, the qualifications of brazing procedures, brazers and brazing operators for all types of manual and machine brazing processes, and the workmanship, braze quality, and inspection of brazements produced during the manufacture of equipment and components. Brazing shall be in accordance with this subarticle unless specific requirements are given in the applicable equipment section of this Code.

(b) Responsibility. Each Manufacturer is responsible for the brazing done by its organization and shall conduct the tests required in this subarticle to qualify the brazing procedures used in the construction of the brazements built under this Code, the performance of brazers and brazing operators who apply these procedures, and the inspections required for workmanship and braze quality verification.

(c) Records. Each Manufacturer shall maintain a record of the results obtained in brazing procedure, and brazer and brazing operator performance qualifications. These records shall be certified by the Manufacturer and shall be accessible for review.

(d) Base Metals. Base metals to be joined by brazing shall be as listed in each section of this Code and applicable to that section.

(e) Filler Metals. Filler metals selected shall be one or a combination of those listed in the ASME Code, Section II, Part C, or ANSI/AWS A5.8 and shall be compatible with the brazing process used and the base metal designated on the Manufacturer's drawings.

(f) Processes. Joining processes under this specification shall include torch brazing (TB), furnace brazing (FB), induction brazing (IB), resistance brazing (RB), and dip brazing (DB).

(g) Terms and Definitions. Terms and definitions shall be interpreted in accordance with ANSI/AWS A3.0.

(h) Symbols. Symbols used on the Manufacturer's drawings shall be in accordance with ANSI/AWS A2.4.

(i) Safety Precautions. Safety precautions shall conform to the latest edition of ANSI/AWS Z49.1.

(j) Standard Units of Measurement. The values stated in the U.S. customary units are to be regarded as the standard. The metric (SI) equivalents of U.S. customary units as given are approximate.

(k) Brazing Procedure and Performance Qualification:

(1) Qualification of the Manufacturer's brazing procedure specifications, and brazer and brazing operator performance, shall be in accordance with the requirements of one or more of the following:

(a) ASME Code, Section IX

(b) ANSI/AWS C3.3

(2) Brazing of performance qualification test samples shall be performed in accordance with the Manufacturer's qualified brazing procedure for the process used.

AA-6420 WORKMANSHIP

AA-6421 Preparation of Base Metal

Surfaces and edges to be brazed shall be free from fins, tears, cracks, and discontinuities that would adversely affect the quality of strength of the brazement. Surfaces to be brazed and surfaces adjacent to a brazement shall also be free from loose mill scale, slag, rust, moisture, grease, and foreign material that would prevent proper brazing.

AA-6422 Joint Fit-Up

Joints to be brazed shall be brought into correct alignment within the tolerances required by the qualified brazing procedure.

AA-6423 Cleaning

AA-6423.1 Where cleaning of base metals is required, it shall be accomplished by wire brushing, grinding, blasting, solvents, pickling, or other suitable means.

AA-6423.2 Upon completion, the brazement and adjacent areas shall be cleaned of flux residues and oxide scale formed during the brazing process.

AA-6430 INSPECTION AND TESTING

AA-6431 Visual Examination

AA-6431.1 Visual examination of brazed joints is used for estimating the soundness by external appearance, such as continuity of the brazing filler metal, size, contour, and wetting of fillet along the joint, and, where appropriate, to determine if filler metal flowed through the joint from the side of application to the opposite side.

AA-6431.2 Brazed joints shall be inspected by visual means prior to mechanical or section tests. As a minimum, visual inspection shall be made. The results of the visual examination shall meet the following requirements:

(a) braze metal shall be present at all edges of the joint

(b) no unfused brazing filler metal shall be present

(c) undercutting shall have a maximum depth of 5% of the base metal thickness, or 0.010 in. (0.254 mm), whichever is less

(d) individual pores shall have a maximum diameter of 0.015 in. (0.381 mm), and the minimum space between such pores shall be 0.5 in. (12.7 mm)

(e) the sum of all pore diameters shall be a maximum of 0.030 in. (0.762 mm) in each linear inch of joint

(f) no cracks are permitted

AA-6431.3 Mechanical or section tests, when required, shall be accomplished in accordance with the applicable code specified in AA-6410.

AA-6432 NDT Methods and Acceptance Criteria

AA-6432.1 When nondestructive testing other than visual inspection is required, it shall be so stated in the Manufacturer's drawings and specifications.

AA-6432.2 Surface inspection, when required, shall be performed using the dye penetrant method. The standard methods set forth in ASTM E 165 shall be used for dye penetrant inspection, and the acceptance criteria shall be in accordance with AA-6431.

AA-6432.3 For detecting surface or subsurface discontinuities, other nondestructive methods may be used. The standard methods set forth in Section V of the ASME Code shall be used for NDT inspection. The extent of examination and acceptance criteria shall be stipulated in the procurement documents.

AA-6433 Inspector Qualifications

AA-6433.1 Personnel performing visual inspections shall meet the requirements of ASME NQA-1, Part I, Requirement 2, to a Level I capability and shall be working under the supervision of a Level II or III individual, or shall be Level II or III individuals.

AA-6433.2 Personnel performing NDT shall be qualified in accordance with SNT-TC-1A. Only individuals qualified for NDT Level I and working under an NDT

Level II or III individual, or individuals qualified for NDT Level II or III, may perform NDT.

AA-6434 Repairs

AA-6434.1 Defects in base metals or brazed joints may be repaired in accordance with written repair procedures mutually agreed upon between the Manufacturer and purchaser. Repairs shall be performed by qualified brazers in accordance with the qualified brazing procedure specification. Repairs shall be inspected to the original acceptance criteria.

(09) AA-6500 CLEANING AND COATING

AA-6510 GENERAL

The Design Specification shall specify the required coating service levels for both internal and external surfaces of the equipment. Coating level designation shall be determined based on equipment location, function, and effect of coating system on intended component or system performance.

The Design Specification shall contain the owner's plant specific Quality Assurance requirements and licensing commitments.

ASTM D 5144, Standard Guide for Use of Protective Coating Standards in Nuclear Power Plants, provides useful guidance in determining appropriate service levels for protective coating used in nuclear power plants. ASTM D 5144 also provides definitions for pertinent terms used for classification of coating systems within the service levels described below (e.g., Safety-Related Coating System, DBA Qualified Coating System, Acceptable Coating System, etc.).

The main criteria for coating systems are to provide corrosion protection, facilitate decontaminability of the exposed surfaces to radioactive nuclide contamination, and provide assurance that safety related coatings will not fail in a manner that will compromise the engineered safety systems or adversely affect the safety function of a safety-related structure, system, or component.

AA-6511 Service Level I Areas

Areas inside the reactor-containment where coating failure could affect the operation of post accident fluids and, thereby, impair safe shutdown. Service Level I protective coatings are classified as being safety-related. Service Level I protective coating system shall conform to the Design Specification.

AA-6512 Service Level II Areas

Service Level II areas are areas where coating failure could impair, but not prevent, normal operating performance. The function of Service Level II protective coatings is to provide corrosion protection and decontaminability in those areas outside the reactor-containment subject to radiation exposure and radionuclide contamination. Service Level II coatings are not safety-related.

AA-6513 Service Level III Areas

Service Level III areas are areas outside the reactor-containment where coating failure could adversely affect the safety function of a safety-related structure, system, or component. Service Level III coatings are safety-related. Service Level III coatings may include linings used in areas such as service water systems, essential cooling water heat exchanger channel heads, and emergency diesel generator air intakes.

AA-6514 Stainless Steel and Galvanized Surfaces

Stainless steel and galvanized surfaces are not normally coated. When protective coatings are applied to these surfaces, the applicable requirements for the service level area for protective coatings where they will be installed shall apply.

AA-6520 DESIGN CONSIDERATION FOR COATING

Clearly define the areas to which protective coatings are to be applied, and identify those areas where coatings are not to be applied.

AA-6522 Coating System Selection and Evaluation

Coating system selection should be consistent with plant-specific Design Specification for the intended coating service level area application. ASTM D 5144 provides useful information on relevant standards for selecting, testing, and evaluating coatings for use in Nuclear Power Plants. When possible, coating systems should be complimentary to the coatings already in use at the facility (i.e., currently or previously used materials should be considered for use whenever possible to minimize impact on future maintenance coating).

AA-6523 Surface Preparation

Surface preparation for both uncoated (new) and previously coated surfaces shall be at least as good as that used in the qualification testing of the coating system intended for use. In those cases where qualification testing of the coating system was not required, then surface preparation requirements may be specified in the Design Specification based on the desired service life required for the applied coating system.

AA-6524 Coating Work Processes Requirements

Requirements for surface preparation and coating applications processes for safety-related (Service Level I and III) coating work shall be established in accordance with the Design Specification. ASTM D 5144 provides guidance for requirements for surface preparation and coating applications for safety-related work. Coating work process requirements may also be established for Service Level II coating work based on criticality. The following Society of Protective Coatings[1] documents provide useful information relevant to coating work processes: SSPC-SP COM, "Surface preparation Commentary"; SSPC-PA1, "Shop Field and Maintenance Painting"; and SSPC-PA Guide 3, "A Guide to Safety Paint Application." Additionally, the coating manufacturer's published technical requirements for the given coating or coating system should be considered when developing coating work process requirements.

AA-6530 REPAIR OF COATING SYSTEM

(a) Safety-related (Service Level I and III) coating systems that require repair due to damage or defects in the original coating system shall be repaired in accordance with the requirements of this subarticle.

(b) Non–safety-related coatings should be repaired in accordance with the applicable sections of this subarticle and the coating manufacturer's written instructions unless otherwise stipulated in the plant-specific Design Specification.

(c) Galvanized surfaces that have been damaged and require repair with a protective coating system shall be repaired in accordance with the requirements of this subarticle for the applicable coating service level location.

AA-6540 CLEANLINESS

Equipment internals shall, as a minimum, be shop cleaned and be prepared for shipment per the requirements of ASME NQA-1. Cleanliness levels shall be the same as for the fluid systems of which the equipment is a part. The Design Specification shall identify the internal cleanliness levels of the associated fluid system. As a minimum, ASME NQA-1, Part II, Subpart 2.1, Class D cleanliness level shall apply.

AA-6541 Component Cleanliness

AA-6541.1 Cleanliness of Moisture Separators. Metal parts of the moisture separator shall be cleaned and degreased in accordance with ASTM A 380 before any welding.

AA-6541.2 Cleanliness of Filter Cells. Metal surfaces shall be cleaned and degreased in accordance with ASTM A 380 before any welding, installation of gaskets or seal pads, and filling with adsorbent.

AA-6541.3 Cleanliness of Type III Adsorbers. All surfaces shall be cleaned prior to acceptance. No halogen bearing materials or carbon steel tools shall be used to clean the stainless steel surfaces. Cleaning shall be performed in accordance with the procedures contained in Article AA-6000 and the Manufacturer's written procedure.

AA-6541.4 Cleanliness of Mounting Frames. All surfaces shall be cleaned per Article AA-6000 prior to acceptance. No halogen bearing materials or carbon steel tools shall be used to clean frames constructed of stainless steel. Cleaning shall be performed in accordance with Manufacturer's written procedure.

AA-6541.5 Cleanliness of Control Panels. Cleaning and coating shall be in accordance with AA-6500.

AA-6542 Surface Preparation

Surface preparation, finishing, and coating of all equipment and components shall be in accordance with the Design Specification. In lieu of specified standards, cleaning, finishing, and coating shall be in accordance with the Manufacturer's written procedures. Surface preparation, finish, and coatings that are compatible with the environmental conditions shall be provided in the Design Specification.

AA-6543 Cleaning and Finishing

This subarticle covers the cleaning prior to surface preparation, coating, or painting. Surfaces shall meet the following requirements.

(a) Surfaces shall be free of particle contaminants such as sand, metal chips, weld slag, or weld spatter.

(b) All surfaces to be coated shall be clean and free from oil, grease, soil, dust, or foreign matter before

[1] Formerly known as Steel Structures Painting Council. Referenced SSPC documents can be found in SSPC Publication, "Systems and Specifications—Steel Structures Painting Manual Volume 2."

further mechanical or chemical surface preparation. Solvent cleaning shall be in accordance with the requirements of SSPC-SP1. Halogen based materials or chlorinated degreasers shall not be used for surface preparation.

AA-6543.1 Surface Preparation

(a) Surface preparation of metal surfaces located inside the containment building shall conform to the following requirements:

(1) All welds shall be continuous where feasible, free from sharp projections and spatters, and blended smoothly into the base metal. The surface shall be cleaned in accordance with SSPC-SP10, as appropriate. The abrasive shall be selected to produce an anchor pattern that is compatible with the substrate and the coating system used and acceptable to the coating manufacturer.

(2) All loose foreign material shall be removed. Crevices, gouges, deep pitting, and joints shall be filled, where required, with a suitable material compatible with the substrate and the coating system used.

(3) The primer shall be applied only to dry surfaces and shall be applied before the prepared surface rusts.

(4) Where special circumstances make it impractical to employ blasting, alternative methods of surface preparation may be used, provided the surface preparation is adequate for the coating system and the intended service.

(b) Surface preparation of metal surfaces located outside the containment building shall conform to the following requirements:

(1) All welds shall be continuous, free from spatter and sharp projections, and blended smoothly into the base metal.

(2) The minimum surface preparation shall be commercial blast cleaning as specified in SSPC-SP6 and to a visual degree of cleanness as described in SSPC-Vis 1.

(3) The abrasive shall be selected to produce an anchor pattern that is compatible with the coating system used and acceptable to the coating manufacturer.

(4) Where special circumstances make it impractical to employ blasting, alternative methods of surface preparation may be used, provided the surface preparation is adequate for the coating system and the intended service.

AA-6543.2 Coating and Application. Coating and application shall be in accordance with the following requirements:

(a) Coating material mixing and thining procedures shall conform to those outlined in SSPC-PA1 and to the recommendations of the coating manufacturer.

(b) Application equipment, its use, and its maintenance shall conform to the requirements of SSPC-PA1 and to the recommendations of the coating manufacturer.

(c) Coating materials and application equipment shall be suitable for the intended purpose and shall be maintained in satisfactory operating condition for the proper coating application.

(d) Application of coating shall conform to the requirements of SSPC-PA1 and to the recommendations of the coating manufacturer.

(e) The dry film thickness of each coat and of the entire coating system shall conform to the requirements of the Design Specification.

(f) No coating materials shall be applied to the coil heat transfer surfaces unless specifically required by the Design Specification.

(g) Quality assurance and quality control for coating materials, surface preparation, and coating application, including procedures and personnel qualifications necessary to provide specified documentation and adequate confidence that the coating work will satisfy service conditions, shall conform to the Design Specification requirements.

AA-6544 Coating of Filter Mounting Frames

Coating of the frames, if applicable, shall be in accordance with AA-6500.

AA-6550 QUALITY ASSURANCE REQUIREMENTS AND DOCUMENTATION

(a) Safety-related (Service Level I and III) coating work shall conform to the quality assurance requirements of the Design Specification. Service Levels I and III coating work is considered a Special Process as defined in 10 CFR 50 Appendix B, Criterion 9.

(b) Quality Assurance requirements for Service Level II coatings are not mandatory (unless otherwise committed to in plant-specific Quality Assurance program or Design Specification) and should be established based on the criticality of the work scope.

(c) Documentation shall be provided to the Owner in accordance with the requirements of Article AA-8000.

AA-6551 Quality Assurance Program

A Quality Assurance Program for safety-related (Service Levels I and III) coating work shall be established in accordance with the Design Specification. ASTM D 3843 provides guidance for achieving the objectives of the Owner's quality assurance program with respect to safety-related coatings work. Quality Assurance requirements may also be established for Service Level II coating work based on criticality. Service Levels I and III coating work is considered a Special Process as defined in 10 CFR 50 Appendix B, Criterion 9.

AA-6552 Inspection

Coatings work shall be inspected by protective coatings inspection personnel qualified and certified in accordance with the plant-specific Quality Assurance Program or Design Specification. Safety-related (Service Level I and III) coating work shall be inspected in accordance with plant-specific Quality Assurance Program or Design Specification. ASTM D 5161 provides guidance in selecting appropriate inspection attributes for coating inspection work.

AA-6553 Coating Inspector's Qualification

Personnel performing inspection work for safety-related coating work (Service Levels I and III) shall be qualified in accordance with the plant-specific Quality Assurance Program or Design Specification. ASTM D 4537 provides an acceptable means for qualifying personnel for inspection of safety-related coating work.

AA-6554 Quality Control Process

Quality Control Procedures for Service Level I and III coating work shall be established in accordance with the plant-specific Quality Assurance Program or Design Specification. ASTM D 3843 provides guidance for achieving the objectives of a Quality Control process with respect to safety-related coatings work. Quality Control requirements may also be established for Service Level II coating work based on criticality.

AA-6555 Coating Applicator's Qualifications

Personnel applying protective coatings in safety-related coating applications (Service Levels I and III) shall be qualified in accordance with the plant-specific Quality Assurance Program or Design Specification. ASTM D 4227 (concrete substrates) and ASTM D 4228 (steel substrates) provide an acceptable means for qualifying personnel for applications of protective coatings for safety-related coating work.

AA-6556 Control of Coating Manufacturing

Unless otherwise stipulated in plant-specific Quality Assurance Program or Design Specification, coating materials used in safety-related applications shall be manufactured under the provisions of 10 CFR 50, Appendix B, or be commercially dedicated for use in a safety-related application. ASTM D 3843 provides an acceptable means for establishing Quality Assurance criteria and documentation requirements to be imposed on coating manufacturers of safety-related coating materials.

AA-6600 INSTALLATION REQUIREMENTS (09)

AA-6610 HANDLING AND RIGGING

(a) Handling and rigging requirements for assembled components or subassemblies shall be identified in Manufacturer's installation procedures in accordance with Article AA-7000. Manufacturer's procedures shall include the classification of the item to be handled as defined in ASME NQA-1.

(b) Items that will be handled or supported during installation by a crane or other lifting device shall be equipped with lifting eyes or other means to maintain the item in proper orientation without exceeding structural design integrity of the assembly while being handled or supported. The Design Specification shall identify any special rigging requirements or restrictions for final erection.

AA-6620 FIELD ASSEMBLY

(a) Where equipment requires component assembly during final installation, the equipment Manufacturer shall provide detailed written procedures for making the proper final assembly. Installation procedures shall include requirements for all other interfacing services, such as electrical, piping, supports, and ductwork. Installation procedures shall also address assembling, setting, erecting, leveling, aligning, securing, doweling, connecting, cleaning, lubricating, final adjusting, inspecting, and all other operations necessary to make the equipment operable.

(b) The equipment Manufacturer shall be responsible for advising the Owner or designee of field connections or services required for the proper and safe operation of the equipment as specified in the Design Specification. These requirements shall be explained in the installation procedures. The equipment Manufacturer shall make provisions in the design of his equipment for the required field connections.

(c) Alignment markings where required for the proper field positioning and connection of parts or subassemblies shall be shown on the Manufacturer's installation drawings.

AA-6630 TEMPORARY FIELD ATTACHMENTS

(a) Field attachments to equipment and ducts not specified in the design drawings, the Design Specification, or this Code are permitted only when authorized in writing by the equipment Manufacturer, Owner, or his designee. The method of attachment shall meet the requirements of the drawings, specifications, or this Code, as applicable, and neither the attachment nor the method of attachment shall adversely affect present or future performance, reliability, or structural integrity of the item or the installed system. Temporary attachments shall be removed before delivery or final acceptance of the installed system, whichever is applicable.

(b) Unauthorized attachments shall not be made to equipment or ducts and, when discovered, shall be removed in a manner that will not affect the immediate or future performance, reliability, or structural integrity of the item or the system. The equipment Manufacturer, or the Owner or his designee, as applicable, shall be advised of the unauthorized attachment and shall review the impact of such attachment. The method of removal or repair, or both, if necessary, shall be authorized by the equipment Manufacturer or the Owner or the Owner's designee. If the attachment does adversely affect immediate or future performance or reliability, and removal of the attachment or repair does not eliminate the adverse result, the item affected shall be replaced.

ARTICLE AA-7000 PACKAGING, SHIPPING, RECEIVING, STORAGE, AND HANDLING

AA-7100 GENERAL

AA-7110 SCOPE AND APPLICABILITY

This article contains general requirements for packaging, shipping, receiving, storage, and handling of components, parts, and equipment.

The requirements of this article are applicable to the extent they are invoked by the other Code sections. Unique requirements are given in each respective Code section.

AA-7120 RESPONSIBILITY

The requirements for the activities covered by this Code are identified in this article and in each Code section. The establishment of practices and procedures, and the providing of resources for personnel, equipment, and services necessary to implement the requirements of this Code, may be delegated to other organizations, and such delegation shall be documented. However, it is the responsibility of each organization performing work covered by this Code to comply with procedures and instructions issued for the project and to conform to the requirements of this Code as it is applicable to its work.

AA-7200 GENERAL REQUIREMENTS

This article contains requirements that are to be fulfilled by organizations responsible for performing any segment of work described in each Code section.

This article establishes measures acceptable for the packaging, shipping, receiving, storage, and handling of air and gas treatment items to be incorporated in the nuclear power plant and for the inspections, examinations, testing, and documentation to verify conformance to specified requirements.

This article is intended to supplement ASME NQA-1, Part II, Subpart 2.2. The provisions of this article shall replace these respective sections and subsections of ASME NQA-1, Part II, Subpart 2.2. The balance of ASME NQA-1, Part II, Subpart 2.2, shall apply and be part of this Code.

Terms used in Article AA-7000 that relate to quality assurance are defined in ASME NQA-1, Part II, Subpart 2.2, Terms and Definitions. Additional terms are defined in Part I, Article 400.

AA-7210 PLANNING, PROCEDURES, AND INSTRUCTIONS

The design specification and drawings for air and gas treatment items shall include provisions for accomplishing the packaging, shipping, receiving, storage, and handling activities described in this Code. The preparation and control of procedures and work instructions for these activities shall be provided. Sufficient details shall be included to ensure compliance with the provisions of Article AA-7000 and each Code section.

AA-7220 PERSONNEL QUALIFICATIONS

Those personnel who perform inspection, examination, and testing activities at the job site to ensure compliance to this Code shall be qualified in accordance with ASME NQA-1, Part I, Requirement 2. Offsite inspection, examination, or testing shall be audited and monitored by personnel who are qualified in accordance with ASME NQA-1, Part I, Requirement 2.

AA-7230 CLASSIFICATION OF ITEMS

The requirements for activities covered by this article (packaging, shipping, receiving, storage, and handling) are divided into four levels with respect to protective measures to prevent damage, deterioration, or contamination of the items, based upon the important physical characteristics and not upon the important functional characteristics of the item with respect to safety, reliability, and operation. It should be recognized, however, that within the scope of each level there may be a range of controls and that the detailed requirements for an item are dependent on the importance of the item to safety or reliability. Items, once classified, shall be restricted to that level or higher for each of the packaging, shipping, receiving, storage, and handling operations. Any package unit or assembly made up of items of different levels shall be classified to the highest level designated for any of the respective parts, unless the higher level subassembly or part can be packaged to its respective level while still attached to the total assembly or is totally protected within the assembly. The balance of the unit or assembly may be classified to a lower level. If the unit is disassembled, a level shall be indicated for each part.

Items covered by this Code are given the appropriate protection classification level in accordance with the provisions of ASME NQA-1, Part II, Subpart 2.2, Article 202 and these levels and detailed requirements are delineated in each equipment section of this Code.

AA-7300 PACKAGING

AA-7310 GENERAL

This subarticle contains the requirements for packaging items for protection against corrosion, contamination, physical damage, or any effect that would lower the quality or cause the item to deteriorate during the time it is shipped, handled, and stored.

Implementation of AA-7300 is accomplished by applying the appropriate criteria contained in ASME NQA-1, Part II, Subpart 2.2, concerning cleaning, preservatives, desiccants, inert gas blankets, cushioning, caps and plugs, barrier and wrapping materials, tapes, blocking and bracing, containers, marking, other quality assurance provisions, and documentation.

AA-7320 LEVEL OF PACKAGING

The packaging criteria are divided into four levels corresponding to the levels designated by AA-7230.

AA-7400 SHIPPING

AA-7410 GENERAL

This subarticle covers the requirements for loading and shipment of items as defined in AA-7230. Described herein are environmental protection during transit, procedures to minimize damage in transit, precaution required when handling items during loading and transit, and identification and inspection on overseas shipments.

The mode of transportation used shall be consistent with the protection classification of the item and with the packaging methods employed.

ARTICLE AA-8000
QUALITY ASSURANCE

AA-8100 GENERAL

AA-8110 SCOPE AND APPLICABILITY

This article contains general requirements for the quality assurance of components, parts, and equipment.

The requirements of ASME NQA-1 apply to the component, parts, and equipment covered by this Code.

The requirements of Article AA-8000 are applicable to the extent they are specifically invoked by each Code section. Additional or supplemental requirements may also be given in each Code section.

AA-8120 RESPONSIBILITY

The organization invoking this Code for the design, construction, and acceptance testing of equipment, parts, and components used in nuclear safety-related air and gas treatment systems in nuclear facilities shall be responsible for specifying any additional requirements and appropriately relating them to specific items or services.

AA-8130 RESPONSIBILITIES OF FABRICATORS, MATERIAL SUPPLIERS, AND MATERIAL MANUFACTURERS

(a) Some or all of the responsibilities of lower tier organizations may be assumed by any higher tier organization (e.g., the Owner may assume some of the responsibilities, such as certifying test results, of the Material Manufacturer). The organization assuming lower tier responsibility shall meet the requirements noted herein for that organization.

(b) In addition to the specific responsibilities delegated to the Fabricator, Material Supplier, and Material Manufacturer by the Owner or designee, the following shall apply:

(1) each member of the chain depicted in Fig. AA-8130 shall be responsible for evaluating and qualifying the suppliers of contracted services or material from the next level down, i.e., the Fabricator shall be responsible for evaluating and qualifying the Material Supplier's quality assurance program, and so forth

(2) each member of the chain depicted in Fig. AA-8130 shall be responsible for notifying the party that qualified their program of planned modifications that might affect the quality of the delivered product

(3) the Fabricator, Material Supplier, and Material Manufacturer shall be responsible for establishing and maintaining an identification and verification program for the traceability of material while under his control

(4) the Fabricator, Material Supplier, and Material Manufacturer shall be responsible for controlling quality during manufacture and fabrication, including control of manufacturing processes, testing, examination, repair, and treatment of the material, including subcontracted services

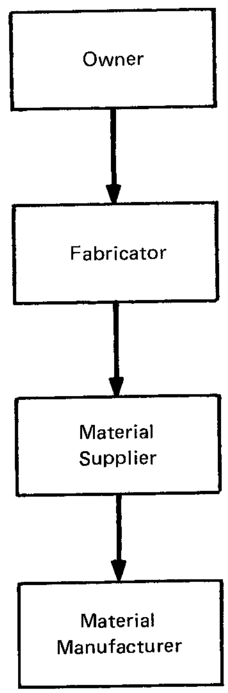
AA-8200 IDENTIFICATION AND CONTROL OF ITEMS

AA-8210 DOCUMENTATION

Documents for procurement of material and subcontracted services shall include requirements necessary to ensure their compliance with ASME NQA-1 and the additional requirements of this paragraph. Measures shall be established to ensure that all purchased and fabricated material and services conform to the requirements of this paragraph.

Measures shall be established for identification and control of material, including partially processed material, throughout the manufacturing and fabrication process and during shipment. These measures shall ensure that identification is maintained either on the material or on records traceable to the material through manufacture and fabrication. Welding filler metal for use in repair of the material shall also be controlled in accordance with this paragraph.

FIG. AA-8130 HIERARCHY OF RESPONSIBILITY



AA-8220 IDENTIFICATION AND COMPLETED MATERIAL

(a) Identification of material from the Material Manufacturer shall consist of marking the material with its applicable specification and grade, heat number or heat code, and any additional marking required by this section to facilitate traceability of the results of all tests and examinations performed on it; except that, for those materials for which the Material Manufacturer's Certificates of Compliance are allowed, heat number or heat code identification need not be indicated either on the material or the certificates. Alternatively, a marking symbol or code that identifies the material with the material certification may be used, and such symbol or code shall be explained in the Certified Material Test Report or Certificate of Compliance, as applicable.

(b) Physical identification on individual material used in the assembly of a component by heat number or code, or specification and grade, need not be done provided the completed assembly is marked with a unique identification number that is traceable to documentation that identifies the material used in the assembly by the requirements of AA-8220(a).

AA-8230 MARKING REQUIREMENTS FOR SMALL PRODUCTS

(a) Except as required by the material specification, small parts need not be individually marked provided they are packed in packages or containers that are clearly identified by legible marking to ensure positive identification of the material up to the point of use.

(b) Welding and brazing materials shall be clearly identified by marking on the package or container to ensure positive identification of the material. The package or container marking shall include the heat or lot number, as applicable, a control marking code that identifies the materials with the Certified Material Test Report, and other information such as specification, grade, classification number, supplier's name, and trade designation.

AA-8240 CERTIFIED MATERIAL TEST REPORTS

The Certified Material Test Report, when required, shall include the actual results of all required chemical analyses, mechanical tests, and examinations.

AA-8250 RECORDS OF EXAMINATIONS AND TESTS

All characteristics required to be reported by the material specifications and by this section shall be traceable to the results recorded. Records shall identify the procedure and revision to which an examination or test was performed and include the recorded results of examinations and tests. Measures shall be established so that the status and results of any required examination and test can be determined for the material.

AA-8300 QUALITY ASSURANCE RECORDS

Documentation required by this section and each of the other sections shall be prepared, maintained, and submitted to the Owner for recording as required by the applicable section and ASME NQA-1.

ARTICLE AA-9000
NAMEPLATES AND STAMPING

AA-9100 GENERAL

AA-9110 SCOPE AND APPLICABILITY

This article contains general requirements of nameplates for components and equipment.

The requirements of this article are applicable to the extent they are specifically invoked by the other Code sections. Unique requirements are given in each Code section.

Stamping is required only for those components constructed in accordance with the ASME Code. No other third party inspection or certification is required by this Code.

AA-9120 REQUIREMENTS

Each item shall have a nameplate, except as otherwise permitted by this Code. Nameplate information shall be as required by (a) through (e) below:

(a) Manufacturer's name

(b) Manufacturer's serial number and, if applicable, model number

(c) capacity in appropriate units

(d) operating temperature and pressure

(e) other data prescribed by the specific equipment section of this Code

The data shall be in characters not less than $^3/_{32}$ in. (2.4 mm) high. All nameplate marking shall be stamped, etched, cast, or impressed on the nameplate. Nameplates shall be of a noncorrosive material. Stamping directly on items, where permitted by the respective equipment section of this Code and used in lieu of a nameplate, shall be done with blunt-nosed continuous or blunt-nosed interrupted dot die stamps. The selected marking method shall not result in any harmful contamination or sharp discontinuities.

AA-9130 ATTACHMENT OF NAMEPLATES

If the nameplate is marked before it is affixed to the item, the Manufacturer shall ensure that the nameplate with a correct marking has been applied to the appropriate item.

The nameplate shall be attached by a method that will not affect the structural or operational integrity of the item and that shall ensure permanent attachment during the life expectancy of the component.

AA-9140 LOCATION OF NAMEPLATES

The location of the nameplate shall be shown on the as-constructed drawing. It should be readily visible when the component is installed. Nameplates shall be located so insulation does not obscure nameplate data.

ARTICLE AA-10000
REPAIR AND REPLACEMENT OF COMPONENTS

AA-10100 GENERAL

AA-10110 SCOPE

This Article establishes the requirements for repair and replacement activities for components designed to the requirements of this Code.

AA-10120 APPLICABILITY

This Article applies to repairs and replacements of components designed to the requirements of this Code. Further, this Article may apply to components designed to the requirements of ASME N509.

This section covers repair and replacement of items not subject to the requirements of the ASME Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components.

Routine maintenance replacements (see AA-10410) are excluded from this Article of the Code.

AA-10121 Criteria

The repair or replacement activity is within the scope of this Article if all three of the criteria listed below apply.

(a) The subject activity applies to a part of a nuclear safety-related air or gas treatment system.

(b) The subject activity involves a component, component part, or a load-bearing member of a component support.

(c) The subject activity is a repair or replacement other than a routine maintenance replacement item.

AA-10122 Code Edition Reconciliation

The repair or replacement activitites shall meet the requirements of the original ASME AG-1 construction Code or as allowed in (a), (b), and (c) below.

(a) A later edition of the construction Code may be used in lieu of the original construction Code edition if appropriate documentation is prepared in accordance with (c) below.

(b) If the repair cannot be performed in accordance with the original construction Code, alternative techniques and processes may be used provided reconciliation as described in (c) below is provided to demonstrate the adequacy of the substitute for its intended purpose.

(c) If a later edition of the construction Code is used for a replacement, the following requirements shall be met:

(1) Only the technical requirements affecting the material, design, fabrication, and examination of the replacement need to be reconciled.

(2) For design purposes, the reconciliation shall include a structural analysis report or other method that demonstrates satisfactory use of the specified loading conditions.

(3) Any changes in mechanical interfaces, fits, and tolerances required by the later edition of the construction Code shall be reviewed to ensure they do not impact the required performance.

(4) Administrative requirements do not need to be reconciled.

(5) The administrative requirements of either the construction Code of the item being replaced or the construction Code of the item used for replacement shall be met.

AA-10200 WELDING

Prior to authorizing repairs/replacements involving welding, a Welding Procedure Specification (WPS) to make the repair/replacement shall be prepared and evaluated for suitability. If the repair/replacement is due to failure of a weld, this evaluation shall consider the cause(s) of failure in the determination that the selected procedure is suitable.

Welding procedures and welders shall be qualified in accordance with the welding requirements specified by the construction Code for the particular component.

AA-10300 REPAIRS

Repair operations shall be performed according to written instructions that delineate the following essential requirements below, as applicable:

(a) the description of the flaw.

(b) the procedures that will be used to perform the repair (e.g., special process welding, heat treatment).

(c) the evaluation for the suitability of the repair procedures.

(d) the flaw removal/isolation method, the method of measuring any cavity created by removing the flaw, and dimensional requirements for reference points during and after the repair.

(e) the preservice examination requirements after the repair.

(f) the Nondestructive Examination (NDE) method that revealed the flaw shall be repeated. If the repair includes the complete removal of the flaw, the NDE method required by the construction Code revealing the flaw need not be repeated.

(g) the testing requirements after completion of the repair.

AA-10400 REPLACEMENTS

AA-10410 ROUTINE MAINTENANCE

The following replacements are considered routine maintenance items and are not covered by this Article:

(a) instruments other than nuclear safety-related instruments

(b) electrical wire and cable, including terminations and markings

(c) seals, packing, gaskets, and valve/damper seats

(d) nonload bearing members of component supports

(e) consumable items

AA-10420 SUITABILITY

The Owner shall review the applicable replacement component design documents against specification requirements and resolve any differences that affect performance.

AA-10422 Component Failure Analysis

A component failure analysis of the original items shall be performed if the original item failed in service. The cause(s) of failure shall be identified. Any recommended change to prevent recurrence shall be incorporated into the specification.

AA-10423 Monitoring Plan

In cases where the failure cause cannot be identified, a monitoring plan for the replacement component shall be established and implemented. This plan shall include the following:

(a) identification of component parameters to be monitored

(b) description of and location within the system of the instrumentation required to perform the monitoring function and to record the data

(c) frequency of physical inspection and sampling activities

(d) criteria for determining the end of the replacement and component's useful life (prior to complete failure) and steps to be taken when such determination has been made that the useful life is at an end

AA-10430 ADDITIONAL DOCUMENTATION

In addition to the requirements of AA-10420, written procedures, instructions, or similar documents shall be available that include the documents described below. If the installing contractor is other than the Owner, all such documents shall be Owner approved prior to commencement of the work.

AA-10431 Replacements Involving Welding or Brazing

(a) the construction Code governing the installation of the replacement

(b) applicable Welding Procedure Specifications (WPS) or Brazing Procedure Specifications (BPS) and Procedure Qualification Records (PQR)

(c) applicable heat treatment procedures

(d) applicable NDE procedures

(e) applicable procedures for preservice examination

(f) applicable system pressure test procedures

(g) acceptance criteria

AA-10432 Replacements Involving Mechanical Joining

(a) the construction procedure or Code governing the installation of the replacement

(b) torque or tension values in accordance with the Contractor's Installation Manual, site procedures, or both

(c) applicable procedures for preservice examination

(d) applicable system pressure test procedures

TABLE AA-10530
LIFETIME REPAIR AND REPLACEMENT RECORDS

1.	Index to Lifetime Records
2.	Manufacturer's Data Reports, if applicable
3.	Design Specification
4.	Stress Report
5.	Material Certification
6.	Suitability Evaluation Report
7.	System Pressure Test Reports
8.	Final NDE Reports
9.	Welding and Brazing Procedures and PQRs

AA-10500 RECORDS

AA-10510 GENERAL REQUIREMENTS

The provisions of ASME NQA-1, Requirement 17, Quality Assurance Records, shall apply.

AA-10520 RECORDS INDEX

The records shall be indexed. The records and the indices thereto shall be accessible.

AA-10530 LIFETIME RECORDS

The records listed in Table AA-10530 shall be classified as Lifetime Records. The installing Contractor shall be responsible for the retention and maintenance of those records while they are under the Contractor's control. The Owner shall be responsible for retention and maintenance of those records transferred from the Contractor. The Owner shall define when the actual transfer shall occur.

TABLE AA-10540
NONPERMANENT REPAIR AND REPLACEMENT RECORDS

Record	Retention Period
QA Program Manual	3 yr after superseded or invalidated
QA Procedures	3 yr after superseded or invalidated
Installation and NDE Procedures	10 yr after superseded or invalidated
Personnel Qualification Records	3 yr after superseded or invalidated
Audit Reports	3 yr after completion of report
Calibration Records	Until recalibration
Process Sheets, Travelers, or Checklists	10 yr after completion

AA-10540 NONPERMANENT RECORDS

The records listed in Table AA-10540 shall be classified as Nonpermanent Records. The organization performing the repair or replacement activity shall be responsible for their retention for the period specified in Table AA-10540. In no case will there be a need for nonpermanent records to be maintained for longer than 10 yr after the installation is complete.

NONMANDATORY APPENDIX AA-A
DESIGN AND QUALIFICATION BY ANALYSIS

ARTICLE AA-A-1000
INTRODUCTION

In many cases, the primary acceptance criterion for design verification is maintenance of structural integrity. If such is the case, analysis is a very practical means of demonstrating acceptability of equipment. Analysis has the advantage of being relatively simple, and it has good reproducibility and auditability. Furthermore, if a piece of equipment similar to one previously analyzed is to be investigated, a significant reduction in effort may be achieved simply by revision of the existing analysis.

Structural analysis is accomplished by manual engineering calculations, finite element calculations, or a combination of the two. The objective of this Appendix is to provide some insight for the designer in application of conventional finite element techniques to sometimes unconventional equipment designs found in HVAC systems. Manual calculations are adequately covered in engineering texts and the literature. Several categories of HVAC equipment are discussed, and specific examples are given for an air handling unit and a duct support.

TABLE AA-A-1000
ANALYSIS CONSIDERATIONS

Analysis Consideration	Manual	FEM
Problem size	Small	Large
Problem complexity	Simple	Complex
Nature of loading	Static, simple, dynamic	Static, dynamic
Number of combined loads	Few	Many
Existence of irregularities (holes, discontinuities)	Few, simple	Many, complex
Design iterations	Few	Many

In choosing an analysis method, manual or finite element, many factors must be considered. Some of these factors and the methods of choice are listed in Table AA-A-1000.

ARTICLE AA-A-2000
FINITE ELEMENT METHOD

The precise solution of complex discrete-parameter structural analysis problems is commonly referred to as the finite element method (FEM). The energy concept is commonly used in formulating the problem's solution. The load vectors, stiffness, mass, and, sometimes, damping matrices are constructed from geometry and loading information developed by the designer. For all but the simplest problems, this matrix work is done entirely by a finite element computer program. The FEM program then performs all of the matrix manipulations necessary to arrive at a solution. For example, given the structural geometry, boundary conditions, and externally applied forces and/or displacements, the program will compute the displacements, support reactions, and internal forces for the equipment components.

Use of the FEM is no more powerful nor accurate than the designer's skill and knowledge of its use. Many modeling decisions and assumptions must be made with the awareness of the resulting impact on the solution accuracy. Considerations particular to HVAC equipment are discussed in detail in Article AA-A-4000.

The designer follows these steps in performing a finite element analysis:

(a) the decision is made that the FEM is a valid method for the problem

(b) the equipment design is reduced to a mathematical model by

(1) locating major structural elements such as frame members and sheet metal (frame members are represented by beam elements and sheet metal by plate or shell elements)

(2) locating nodes (intersection points of structural elements, anchorage points, external loading points, device mounting points)

(3) defining connectivity (identifying nodes at ends and corners of structural elements)

(4) defining material properties

(5) locating and defining supported masses

(6) defining internal and external loadings

(c) the above information is coded and entered on a computer for subsequent analysis

(d) the resulting output is examined, combined, and evaluated to determine if stresses, displacements, etc., are within allowable limits

Guidelines specifically related to HVAC equipment undergoing a FEM analysis are given in the following articles.

ARTICLE AA-A-3000
EQUIPMENT CONSTRUCTION

Equipment for air and gas treatment systems is generally fabricated with metal that lends itself to linear–elastic or inelastic analysis techniques. Framing systems for such equipment are generally constructed of AISC standard cold-rolled shapes or formed shapes made by bending sheet metal steel. The standard shapes used are primarily angles, structural tubing, and channels, although W sections are often used as floor members. Bent-up shapes are used in a wide variety of forms such as angles, channels, hat sections, U, C, and Z sections. Structural members, as in the case of sheet metal, may be made of carbon steel or stainless steel. These structural members and sheet metal may be connected using welded, bolted, riveted, Pittsburgh lock, or mechanical-type connections.

For welded-type connections, the gas-arc weld process using standard E 50, E 60, or E 70 electrodes is commonly used. Common types of welds are fillet welds, butt welds, groove welds, and plug welds. Sheet metal may be welded to structural framing members using intermittent welds.

Bolts used in the construction of housings and structural components of equipment are usually of low strength coated carbon steel and are generally small in diameter [less than $^3\!/_4$ in. (18 mm)]. Anchor bolts used to hold down a framing system may be either of low strength or high strength steel.

Equipment may be wall or floor mounted, or suspended from the ceiling. External supports are usually used for wall and ceiling supported equipment and sometimes for floor mounted equipment where the equipment must be elevated. Most external supports are trapeze-type moment frames or simple trusses or, in the case of wall mounted units, cantilever supports may be used. Cantilever supports are usually braced against side sway. Supports may be attached to clips, base plates, or cast-in-place embedments. Floor mounted equipment, especially large air handling units, often has no external supports. Integral supports such as base-frame footings, runners, or clips are bolted directly to the floor.

Equipment may be attached to existing structures either with built-in anchors or installed anchors. Built-in anchors commonly used are cast-in-place embedments or anchor bolts. Installed anchors are drilled-in expansion or drilled and grouted anchor bolts, or bolts placed into existing inserts.

Nonstructural components must be supported. These include, but are not limited to, filters, cooling coils, heating coils, fans (or fan internal components, such as bearings, shafts, fan wheels, and inlet and outlet cones), motors, screens, registers, grilles, dampers, transitions, ductwork connections, control and monitoring instruments, tubing and piping, compressors, chillers, and access doors and panels. Since most of these components must be removable for servicing, they are generally installed using detachable connections such as bolts, screws, clamps, racks, or rollers.

ARTICLE AA-A-4000 MODELING TECHNIQUES

Finite element modeling of HVAC equipment involves many considerations that are beyond the scope of this Appendix. The analyst must have a working knowledge of the behavior of the structure and its components under various types of loadings and the governing acceptance criteria for the particular load combination.

(a) This article addresses the formulation of equipment models for five categories of HVAC equipment:

(1) air-handling units (AHU)

(2) fans

(3) instruments and controls (I & C) cabinets

(4) duct supports

(5) equipment supports (e.g., refrigeration equipment, filters, cooling coils, heating elements, etc.)

(b) The equipment may be separated into various modeling systems such as

(1) the framing system or skeleton, which may consist of structural members modeled using beam-type finite elements

(2) sheet metal housing covering the structural framing, which may be modeled using plate-type finite elements; in some cases, the structural framing may be formed by making standing seams from the sheet metal housing without the use of additional structural load-bearing members; these members may be modeled using beam-type finite elements

(3) the connections between the structural frame and sheet metal housing, which may be modeled using shear-type finite elements or appropriate boundary conditions

(4) nonstructural components within the housing and their local support systems; these components may be modeled using an equivalent mass and stiffness with appropriate boundary conditions, and the local supports may be modeled using beam-type finite elements

(5) equipment supports consisting of structural members attached to the floor using anchors or welds; the supports may be modeled using beam-type finite elements, and the anchors and welds are modeled by selecting appropriate boundary conditions

AA-A-4100 AIR HANDLING UNIT (AHU) MODEL

Formulating a model for an AHU requires a fabrication and assembly drawing showing the external framing and internal components. The external framing could be modeled using beam-type elements with the skin represented by plate-type elements. In developing a plate mesh, care should be exercised in keeping the aspect ratio of each element to a minimum (preferably below 2). Provision should be made for representing internal components such as heating elements, cooling coils, filters, and dampers by an appropriate mass and stiffness representation at nodal points where these components are attached. Supports for such components are modeled using beam-type elements with the proper boundary conditions representing a fixity, release, or a combination for developing end forces and moments. The attachment of the equipment skid to the floor should also be represented to obtain the proper reaction loads and overturning moments. An example of a mathematical model for an AHU is shown ahead in Figs. AA-A-7100-1 and AA-A-7100-2. This model can be used to perform a deadweight analysis, an internal pressure analysis (with the internal pressure applied on the plate elements of the AHU), external duct and piping loads applied at the connections to the AHU, and dynamic loads as applicable.

AA-A-4200 FAN MODEL

A model for fans is developed using the assembly drawings and fan component specifications. Components of structural importance to the model include the support framework, the bearing supports, fan shaft, and the fan housing sheet metal. Nonstructural components such as the fan wheels and the bearings are represented in the models by masses lumped at appropriate nodes. The fan model is composed of nodes connected by beam and plate finite elements. The base, vertical supports, and the bearing supports are modeled with prismatic beam elements. The fan shaft is modeled as a simply supported beam with a node in the center at which the mass of the fan wheel is lumped. The fan housing is bolted or welded to the supporting framework. Nodes are included in the model at the approximate locations where the beams of the framework are connected to the plates used to model the fan housing. Nodes representing anchor bolts are restrained against translation. A typical mathematical model used to analyze the fans is shown in Fig. AA-A-4200. This model can be used to determine the dynamic behavior and perform a detailed stress analysis of the fan.

AA-A-4300 INSTRUMENTS AND CONTROLS (I & C) CABINETS

Formulating a model for an I & C cabinet requires an assembly and fabrication drawing showing the cabinet framework, component supporting structures, I & C components, and their attachment to the supporting structures. The cabinet framework can be modeled using beam elements and the panels using plate elements. The I & C support structures may be modeled using beam or plate elements at their proper locations. The component mass must be incorporated in the finite-element representation. A model of an I & C cabinet is shown in Fig. AA-A-4300. This model can be used to perform a deadweight and dynamic analysis.

AA-A-4400 DUCT SUPPORTS

Duct supports can be modeled using beam elements; however, duct mass and flexibility should be properly simulated. The natural frequency of the ductwork can be dominated by either hanger displacement or duct deflection. The interaction of the ductwork with the supports should be represented through appropriate spring and mass boundary conditions. A sample model for duct supports is shown in Fig. AA-A-4400. This model may be used to perform a deadweight, concentrated load, and dynamic analysis.

AA-A-4500 EQUIPMENT SUPPORTS

Equipment supports can be modeled using beam elements. The mass and stiffness of the equipment should be included with the beam elements that represent the framework. The attachment of the frame to the floor should be represented through accurate boundary conditions. A sample of such a model, a refrigeration system support, is shown in Fig. AA-A-4500. This model can be used for evaluating the equipment support for deadweight, operating loads, and dynamic loads.

FIG. AA-A-4200 ISOMETRIC VIEW OF A TYPICAL FAN MODEL

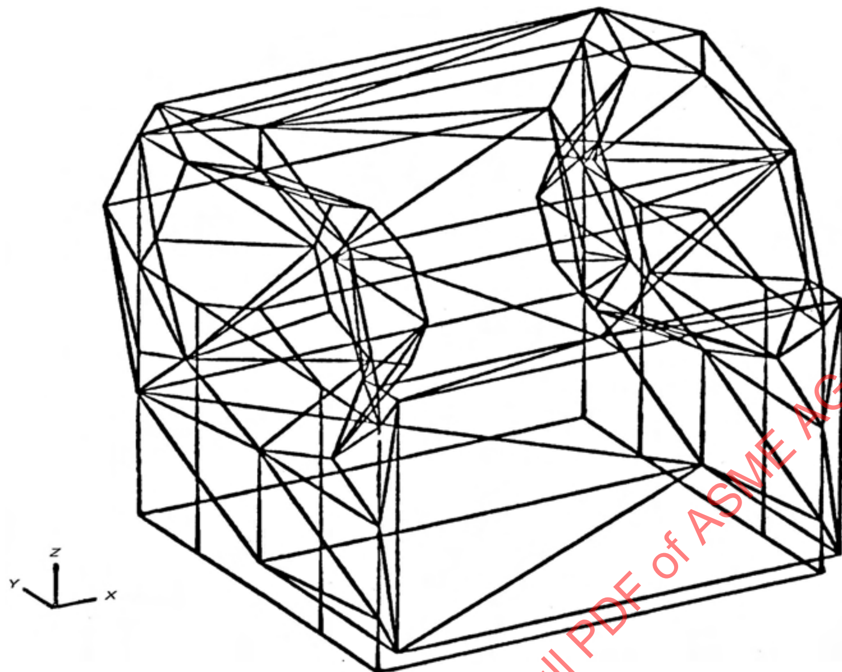


FIG. AA-A-4300 ISOMETRIC VIEW OF A TYPICAL I & C CABINET MODEL

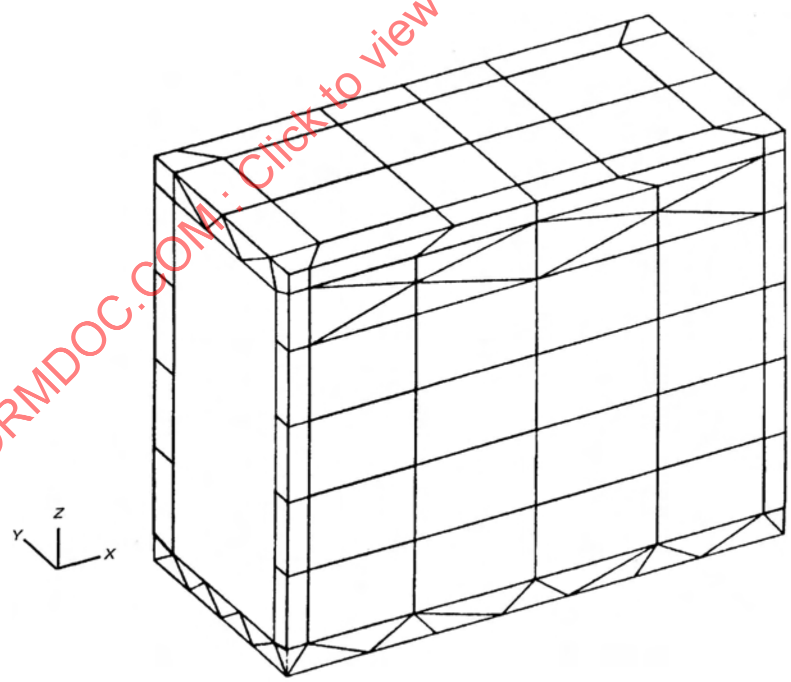


FIG. AA-A-4400 ISOMETRIC VIEW OF A TYPICAL DUCT SUPPORT MODEL

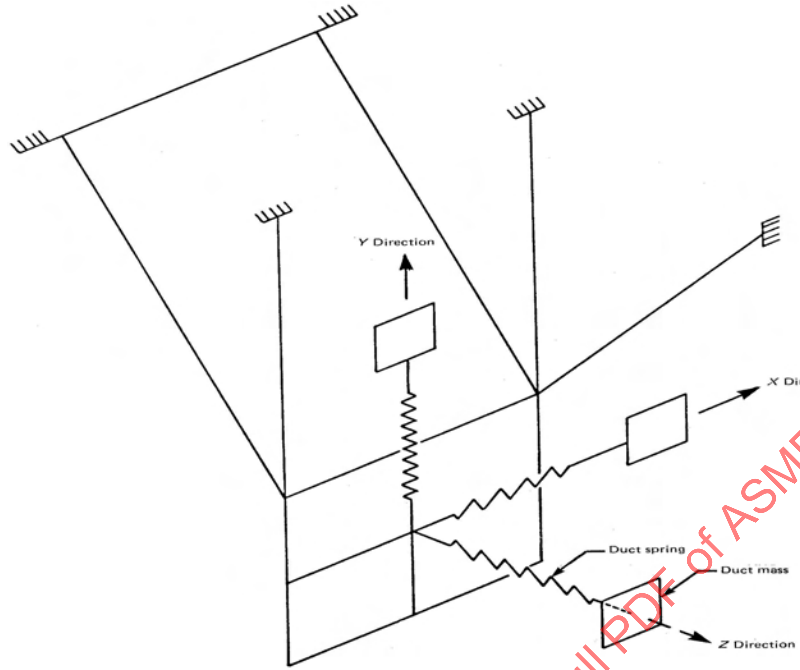
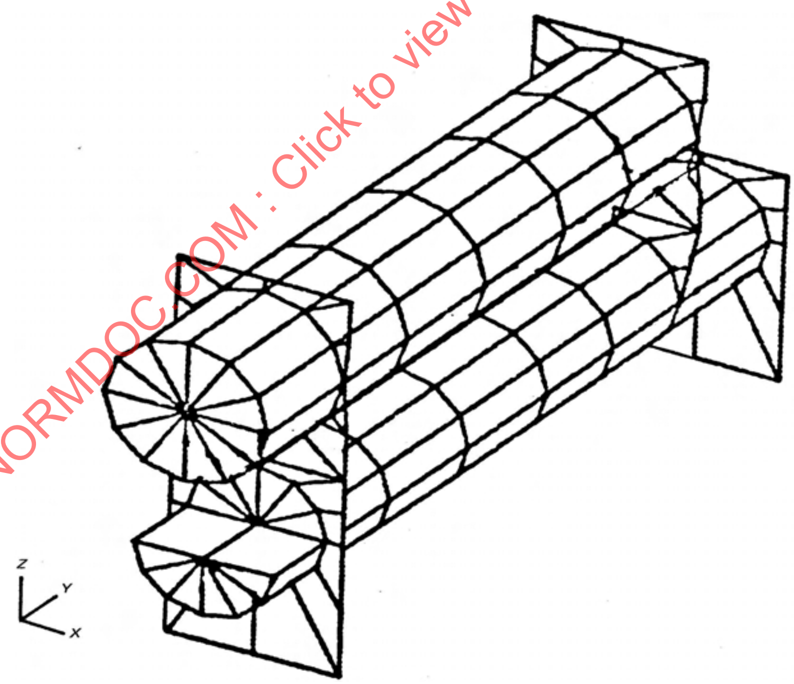


FIG. AA-A-4500 ISOMETRIC VIEW OF A TYPICAL REFRIGERATION EQUIPMENT SUPPORT



ARTICLE AA-A-5000
ANALYSIS

The structural and stress analyses necessary for designing the equipment and supports listed in Article AA-A-4000 should be performed using the methods outlined in this article. Other methods meeting the intent of this article may also be used. These analyses would use the models similar to those shown in Article AA-A-4000.

AA-A-5100 STATIC ANALYSIS

AA-A-5110 STATIC LOADS

Equipment and supports can be analyzed for static loads, which may include the following loads defined in A-4211:

(a) deadweight
(b) design pressure differential load
(c) live loads
(d) constraint of free end displacement loads (static or static equivalent)
(e) external loads (static)
(f) inertia loads (static equivalent)
(g) design wind load

AA-A-5200 DYNAMIC ANALYSIS

AA-A-5210 DYNAMIC LOADS

Dynamic analyses should be performed to determine the stresses and/or deflections of equipment and supports for the applicable dynamic loads, which may include the following loads defined in AA-4211:

(a) seismic loads
(b) additional dynamic loads

AA-A-5220 DYNAMIC ANALYSIS TECHNIQUES

Dynamic analysis can be performed using either response spectrum or time history techniques. Equivalent static analysis can also be performed, if justified. Dynamic analysis methodology outlined in Appendix N of the ASME Code, Section III, can be used to verify the adequacy of the equipment and supports.

AA-A-5230 INPUT MOTION

(a) The input motion representing the dynamic load will be applied at the location or locations at which the equipment and supports are supported from the primary structure (often a building floor, beam, or wall). If the equipment and supports are attached to an intervening component, the flexibility of the component providing the load path to the primary structure will be considered in defining the input motion.

(b) If the equipment and supports are connected to more than one supporting structure having different motions, the dynamic analysis should be performed using response spectra that envelop the individual response spectra for each support as input motion. If significant, the relative difference in displacements between support locations may also have to be considered.

AA-A-5240 TWO-STEP ANALYSIS

Stresses and loads in the equipment and supports due to dynamic loads may be determined by a two-step analysis. In the first step, the equivalent dynamic loads and accelerations, or both, applicable to the various elements of the equipment and supports, are determined from the dynamic analysis of a simplified model. In the second step, these loads are applied statically to a detailed model to determine the design stresses and loads, or both.

ARTICLE AA-A-6000
EVALUATION OF RESULTS

The results of the analyses should be presented in a format with convention, nomenclature, bases, modeling, and input data clearly stated. The analyses must be verified and the reproducible input preserved in accordance with appropriate quality assurance requirements. Documentation must meet the requirements of AA-4400.

AA-A-6100 STRESSES

Stresses should be combined in accordance with the requirements of AA-4212 to allow evaluation of all service level stresses against the respective service level limits of Table AA-4321 and the requirements of AA-4321 for plate- and shell-type components. Similarly, all service level stresses for linear-type systems must be evaluated against the respective service level limits of Table AA-4323 and the requirements of AA-4323. Acceptance criteria for these evaluations are given in AA-4214.

AA-A-6200 DEFLECTIONS

AA-A-6210 LINEAR

Because of critical operating or functional requirements, the equipment specifications may place limits upon the deflections at identified points of the equipment undergoing analysis. The equipment must be modeled to provide this information at these specific points. The final analysis must demonstrate that the deflection will not exceed the stated limit for the respective service levels identified.

AA-A-6220 NONLINEAR

Normally, Service Levels C and D will not require evaluation of linear (elastic) deflections. However, deflection limits that are controlled by buckling stress criteria are imposed. These limits must be satisfied as required by AA-4323.

AA-A-6300 SUPPORT LOADS

Equipment models must allow estimation of loads at all interfacing support points. (Characteristics of the supports must be included in the model.) The resultant support loads must be coordinated through the equipment support interface points to those responsible for design of the supporting structure.

AA-A-6400 CONNECTION LOADING

Assumptions regarding connections (internal structural connections and attachment of devices) must be evaluated upon completion of the analyses. The analyses results must be used to ensure that internal structural connections and connections that attach individual devices to the equipment are adequate.

AA-A-6500 DEVICE LOADING

The method of analysis described in this appendix is not intended for, nor is it generally adequate for, operational qualification for active equipment. However, proper attention to modeling and to the type of output required will allow the analysis to provide information as to the static or dynamic field to which the device must be qualified. After identification of this environment, the device can be qualified by the method given in AA-4351.8.

ARTICLE AA-A-7000
SAMPLE PROBLEMS

This article presents sample analyses of an air handling unit (AHU) and a duct support.

AA-A-7100 SAMPLE AHU ANALYSIS

Computer generated plots of the mathematical model of a sample AHU are shown in Figs. AA-A-7100-1 and AA-A-7100-2. Figure AA-A-7100-1 shows the structural framework, internal bracing, and duct attachment frames. Figure AA-A-7100-2 shows the triangular plate finite element mesh used to model the external sheet metal skin of the AHU. There are a number of components on the inside of the unit, such as a filter, heating element, cooling coil, and dampers. Some of the components have attachment frames that add stiffness to the structure and are therefore included in the model. The masses of the components are included in the model by lumping mass at appropriate nodes. The AHU is attached to the floor via an integral base composed of channel skids. The channels are included in the model as beam elements. The left end of the AHU is attached to a wall. There is no sheet metal covering on that end of the unit. Several gaps will be noticed in the mesh in other places on the unit. It is at these locations that ducts attach to the AHU; therefore no elements are necessary. One feature of the model that should be noted is that, in each plane of the triangular plate mesh, the elements are oriented as randomly as possible to prevent development of an unrealistic stiffness bias in one direction.

The model geometry, boundary conditions, and loads are coded and entered into a finite element computer program. The program calculates deflections, natural frequencies, and mode shapes. The program then does a response analysis by combining modal responses with a method defined by the analyst. The static and dynamic results are then combined to calculate individual element stresses, frame deflections, and support reactions. Also, accelerations may be calculated at the model nodes.

AA-A-7200 DUCT SUPPORT (HANGER) SAMPLE PROBLEM

A duct support would appear to be a simple piece of hardware to evaluate. In fact, many variables must be considered because they may have significant effects on the outcome of the analysis. Among these variables are

(a) duct support frame
(b) frame connection details
(c) bracing
(d) baseplates
(e) duct size and span lengths
(f) duct construction
(g) supported accessories and insulation
(h) adjacent supports and duct branches

The following paragraphs give a step-by-step description of one possible method for analysis.

AA-A-7210 HANGER MODEL

The hanger is modeled from an as-installed drawing that documents geometry, member sizes, joint fittings, baseplates, welds, and anchor bolts. A typical as-built drawing is shown in Figs. AA-A-7210-1 and AA-A-7210-2.

AA-A-7211 Baseplates

Baseplates are modeled as either completely restrained or as ground springs if the baseplate flexibility is sufficient to significantly affect hanger frequency. The model should provide all possible components of baseplate loading. See Fig. AA-A-7211.

AA-A-7212 Connections

If special joint fittings are used, joint flexibility members are included in the hanger model.

FIG. AA-A-7100-1 COMPUTER PLOT OF FINITE ELEMENT MODEL OF SAMPLE AHU (PERSPECTIVE VIEW OF TRI-PLATE MESH)

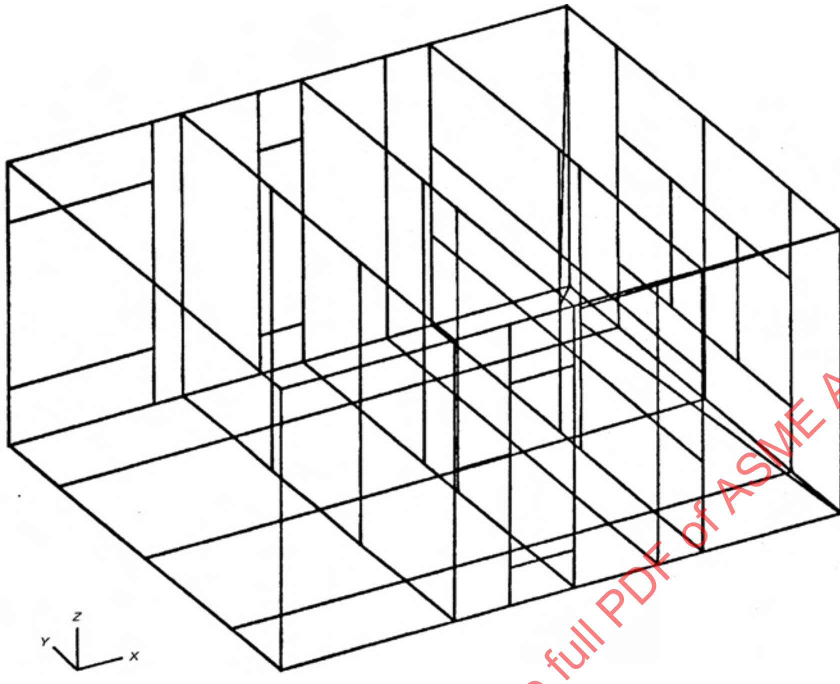


FIG. AA-A-7100-2 COMPUTER PLOT OF FINITE ELEMENT MODEL OF SAMPLE AHU (PERSPECTIVE VIEW OF TRI-PLATE MESH)

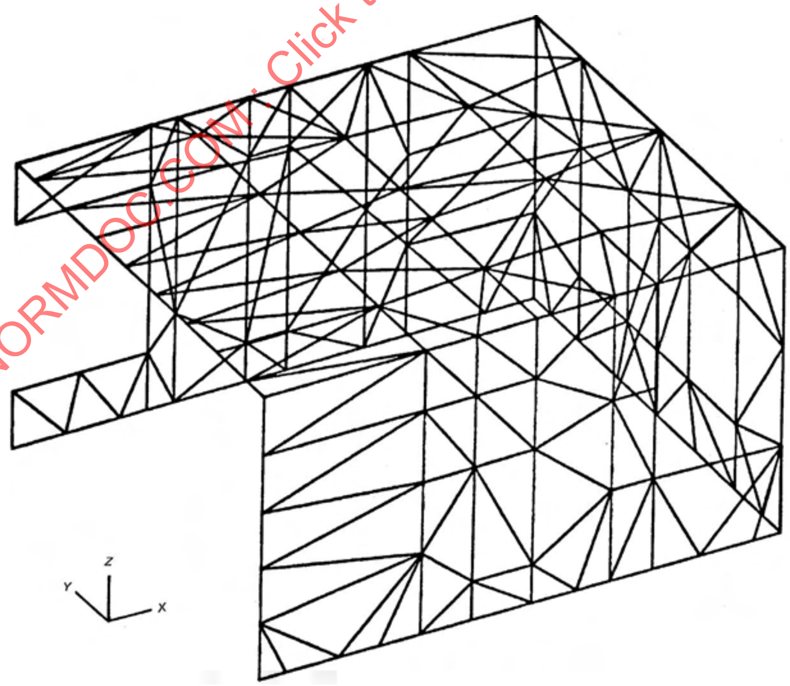


FIG. AA-A-7210-1 TYPICAL DUCT SUPPORT AS-BUILT
(DIMENSIONS AND MEMBER SIZES NOT SHOWN)

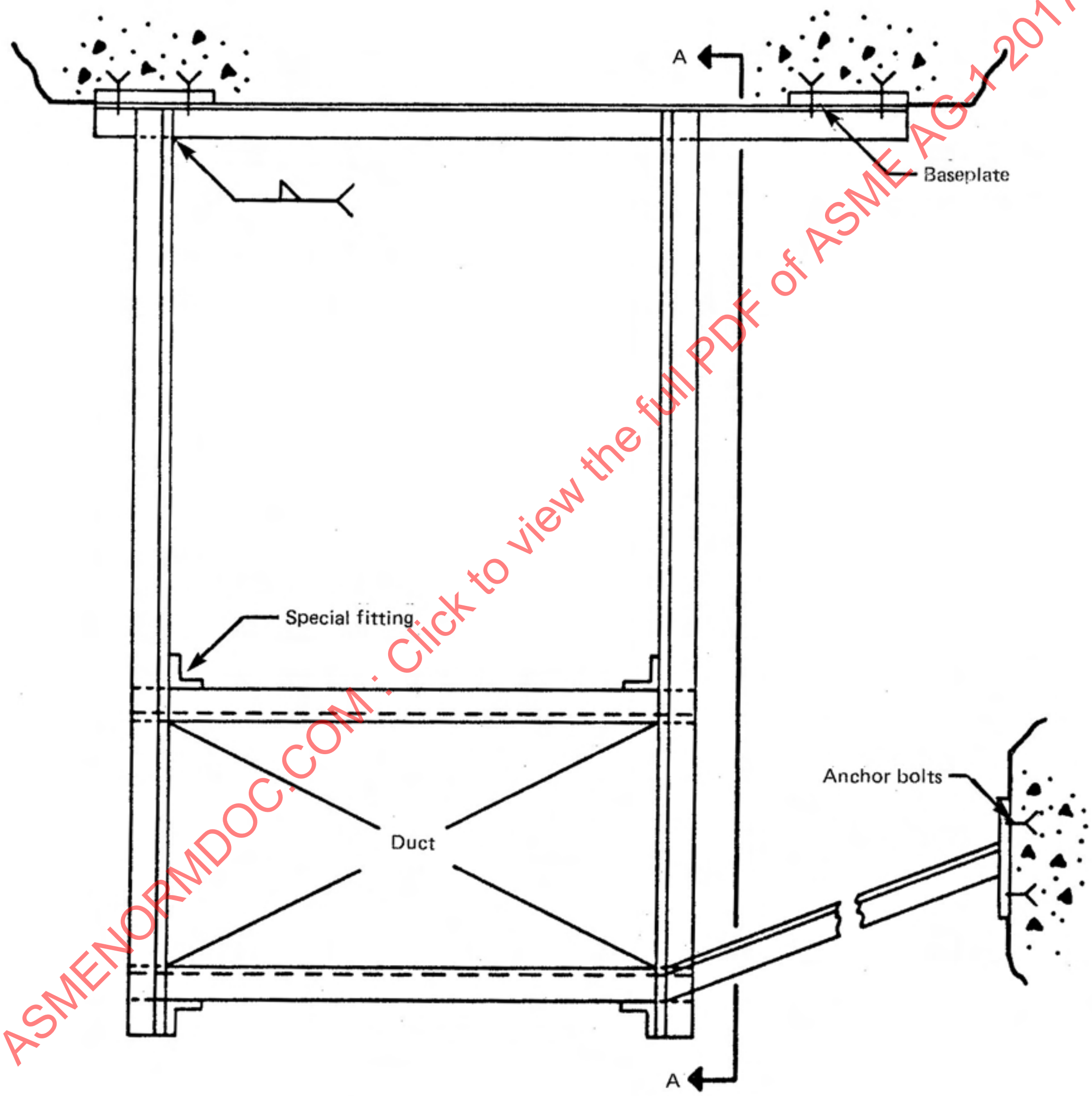


FIG. AA-A-7210-2 TYPICAL DUCT SUPPORT AS-BUILT
(DIMENSIONS AND MEMBER SIZES NOT SHOWN)

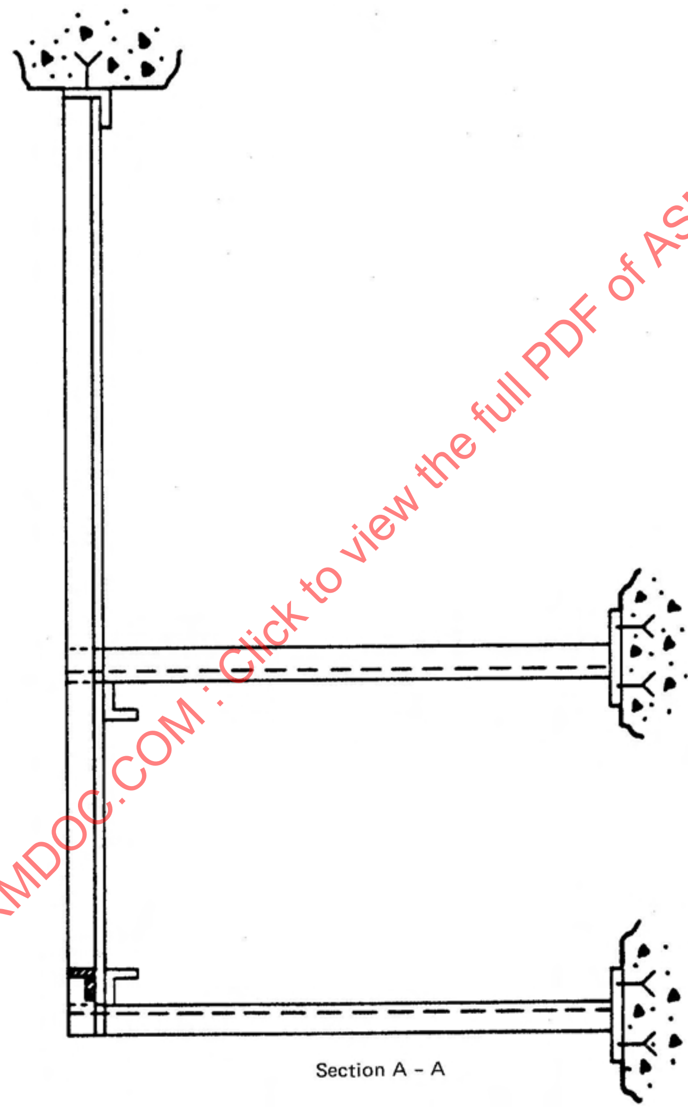


FIG. AA-A-7211 DUCTWORK SUPPORT BASEPLATE MODEL

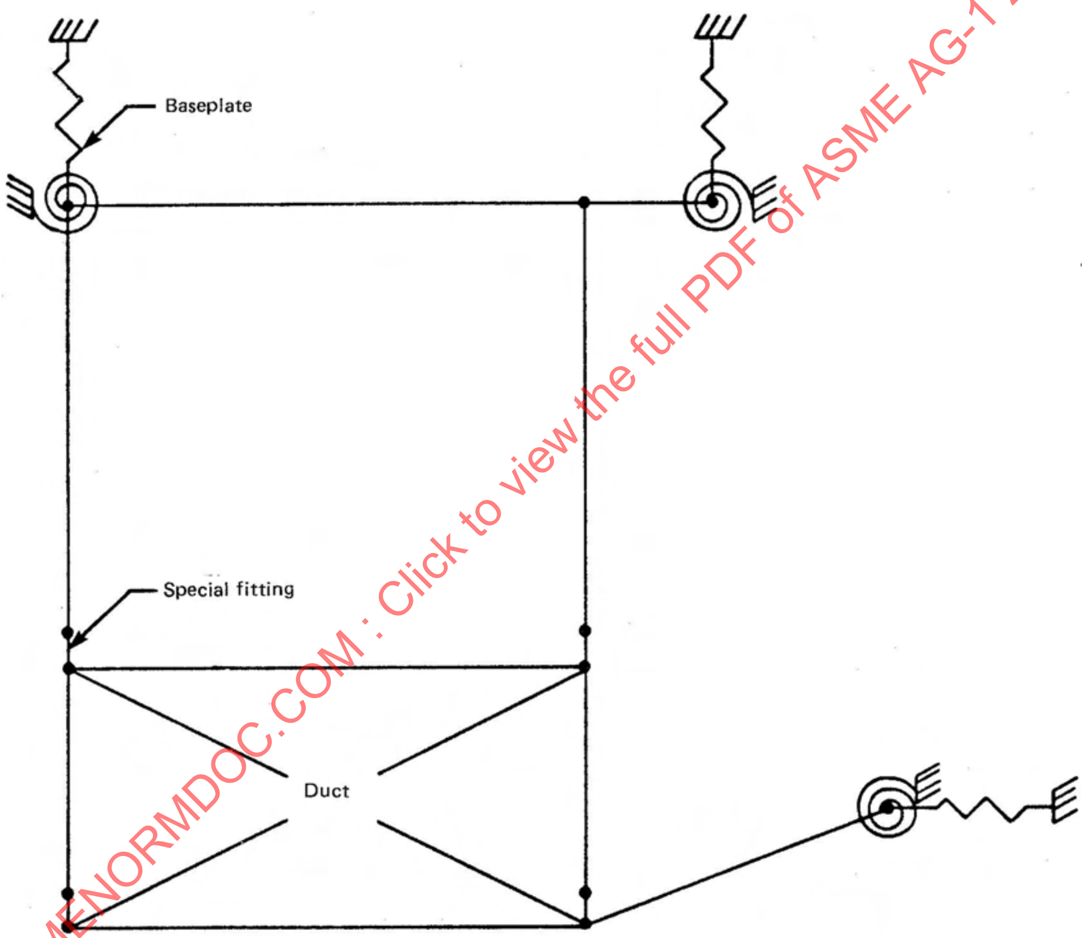
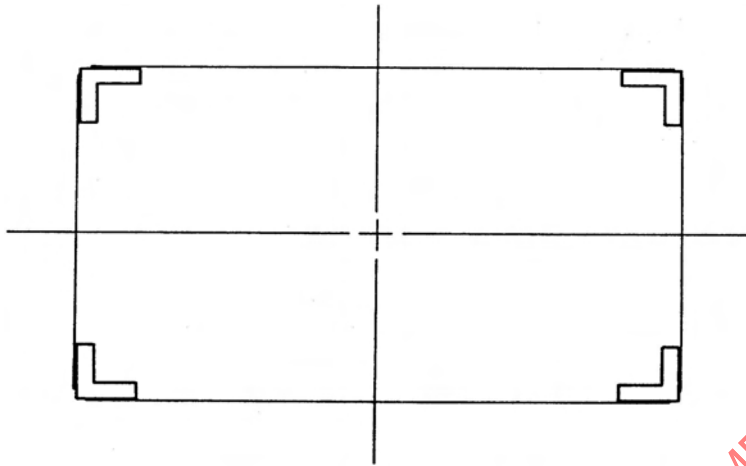


FIG. AA-A-7224 EFFECTIVE DUCT CROSS SECTION



AA-A-7220 ANALYSIS

AA-A-7221 Spring Calculations

A unit load is applied (divided evenly among the four duct nodes) to the hanger model in each principal direction. The average duct displacement is determined for each case, and the effective spring rates of the hanger are calculated in each principal direction.

AA-A-7222 Effective Hanger Weight

A unit load is applied to the hanger in each principal direction. The average duct displacement is determined for each case, and the effective hanger weight is calculated in each principal direction as the product of the effective spring rate from AA-A-7221 and the average duct displacement.

AA-A-7223 Allowable Loads

For each load case of AA-A-7221, the maximum allowable load that satisfies the following criteria is determined:

(a) an interaction formula relating reaction loads from the hanger model at the baseplate location to allowable baseplate or anchor bolt loads is satisfied

(b) an interaction formula relating member end loads from the hanger model to appropriate weld stress or allowable joint fitting loads is satisfied

(c) integrity of transverse braces is verified using member end loads from the hanger model

(d) duct displacements are within allowable values

(e) member stresses from the hanger model are within allowable values

AA-A-7224 Duct Beam Properties

The equivalent beam properties of rectangular ducts are determined. The duct is fabricated with walls slightly buckled; therefore, only the corner area is considered when calculating bending properties. The effective corner length can vary with duct construction (see Fig. AA-A-7224). The shear modulus is reduced to account for shearing of gasket material and for web buckling. Equivalent corner length and shear moduli are best determined by modal test curve fits.

The equivalent beam properties of round ducts are determined. The full cross section is assumed effective in bending. The shear modulus is reduced to account for gasket material and for web buckling. Effective beam properties vary with ductwork construction and are best determined by modal test curve fits.

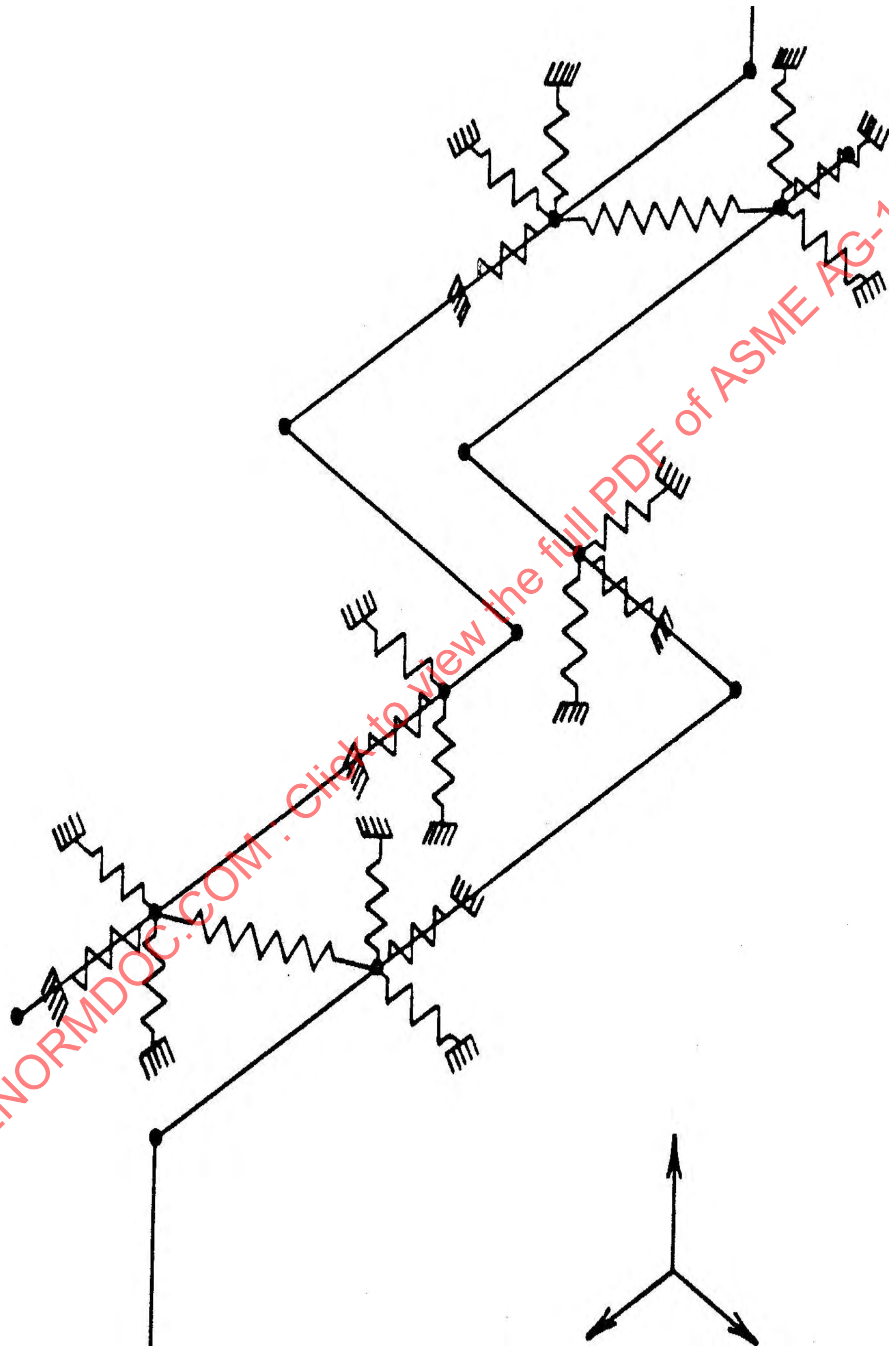
AA-A-7225 System Model

A system model of the duct run is developed using equivalent springs and masses at each duct location. The intermediate nodes between hanger locations are included to model significant midspan masses such as dampers (see Fig. AA-A-7225).

The fundamental frequency of the duct run is then determined; these results are used to determine appropriate seismic loads for the duct supports.

The load cases are combined and loads in the hanger springs are determined. Each hanger is evaluated using an interaction formula relating hanger loads to allowable loads generated in AA-A-7223. The ductwork layout and system model may be adjusted until all hangers qualify.

FIG. AA-A-7225 TYPICAL DUCT SYSTEM MODEL



The integrity of the duct itself is evaluated using member end loads from the system model. Interaction formulae can be used to establish that the duct is within allowable load limits established by analysis or test. Alternatively, duct integrity can be evaluated by relating maximum corner stress to theoretically equivalent allowable stress generated by test or analysis.

NONMANDATORY APPENDIX AA-B
QUALIFICATION BY TESTING

ARTICLE AA-B-1000
GENERAL

The test plan is an important document in that it provides the control for performing all aspects of the test program.

The test plan outline contained in this Appendix is developed as an effort to provide guidance for minimum acceptability requirements and to instill a level of uniformity without asserting mandatory controls.

The commentary is provided for guidance to the user in preparing a test plan in accordance with the nonmandatory test plan outline. The commentary is arranged in one-to-one correspondence with the items shown in the typical test plan outline.

The discussion is general in nature and is intended to be representative only; the development of a test plan for specific equipment may vary due to unique features of particular equipment, but the level of presentation should be equivalent to that shown herein.

This commentary addresses only qualification testing done in a laboratory. It does not address in-situ testing, modal survey methods, or combined test and analysis.

ARTICLE AA-B-2000
OUTLINE FOR TYPICAL SEISMIC TEST PLAN

AA-B-2100 PURPOSE

AA-B-2200 SCOPE

AA-B-2300 TEST SPECIMENS

AA-B-2400 SPECIAL EQUIPMENT OR FIXTURES (IF REQUIRED)

AA-B-2500 TEST SETUP

(a) specimen orientation
(b) specimen/fixture interface
(c) test machine interface
(d) services for specimen operation
(e) special external loads

AA-B-2600 TEST REQUIREMENTS

(a) number of simultaneous axes for test (biaxial or triaxial)
(b) test machine capabilities
(1) force
(2) displacement
(3) frequency
(4) stiffness (machine/system/specimen coupled response)
(5) control (ability to produce required input motion)
(c) excitation
(1) type
(2) duration
(3) level
(d) instrumentation
(1) control
(2) structural monitoring
(a) accelerometers
(b) strain gages
(c) load cells
(d) stresscoat
(e) low voltage differential transmitters
(f) other
(3) equipment monitoring
(a) flow rates
(b) contact chatter
(c) input or output
(1) voltage
(2) amperage
(d) component cycling
(e) pressure boundary
(f) pressure level

AA-B-2700 ACCEPTANCE/FAILURE CRITERIA

AA-B-2800 TEST PROCEDURE

(a) calibration
(1) specimen
(2) test equipment/instrumentation
(b) sequence of tests
(1) exploratory tests
(2) order of specimens tested
(3) order of applied tests
(a) inspection
(b) operation under normal conditions
(c) operation under extreme conditions
(d) aging, if applicable (thermal, radiation, mechanical cycling)
(e) dynamic testing with in-process functional testing (OBE and SSE levels)
(f) postaccident testing, if applicable
(g) inspection of equipment
(h) fragility testing, if required
(c) in-process evaluation
(1) test input (comparison of TRS versus RRS)
(2) monitoring of seismic response
(3) monitoring of equipment function
(4) data acquisition
(d) test data
(1) data obtained or used as input
(2) type of record
(3) format of data
(4) level of reduction

AA-B-2900 FINAL REPORT

ARTICLE AA-B-3000 COMMENTARY ON OUTLINE FOR TYPICAL SEISMIC TEST PLAN

AA-B-3100 PURPOSE

The purpose should be a brief and distinct statement that clearly identifies the objectives of the test program.

AA-B-3200 SCOPE

This section should precisely define the boundaries of the test requirements for the specific equipment and test(s). Inclusion of sufficient detail in this section will ultimately result in increased efficiency and will minimize the possibility of changes. It should include, where appropriate, concise, detailed statements concerning the following:

(a) a general description of the specific test item(s) to be tested

(b) any requirements for design, fabrication, modification, packaging, handling, or shipping of test items and test fixtures

(c) mating/installation of test items and test fixtures on test machine

(d) test setup, including special control and data acquisition instrumentation and recording requirements

(e) any data organization, data reduction, data processing, or data analysis required by the Contractor

(f) contractual terms

(1) the Contractor's responsibility for providing labor or other resources for repairs, modifications, or other corrective actions

(2) the Contractor's responsibility for retest, whether required because of failure of test items, test fixtures, test equipment, or other causes

(3) whether the testing is straightforward qualification testing to specific requirements, or whether it is of a research and development nature (involving time and materials)

(g) any other identifiable boundaries or parameters that will enhance the Contractor's ability to understand the requirements, estimate, and schedule the testing

AA-B-3300 TEST SPECIMENS

A unique identification and quantities of the specific items to be tested should be provided. This should include, where appropriate, tag number, model, type, class, size, or other distinguishing identification.

AA-B-3400 SPECIAL EQUIPMENT OR FIXTURES

Any special equipment or test fixtures should be identified, and an assignment for their responsibility should be made. If not provided by the Contractor, these equipment or fixtures must be provided to the Contractor (with adequate instructions for use), or, if the Contractor is to buy or fabricate them, adequate definition must be provided for fabrication purposes.

AA-B-3500 TEST SETUP

The test plan should include a complete description of the total test setup, including, but not limited to, the following:

(a) Specimen Orientation. Depending upon the size of the test items and the capabilities of the test machine, it may be possible to test multiple axes (two or three). For very large equipment, it may be possible to test only one axis at a time; however, qualification by single-axis testing should be avoided (see AA-4358). The test items may be designed such that they will function in only one attitude, thus requiring that the test machine be manipulated to excite certain axes of the test items.

Whatever the requirements, the orientation of the specimen must be identified, consistent with its operational limitations and the capabilities of the test machine.

(b) Specimen/Fixture Interface. Where a special test fixture is required, the specimen/fixture interface must

be defined, and any performance requirements placed upon the fixture, such as stiffness, must be identified and verified prior to or during the test. Methods of attachment of the specimen to the fixture, such as hole patterns, welding, materials, or other items, must be specified and must represent the actual installation.

(c) Test Machine Interface. The specimen/test machine, or fixture/test machine interface(s), or both, must be specified. This interface must represent, to an acceptable degree, the anticipated attachment characteristics of the actual installation.

(d) Service for Specimen Operation. Where the testing is required to demonstrate continued operation during and following a seismic excitation and where this operation can only be verified by measuring an equipment operational output such as fluid flow, electrical current or voltage, and heating or cooling capability, external services may have to be supplied. These services may be an oil supply, water supply, air supply, electrical source, electrical load, or other services. These requirements should be clearly defined in the test plan.

(e) Special External Loads. Some test items, during normal operation, are acted upon by mechanical or other loads produced by other equipment. These loads may result from operation of attached motors, fans, hydraulic, mechanical, or pneumatic actuators, or other reactive types of equipment. Where these force, momentum, or torque producing attached components are significant, the magnitude and orientation of these reactions must be simulated.

AA-B-3600 TEST REQUIREMENTS

(a) Number of Simultaneous Axes for Test. Depending upon the size of the test item and the capabilities of the test machine, it may be possible to test multiple axes: three simultaneous axes of test are preferable. For very large equipment, it may only be possible to test two or even a single axis, contingent upon test machine capabilities and availability. Justification must be developed for testing with single-axis input motion (AA-4358). This justification could be based upon a unique feature of the test item (directional sensitivity). It may be possible to increase the excitation level and test the individual axes separately where the test item is too large for existing test machines.

(b) Test Machine Capabilities. Before a Contractor is selected to perform the seismic testing, a thorough review of test machine capabilities should be made. Assurance should be established that the test machine selected can meet the requirements. It should be determined that

(1) the test machine has the capability, including reserve, to provide the necessary force to drive the test table and the test item to the required accelerations.

(2) machine displacement capabilities are acceptable. Because many test machines are displacement limited in the low frequency range, if the test requirements include frequencies below 5 Hz, a check of the machine displacement capabilities should be made and compared to those required.

(3) machines that are displacement-limited at the low end of the frequency stroke capability. Similarly, high frequency response, especially precise control at high frequencies, is often difficult to attain on very large machines. It is recommended that a plot of test table response (throughout the frequency range involved) be required prior to selection of a test table. This is recommended in lieu of theoretical plots, such as the usual force/frequency/velocity/acceleration charts. A degree of informed judgment is necessary in the critique of actual response plots to recognize what is and what is not acceptable.

(4) the plot recommended in (b)(3) above will provide clues to the existence of unwanted system resonances in the frequency range of interest. This plot incorporates participation by structures, mechanisms, oil columns, bearings, servos, and actuators into an integral response. It does not, however, include the effects of the mass and center of gravity of the test item, which may be significant. A judgment should be made as to the necessity of securing a plot as mentioned in (b)(3) above using a simulated test item, before committing to a particular test machine. Large test item weights or high centers of gravity, or both, compared to that of the test table are major factors entering into this decision.

(5) the plot recommended in (b)(3) will show the control capabilities of the bare test table. If a plot is made using a simulated test item as in (b)(4) above, control capabilities will be even better demonstrated.

(c) Excitation. All aspects of the required excitation should be defined as follows:

(1) the type of excitation, such as sine sweep, sine dwell, sine beat, time history, response spectra (either synthesized or extracted from a particular time history), complex wave, or other, should be shown in the test plan

(2) the duration of the excitation, the sweep rate, or the number of beats as well as the cycles per beat should be identified as appropriate

(3) the full acceleration level of the excitation and any intermediate level(s) that may be required should also be included in the plan

(d) *Instrumentation*. Instrumentation is generally of three types: control, structural monitoring, and functional monitoring.

(1) Control instrumentation is necessary to provide systems responsible for controlling the test input. This equipment is an integral part of the test machine.

(2) Structural monitoring may be required where limitations of accelerations, stresses, strains, displacements, or forces are important to the function of the test item, or are required by a code or specification. Well-known standard components are available for measuring these parameters, either statically or dynamically.

(3) Pass/fail indicators for some equipment functions may involve special measurements of equipment output. Both standard and nonstandard equipment may be used for these measurements.

AA-B-3700 ACCEPTANCE AND FAILURE CRITERIA

Acceptance and failure criteria are not always readily quantifiable. Engineering judgment to identify and assign somewhat arbitrary, but meaningful, limits to measurable parameters is sometimes required. Other cases are more easily defined. The equipment specification or specific code section may be explicit as to what constitutes failure. An interruption of flow rate, voltage, current, or other equipment output may be considered a failure, and these parameters are readily measurable. Excessive contact chatter, violation of a pressure boundary, excessively high or low pressures, or failure for a component to cycle may also constitute failure. Failure criteria should be realistic; and, if possible, allowances should be made for insignificant anomalies that are unimportant to the function of the equipment, consistent with the service level being tested. Acceptance and failure criteria must be identified in the test plan.

AA-B-3800 TEST PROCEDURE

The test procedure should be given in the test plan. It should be defined in considerable detail and preferably in the sequence in which it will be performed.

(a) Any required calibration of either the test item, test equipment, or instrumentation must be included in the test procedure.

(b) The order of test items, the sequence of testing, and a definition of the specific tests must be clearly defined.

(c) A constant evaluation of the in-process work must be made and should be a distinct requirement of the test procedure. Feedback or process sampling must be continuous to ensure that the test input is accurate, that the specimen response is consistent with other known factors, that the equipment continues to function (or that a failure is identified), and that the type, quality, and quantity of data is acceptable. Failure to perform in-process monitoring may result in additional tests, additional time, and unnecessary wear and tear on the test item.

(d) The data items (stresses, strains, flow rates, voltage, current, chatter time, etc.), type of data record (permanent, nonpermanent, oscillograph, magnetic tape, hard record, movies, videotape, etc.), data format, and the degree to which the Contractor is to reduce or otherwise process the test data must be specified.

AA-B-3900 FINAL REPORT

The final report, upon succesful completion of the testing, shall serve as a qualification document for the test item. The basis for the qualification determination must be fully explained. The final report should contain, as a minimum

(a) the objective of the test

(b) a description of the test item and its function

(c) a description of the specific function(s) or feature(s) to be verified by the test

(d) the test procedure

(e) a synopsis of the test results

(f) an appendix for the test data that contains selected data and references the location of data taken but not submitted

(g) summary, conclusions, and recommendations

(h) all test anomalies along with their disposition

(i) any other pertinent supporting data

(j) signature (preferably a professional engineer attestation) and date

NONMANDATORY APPENDIX AA-C
QUALIFICATION BY A COMBINATION OF ANALYSIS AND TESTING

ARTICLE AA-C-1000
INTRODUCTION

Many factors control the design of a qualification program. If qualification is to be achieved by analysis only, all assumptions used in the analysis must be justified. If testing alone is used for qualification, all applicable loads shall be simulated during the test, unless it can be shown that the simultaneous application of certain loads is not necessary for assuring the safety function.

ARTICLE AA-C-2000
QUALIFICATION BY ANALYSIS ONLY

Analytical calculations alone may be adequate as a qualification method in the following situations:

(a) for equipment that requires only that structural integrity be maintained to ensure the performance of the safety function

(b) for equipment that is structurally simple

(c) for equipment having a response that is linear or a simple nonlinear behavior

(d) for equipment in which the superposition of load conditions, or combinations, or both, are too complex for testing

ARTICLE AA-C-3000
QUALIFICATION BY TESTING ONLY

Qualification by testing only is recommended when the following conditions are fulfilled:

(a) the structural configuration of the equipment is highly complex and beyond the capability of mathematical modeling techniques

(b) the response of the equipment is expected to be highly nonlinear

AA-C-3100 TESTING PROGRAM CONSIDERATIONS

When a qualification by testing program is being considered, the following factors are important to the validity of the program:

(a) the test machine is capable of producing the required motion

(b) the applicable loads are of a simple nature, or it is possible to simulate them

(c) the test machine allows the simulation of actual mounting

(d) it is possible to monitor the functional capability of active equipment during the test

ARTICLE AA-C-4000 SUPPORTING TEST

AA-C-4100 COMMON APPLICATIONS

Supporting tests may be used to determine

(a) deflection limits within which operability is maintained

(b) dynamic parameters needed for constructing or verifying mathematical models

(c) damping values

(d) assumptions to be used in the analysis

(e) the amount of nonlinearity involved

AA-C-4200 DYNAMIC AND STATIC SUPPORTING TESTS

Supporting tests may be static or dynamic. A dynamic test shall be conducted using a test machine or single point exciters.

After collecting the needed information from supporting tests, analytical techniques shall be used to show, in a reliable way, that the structural integrity or operability of equipment, or both, are maintained. It must be noted that, without supporting tests, analytical calculations may not provide sufficient evidence for operability assurance.

AA-C-4210 DYNAMIC SUPPORTING TESTS

For dynamic supporting tests, the equipment shall be excited by dynamic forcing functions by using a shake table or single point exciters applied at a sufficient number of points. The excitations shall be of sufficient strength to excite all significant modes. Typical data obtained from these tests are

(a) dynamic characteristics of the equipment (natural frequencies, mode shapes, and damping factors)

(b) cross-coupling effects, i.e., the response in any direction due to the excitation in any other direction (in the locations where installing accelerometers is impractical, the cross-coupling may be estimated based on the response at the available locations)

(c) the significance of the response of the equipment to vibratory motion to determine the necessity of combining the nozzle loads with seismic loads

AA-C-4220 STATIC SUPPORTING TESTS

Static supporting tests are conducted by applying static forces to the equipment. Typical data obtained from these tests are

(a) static deflections and flexibility parameters that are needed for constructing a mathematical model

(b) distortions, due to nozzle loads, for example, and the deformation limits within which the equipment would maintain its functionality

NONMANDATORY APPENDIX AA-D
DESIGN OF DUCTWORK BY ANALYSIS (SUGGESTED APPROACH)

ARTICLE AA-D-1000
INTRODUCTION

This Appendix is nonmandatory and presents suggested approaches to the analysis of ductwork subjected to various loadings. Both circular and rectangular ductwork are considered together with stiffener analysis for each type of ductwork. Analysis of ductwork supports is not specifically addressed in this appendix.

Where applicable, the requirements of Article AA-4000 are referenced with the solution technique. Other methods may be used to determine the adequacy of ductwork for design loadings. These include the techniques presented in the Sheet Metal and Air Conditioning Contractor's National Association (SMACNA) Rectangular Industrial Duct Construction Standards. Also, design qualification of ductwork by testing is another effective way to determine adequacy under design loadings. Article AA-4000 should be consulted for testing requirements.

ARTICLE AA-D-2000 CIRCULAR DUCTWORK

AA-D-2100 INTRODUCTION

The major factor to consider in the design of circular ductwork is buckling. The following sections provide techniques for designing circular ductwork that can withstand various design loads.

AA-D-2200 ALLOWABLE DESIGN STRESSES: SERVICE LEVEL A

The maximum normal allowable stresses to be used in design for Service Level A load combinations given in Table SA-4212 shall not exceed the following stresses.

AA-D-2210 AXIALLY LOADED COMPRESSION MEMBERS

Ducts subjected to axial loads can be designed so that the average axial compression stress, P/A, does not exceed the values presented below for the appropriate configuration. Both column buckling of the entire section and local buckling of the shell must be checked and the controlling allowable stress used in the design.

Equation (1a) illustrates combined column and local buckling for a circular cross section.
where

for $\sigma_e \leq \sigma_y/2$

$$\sigma_o = 0.521 \frac{\Pi^2 E}{(KL/r)^2} \tag{1a}$$

for $\sigma_e > \sigma_y/2$

$$\sigma_o = \frac{\sigma_y[1 - \sigma_y/4\sigma_e]\ [1 - (1 - R^2)\ (1 - \alpha)]}{\frac{5}{3} + \frac{3}{8} R - \frac{R^3}{8}} \tag{1b}$$

Column buckling:

where $D/t > 0.441 \dfrac{E}{\sigma_y}$

For cylindrical sections, the general buckling expressions may be used [see Article AA-D-5000 (Yu 1985)].

For $KL/r < C_c$

$$\sigma_o = \left[0.522\ \sigma_y - \frac{(KL/r)^2 \sigma_y{}^2}{1494^2}\right] \tag{2a}$$

For $KL/r \geq C_c$

$$\sigma_o = \frac{151{,}900}{(KL/r)^2} \tag{2b}$$

Local buckling:

For $D/t \leq 3{,}300/\sigma_y$

$$\sigma_l = 0.60\sigma_y \tag{3}$$

For $3{,}300/\sigma_y < D/t \leq 13{,}000/\sigma_y$

$$\sigma_l = \frac{662}{D/t} + 0.399\ \sigma_y \tag{4}$$

For $D/t > 13{,}000/\sigma_y$

$$\sigma_l = \frac{5{,}860}{D/t} \tag{5}$$

where

A = full, unreduced cross-sectional area of the duct, in.^{2}
C_c = $\sqrt{2\pi^2 E/\sigma_y}$
D = outside duct diameter, in.
E = modulus of elasticity, typically 29,500 ksi
K = effective length factor

L = unbraced length of member, in.
P = total axial load, kips
$R = \sqrt{(\sigma_y/\sigma_e)}$
r = radius of gyration of the unreduced cross section, $\sqrt{I/A}$, in.
t = duct thickness, in.
α = area factor, $= \left(\frac{0.037}{D\sigma_y/tE} + 0.667\right) \leq 1.0$
σ_e = elastic buckling stress $= \frac{\pi^2 E}{(KL/r)^2}$ ksi
σ_l = allowable compression stress for local buckling under axial loading, ksi
σ_o = allowable compression stress for column buckling under axial loading, ksi
σ_y = material yield stress, ksi

AA-D-2220 CYLINDRICAL TUBULAR MEMBERS IN BENDING

The local-buckling behavior in the compression portion of a cylindrical tubular member subjected to a bending load is similar to the local-buckling behavior under axial compression. Therefore, eqs. (3), (4), and (5) of AA-D-2210 may be used to determine both local-buckling stresses due to axial compression as well as the onset of flexural buckling. According to published research [see Article AA-D-5000 (Gerard and Becker 1957)], this approach leads to a conservatism of about 30% in the case of flexural buckling. Section properties for stress calculations shall be based on the full section.

As an option, more accurate determination of the allowable bending stress for circular sections under bending moments alone can be found as follows for ductwork where $D/t \leq 0.441E/\sigma_y$. [See Article AA-D-5000 (*Specification for the Design of Cold-Formed Steel Structural Members* and Yu 1985)].

For $D/t \leq 0.070\ E/\sigma_y$

$$\sigma_a = 0.75\sigma_y \tag{6}$$

For $0.070\ E/\sigma_y < D/t \leq 0.319\ E/\sigma_y$

$$\sigma_a = \left[0.581 + 0.012\frac{(E/\sigma_y)}{D/t}\right]\sigma_y \tag{7}$$

For $0.319\ E/\sigma_y < D/t \leq 0.441\ E/\sigma_y$

$$\sigma_a = [0.196\ E/(D/t)] \tag{8}$$

where

σ_a = the allowable bending stress, ksi, based on the section modulus of the full, unreduced cross section

AA-D-2230 TORSION

The normal allowable shear stress, v_t, due to local buckling of a circular tubular member subjected to torsion shall not exceed the following [see Article AA-D-5000 (Schilling 1965)]:

$$v_t = 0.395aE\left(\frac{t}{R}\right)^{5/4}\left(\frac{R}{L}\right)^{1/2} \tag{9}$$

where

a = plasticity reduction factor $= 1.16\frac{E_s}{E}$
E = modulus of elasticity, typically 29,500 ksi
E_s = secant modulus, ksi
L = length of duct between supports, in.
R = outside duct radius, in.
t = duct plate thickness, in.
v_t = allowable shear stress due to torsion, ksi

The above equation is specifically for circular ducts with pinned ends; the critical buckling stress of a circular duct with clamped ends would be approximately 10% higher.

A method for calculating the plasticity reduction factor can be found in Article AA-D-5000 (Schilling 1965).

AA-D-2240 TRANSVERSE SHEAR

The allowable shear stress, σ_v, due to local buckling of a circular tubular member subjected to transverse shear shall not exceed the following:

$$\sigma_v = 0.493aE(t/R)^{5/4}(R/L)^{1/2} \tag{10}$$

[see Article AA-D-5000 (Lunquist 1935)]

where

a = plasticity reduction factor $= 1.16\frac{E_s}{E}$
E = modulus of elasticity, typically 29,500 ksi
E_s = secant modulus, ksi
L = length of duct between supports, in.
R = outside duct radius, in.
t = duct plate thickness, in.
σ_v = allowable transverse shear stress, ksi

A method for calculating the plasticity reduction factor can be found in Article AA-D-5000 (Schilling 1965).

AA-D-2250 COMBINED AXIAL COMPRESSION AND BENDING

When subject to both axial compression and bending loads, members shall be proportioned so that the interaction of these loads does not overstress the ductwork. [See Article AA-D-5000 (*Specification for Design of Cold-Formed Steel Structural Members*)]

The subscripts x and y in the above equations indicate the axis of bending about which a particular stress or design property applies.

For $\frac{f_a}{\sigma_c} \leq 0.15$ where σ_c is the lesser of σ_o and σ (from AA-D-2210).

$$\frac{f_a}{\sigma_c} + \frac{f_{bx}}{\sigma_a} + \frac{f_{by}}{\sigma_a} \leq 1.0 \qquad (11)$$

For $\frac{f_a}{\sigma_c} > 0.15$

$$\frac{f_a}{\sigma_c} + \frac{f_{bx}}{\left(1 - \frac{f_a}{F'_{e_x}}\right)\sigma_a} + \frac{f_{by}}{\left(1 - \frac{f_a}{F'_{e_y}}\right)\sigma_a} \leq 1.0 \qquad (12)$$

where

$F'_e = 0.521 \dfrac{\pi^2 E}{(KL/r)^2}$

f_a = the applied compressive stress, ksi

f_b = the applied bending stress, ksi, in the x or y direction

σ_a = the allowable bending stress, ksi

AA-D-2260 COMBINED TORSION AND AXIAL COMPRESSION OR BENDING

Experimental work [see Article AA-D-5000 (Gerard and Becker 1957)] has shown that the following nonlinear interaction equation predicts the behavior of ducts subjected to combined torsion and bending or combined torsion and axial compression:

$$\left(\frac{f_c}{\epsilon_c}\right)^2 + \left(\frac{\sigma_v}{\epsilon_v}\right)^2 \leq 1.0 \qquad (13)$$

where

f_c = applied compressive stress due to axial loading or bending, ksi

σ_v = applied torsional shear stress, ksi

Σ_c = allowable compressive stress due to axial loading or bending, ksi

Σ_v = allowable torsional shear stress, ksi

AA-D-2270 COMBINED TORSION AND TRANSVERSE SHEAR

The combined shear stresses due to torsion and transverse shear shall be evaluated based on the following linear interaction equation:

$$\frac{f_t}{v_t} + \frac{f_v}{\sigma_v} < 1.0 \qquad (14)$$

where

f_t = applied torsional shear stress, ksi

f_v = applied transverse shear stress, ksi

v_t = allowable torsional shear stress, ksi

σ_v = allowable transverse shear stress, ksi

AA-D-2280 PRESSURE

For typical applications, the duct internal pressure does not exceed 10 in. water gage. The tensile and compressive stresses caused by this pressure level are low. The following equations may be used to demonstrate that pressure-induced stresses can usually be neglected.

(a) Positive Internal Pressure. Positive internal pressure causes tensile stresses within the duct and actually reduces the tendency toward buckling. The tensile stresses due to internal pressure are

$$\sigma_H = \frac{P'R}{t} \qquad (15)$$

$$\sigma_L = \frac{P'R}{2t} \qquad (16)$$

where

P' = internal pressure, ksi

R = outside duct radius, in.

t = duct plate thickness, in.

σ_H = hoop stress, ksi

σ_L = longitudinal stress, ksi

(b) Negative Internal Pressure. The critical hoop stress results from an external or negative internal pressure. The critical elastic buckling pressure for ducts subjected to external pressure is given below [see Article

AA-D-5000 (Timoshenko and Woinowsky-Krieger 1959 and Johnston 1976)]:

$$P'_{CR} = \frac{2.60E}{\left(\frac{L}{D}\right)\left(\frac{D}{t}\right)^{2.5}} \text{ for } 10 < \frac{1.818\,L}{D}\left(\frac{D}{t}\right)^{1/2} < \frac{D}{t} \qquad (17)$$

$$P'_{CR} = 2.2E\left(\frac{t}{D}\right)^{3} \text{ for } \frac{1.818L}{D}\left(\frac{D}{t}\right)^{1/2} < \frac{4D}{t} \qquad (18)$$

where

D = duct diameter, in.
E = modulus of elasticity, typically 29,500 ksi
L = spacing of duct stiffeners, in.
P'_{CR} = critical elastic buckling pressure, ksi
t = duct plate thickness, in.

The allowable pressure can be obtained by applying a factor of safety of 1.67 to the critical elastic buckling pressure calculated above.

AA-D-2281 Compression in Combination With Internal Pressure

Internal pressure stiffens the duct against buckling from external loads and reduces the net compressive stress in the section. For conservatism, the internal pressure should be ignored and the external load used for calculation. If the internal pressure is to be included, then eq. (19) should be used:

$$\frac{\sigma}{\sigma_{CR}} - \frac{P'}{P'_{Allow}} \leq 1.0 \qquad (19)$$

where

P' = applied internal pressure, ksi
P'_{Allow} = allowable internal pressure, ksi
σ = applied axial stress, ksi
σ_{CR} = allowable axial stress, ksi

AA-D-2282 Compression in Combination With External Pressure

The following interaction equation can be used to predict the behavior of a duct subjected to compressive loads and external pressure.

$$\frac{\sigma}{\sigma_{CR}} + \frac{P'}{P'_{CR}} \leq 1.0 \qquad (20)$$

where

P' = applied external pressure, ksi
P'_{CR} = allowable external pressure, ksi
σ, σ_{CR} = (defined in AA-D-2281)

Applying the appropriate factor of safety to the allowable pressure and stress will convert the interaction equation to an equation for design purposes.

AA-D-2300 ALLOWABLE DESIGN STRESSES FOR SERVICE LEVEL B, C, OR D

Members and assemblies subject to stresses produced by Service Level B, C, or D load combinations shown in Table SA-4212, may be proportioned for unit stresses 1.3 (Service Level B) or 1.6 (Service Level C or D) times greater than those specified in AA-D-2210 through AA-D-2240 for Service Level A load combinations. However, the increased stress allowables shall not exceed the following limits:

Axially loaded compression members:

$$\sigma_o \text{ (max.)} = 0.9\ \sigma_y \qquad (21)$$

$$\sigma \text{ (max.)} = 0.9\ \sigma_y \qquad (22)$$

Members in bending:

$$\sigma_a \text{ (max.)} = 0.9\ \sigma_y \qquad (23)$$

Members subjected to torsion:

$$v_t \text{ (max.)} = \frac{0.9\ \sigma_y}{\sqrt{3}} \qquad (23a)$$

Members subjected to transverse shear:

$$\sigma_v \text{ (max.)} = \frac{0.9\ \sigma_y}{\sqrt{3}} \qquad (24)$$

where

σ_o, σ, σ_a, v_t, σ_v, and σ_y = (defined previously)

AA-D-2400 STIFFENER DESIGN

The presence of external loads applied to the thin-shell ductwork may require that the duct be reinforced.

The reinforcement may take the form of external ring stiffeners applied at intervals along the duct system. Alternatively, a thicker wall duct may be used in the location where the duct may be subject to buckling. Generally, the most efficient method is the use of ring stiffeners at intervals, and particularly at supports where large support loads may increase the chances of collapse of the duct.

The presence of stiffeners is advised where large external loads, such as pressure and shear, may cause buckling. The added stiffening effect of rings will have a negligible effect in preventing buckling due to bending, torsion, or axial loads. Therefore, in applications where bending is the governing load, the duct wall thickness should be increased or the duct span should be decreased in order to prevent buckling, and no credit should be taken for the presence of stiffeners unless a detailed structural analysis of the duct system is performed. Thus, the performance of the duct can be predicted by traditional beam analysis of the duct system without requiring complex analysis, unless stiffener interaction with the duct system stiffness is required (see Article AA-D-4000).

The stiffener may be designed in accordance with the recommendations of SMACNA, or as indicated below.

AA-D-2410 STIFFENER SPACING

When the preceding equations on duct design indicate that the duct is unacceptable in its present condition, stiffeners may need to be added, or the space between stiffeners reduced.

The maximum allowable span between stiffeners can be found by solving the equation for critical pressure or critical shear load for the maximum allowable span for the known loads.

For transverse shear, the maximum span between stiffeners is [from eq. (10)]:

$$L = \frac{(0.790)^2 a^2 E^2 \left[\frac{t}{R}\right]^{2.5} R}{(1.67)^2 \, \sigma_v^2} \qquad (25)$$

where

L = stiffener spacing, in.

σ_v = transverse shear stress, ksi

a, E, t, R, and σ_v = (defined previously)

For external pressure P', the maximum span between stiffeners is [from eq. (17)]:

$$L = \frac{2.60\, E}{1.67 \left[\frac{P'}{D}\right] \left[\frac{D}{t}\right]^{2.5}}$$

for

$$10 < \frac{1.818L}{D} \left[\frac{D}{t}\right]^{1/2} < \frac{D}{t} \qquad (26)$$

Ducts where $1.818(L/D)(D/t)^{1/2}$ is less than 10 are short ducts and should not require stiffeners.

As an alternative, the spacing recommendation contained in SMACNA may be used as an initial spacing value. The spacing length l can then be used in the equation for critical pressure and shear to verify that the loads do not exceed the critical values.

AA-D-2420 RING STIFFENER ANALYSIS

The ring stiffeners are generally rolled equal-leg angles welded to the duct. This type of companion angle construction can be based on the spacing equation above and the equations presented below for ring design.

For external pressure on a ring of mean radius R (in.) the critical buckling pressure is [see Article AA-D-5000 (Roark and Young 1975)]:

$$P'_{CR} = \frac{3EI}{R^3} \qquad (27)$$

where

E = modulus of elasticity, ksi

I = moment of inertia of ring about its longitudinal axis, in.^{4}

P'_{CR} = critical elastic buckling pressure, ksi

For a concentrated diametric load of W(kips), the ring can be designed based on the following relationships [see Article AA-D-5000 (Roark and Young 1975)]:

$$D_H = 0.137 \frac{WR^3}{EI} \qquad (28)$$

$$D_v = -0.149 \frac{WR^3}{EI} \qquad (29)$$

$$M_{max} = 0.3183\, WR \qquad (30)$$

$$\sigma_{max} = \frac{0.3183\ WRC}{I} \quad (31)$$

where

D_H = horizontal diametric deflection, in.
D_v = vertical diametric deflection, in.
M_{max} = maximum moment in ring, K-in.
W = diametric load, kips
σ_{max} = maximum bending stress, ksi
C = distance from center of section to outer face, in.

Note that C and I are functions of the ring section about its own axis. The load W is a function of the adjacent spans and the deadweight and seismic loads that are applicable. If the desired stiffener size does not meet the allowable stresses for the actual load W then consideration should be given to increasing the size of the ring or decreasing the span that will reduce the load W being applied.

ARTICLE AA-D-3000 RECTANGULAR DUCTWORK

AA-D-3100 INTRODUCTION

The methods presented in this article are suggested means of approach for analysis of rectangular ductwork.

The presence of compressive loads due to pressure or external forces requires that the ductwork and supports be designed properly for these loads. Buckling is the major concern in the design of rectangular ductwork and is the governing failure mode to be considered in design. The advantage of using rectangular ductwork is that it exhibits significant post-buckling strength. Plates possessing this behavior can accept significant amounts of load after they have exceeded the elastic buckling load.

The methods contained in this article, or other sources may be used. However, the requirements of Article SA-4000 must be met.

AA-D-3200 RECTANGULAR DUCT ANALYSIS

Properties of sections (cross-sectional area, moment of inertia, section modulus, radius of gyration, etc.) shall be determined in accordance with conventional methods of structural design. Properties shall be based on the full cross section of the members (or net sections where applicable) except where the use of a reduced cross section, or effective design width, is required by the provisions of the American Iron and Steel Institute's (AISI) Specification for the Design of Cold-Formed Steel Structural Members [see Article AA-D-5000 (*Specifications for the Design of Cold-Formed Steel Structural Members*)].

Use of AISI Specification provisions, however, with the specified maximum effective design widths and heights (w/t and h/t ratios where w and h are the width and height of the duct respectively), may result in duct thicknesses in excess of those commonly used for ductwork constructed to, or similar to, SMACNA specifications. Tests performed have demonstrated that ducts constructed to SMACNA specifications can adequately withstand specified dynamic loads. In effect, the following options may be utilized to calculate properties of ductwork sections.

(a) AISI specifications

(b) Testing as permitted by the AISI specification

(c) Finite element models using large displacement criteria

Option (c) can be used to extend the range of applicability of the AISI equations and/or arrive at other suitable provisions in place of the AISI provisions. In addition, these models can be used to develop values for pressure-induced stresses not readily covered by the AISI provisions.

AA-D-3300 ALLOWABLE DESIGN STRESSES: SERVICE LEVEL A

The maximum normal allowable stresses to be used in design for Service Level A load combinations given in Table SA-4212 shall not exceed the following equations.

AA-D-3310 AXIALLY LOADED COMPRESSION MEMBERS

The average axial stress, P/A, in compression members shall not exceed the following values of σ_{a1} [see Article AA-D-5000 (*Specifications for the Design of Cold-Formed Steel Members* and Yu 1985)]:

for $\sigma_e \leq \dfrac{\sigma_y}{2}$

$$\sigma_{a1} = \frac{\sigma_e Q}{1.92} \qquad (32)$$

for $\sigma_e > \sigma_{y/2}$

$$\sigma_{a1} = \frac{Q\sigma_y(1 - \sigma_y/4\sigma_e)}{1.92} \qquad (33)$$

where

P = total load, kips

A = full, unreduced cross-sectional area of the member, in.^{2}

$\sigma_e = \dfrac{\pi^2 E}{(K/r)^2}$

σ_{a1} = allowable average compression stress under concentric loading, ksi

E = modulus of elasticity, typically, 29,500 ksi

K = effective length factor

L = unbraced length of member, in.

r = radius of gyration of full, unreduced cross section, in.

σ_y = yield strength of steel, ksi

Q = area reduction factor determined as Ae/A — where Ae is the effective cross-sectional area computed per AA-D-3200 and A is the full or unreduced area of the cross section.

AA-D-3320 BASIC DESIGN STRESS

Stresses on the net section of tension members, and tension and compression on the extreme fiber of flexural members including membrane stresses shall not exceed the value σ_c specified below:

$$\sigma_c = 0.60\ \sigma_y \tag{34}$$

where

σ_y = the specified minimum yield strength, ksi

AA-D-3330 LOCAL PLATE BENDING

The allowable stress, σ, for local plate bending calculated on an elastic basis, plus membrane (tension), shall not exceed the following value:

$$\sigma = 0.90\ \sigma_y \tag{35}$$

AA-D-3340 SHEAR STRESSES IN WEBS

The maximum average shear stress in kips per square inch on the gross area of a flat web shall not exceed:

$$h/t \leq 164\sqrt{K_v \sigma_y} \tag{36}$$

$$\sigma_v = 0.4\sigma_y$$

$$164\sqrt{K_v \sigma_y} < h/t \leq 237\sqrt{K_v \sigma_y} \tag{37}$$

$$\sigma_v = \frac{65.7\sqrt{K_v \sigma_y}}{h/t}$$

$$h/t > 237\sqrt{K_v \sigma_y} \tag{38}$$

$$\sigma_v = \frac{15{,}600 K_v}{(h/t)^2}$$

where

h = clear distance between flanges measured along the plane of web, in.

K_v = shear buckling coefficient that for unreinforced webs equals 5.34. Values of K_v for other than unreinforced webs may be extracted from the AISI specification.

t = base steel thickness of the web element, in.

σ_v = allowable shear stress, ksi

σ_y = yield strength, ksi

For h/t ratios exceeding 200, use of eq. (38) will result in very small values for allowable shear stress. Options discussed in AA-D-3200 may be used to increase the allowable shear stress.

AA-D-3350 COMBINED AXIAL AND BENDING STRESSES

When subject to both axial compression and bending, members shall be proportioned to meet the following requirements [see Article AA-D-5000 (*Specifications for the Design of Cold-Formed Steel Structural Members*)].

for $f_a/\sigma_{a1} \leq 0.15$

$$\frac{f_a}{\sigma_{a1}} + \frac{f_p}{\sigma_c} + \frac{f_{bx}}{\sigma_c} + \frac{f_{by}}{\sigma_c} \leq 1.0 \tag{39}$$

for $f_a/\sigma_{a1} > 0.15$

$$\frac{f_a}{\sigma_{a1}} + \frac{f_p}{\sigma_c} + \frac{C_{mx} f_{bx}}{\left(1 - \frac{f_a}{F_{ex}{}^1}\right)\sigma_c} + \frac{C_{my} f_{by}}{\left(1 - \frac{f_a}{F_{ey}{}^1}\right)\sigma_c} \leq 1.0 \tag{40}$$

The subscripts x and y in the preceding equations indicate the axis of bending about which a particular stress or design property applies,
where

f_a = the applied compressive stress, ksi
$f_{bx,y}$ = the applied bending stress, ksi
f_p = the applied membrane stress due to pressure, ksi

Values for $C_{mx,y}$ may be obtained from the AISI specification.

$$F_{ex}^{1} = \frac{12\,\pi^{2}E}{23\,(KL/r_x)^2} \tag{41a}$$

$$F_{ey}^{1} = \frac{12\,\pi^{2}E}{23(KL/r_y)^2} \tag{41b}$$

AA-D-3360 STRESSES AT DUCT OPENINGS

Stress intensification and local stresses due to the presence of openings at duct walls for equipment installation, shall be evaluated to permit proper design of ductwork. Local reinforcing of the duct plate in the vicinity of the opening may be required.

AA-D-3370 COMBINED BENDING AND SHEAR STRESSES IN WEBS

For unreinforced beam webs subjected to both bending and shear stresses, members shall be proportioned to meet the following requirements [see Article AA-D-5000 (La Boube and Yu 1978)]:

$$\left(\frac{f_{bw}}{\sigma_c}\right)^2 + \left(\frac{f_v}{\sigma_v}\right)^2 \leq 1.0 \tag{42a}$$

For beam webs with transverse stiffeners satisfying the requirements of the AISI specification, members shall be proportioned to meet the following requirement:

$$0.6\left(\frac{f_{bw}}{\sigma_c}\right) + \frac{f_v}{\sigma_v} \leq 1.3 \tag{42b}$$

when $f_{bw}/\sigma_c > 0.5$ and $f_v/\sigma_v > 0.7$
where

f_{bw} = applied web bending stress, ksi
f_v = applied web shear stress, ksi
σ_c, σ_v = (defined previously)

AA-D-3400 ALLOWABLE DESIGN STRESSES — SERVICE LEVEL B, C, OR D

Members and assemblies subject to stresses produced by Service Level B, C, or D load combinations shown in Table SA-4212, may be proportioned for unit stresses 1.3 (Service Level B) or 1.6 (Service Levels C or D) times those specified in AA-D-3310 through AA-D-3340 for Service Level A load combinations. However, the increased stress allowables shall not exceed the following limits.

Axially loaded compression members:

$$\sigma_{a1}\ (\text{max.}) = 0.90\sigma_y \tag{43a}$$

Basic design stress:

$$\sigma_c\ (\text{max.}) = 0.9\sigma_y \tag{43b}$$

Local plate bending:

$$\sigma\ (\text{max.}) = 1.35\ \sigma_y \tag{43c}$$

Members subjected to shear:

$$\sigma\ (\text{max.}) = 0.90\sigma_y/\sqrt{3} \tag{43d}$$

AA-D-3500 STIFFENERS

AA-D-3510 STIFFENER DESIGN

Duct stiffeners are generally equal leg-angle shapes welded to the duct. Duct stiffeners shall be designed for loads resulting from duct internal pressure and duct plate local seismic excitation based on the tributary areas (Fig. AA-D-3510), as well as stiffener self-weight excitation and loads from equipment mounted directly on the duct plate. Other loads as specified in AA-4211, if present, shall also be considered (e.g., fluid momentum loads).

In Fig. AA-D-3510, the cross-hatched area represents the duct plate area tributary to the stiffener for load determination.
where

ℓ' = $s/2$
s = stiffener spacing
W or H = width or height of the duct respectively

In lieu of the trapezoidal tributary area, a rectangular tributary area may be conservatively used for simplification.

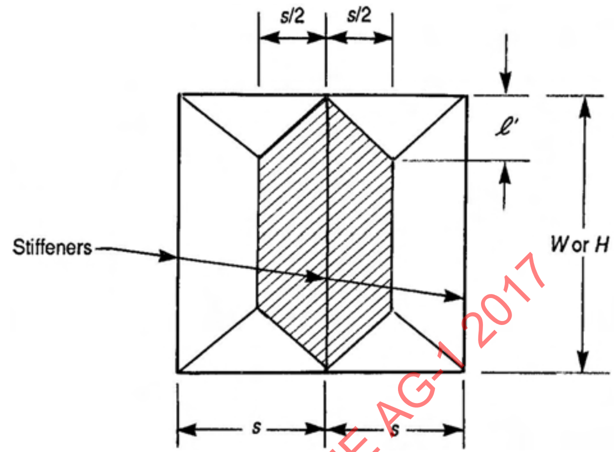
The capacity of duct stiffeners shall be determined in accordance with conventional methods of structural design.

AA-D-3520 STIFFENER SIZE AND SPACING

Duct stiffener size and spacing is contingent upon many parameters including duct plate thickness, duct pressure levels, seismic excitation levels, and other loads as discussed in AA-D-3510.

It is recommended that as a starting point, the stiffener size and spacings given by SMACNA, which are primarily based on operational requirements, be used. Then, based on detailed duct analysis, if a closer stiffener spacing is required for a particular duct size, that spacing shall be used.

FIG. AA-D-3510



ARTICLE AA-D-4000
DUCTWORK DESIGN

The ductwork should be laid out with the stiffener spacing as required for the particular application. All of the loads should be identified, and the equations presented in AA-D-3300 and AA-D-3400 checked to see which type of load will be the governing load. This load and its defining equation will then define the spacing between supports.

The allowable span (spacing between hangers) can be found by solving the appropriate equation for the span L required to produce a given stress level.

The loads required for this calculation are dependent on whether the span being computed is due to deadweight loading or dynamic loading. For deadweight spans, the 250 lb midspan load over a 10 in.^{2} area must be applied in addition to the distributed load due to duct, stiffener, and other weights. During a dynamic event, the 250 lb load does not apply, and the solution for the span depends only on the distributed weight of the system. For a bending stress dominated system, the solution for allowable span for a *circular* duct is:

$$\sigma_{CR} = \frac{0.33\ Et}{D} \tag{43}$$

The deadweight span can be found by solving for L in the following equation:

$$\sigma = \frac{Mc}{I} = \frac{WL^2C}{8I} + \frac{PLc}{4I} = \frac{0.33Et}{D} \tag{44}$$

Similarly, the dynamic span can be found by solving for L in the following equation:

$$\sigma = \frac{Mc}{I} = \frac{WL^2C}{8I} = \frac{0.33Et}{D} \tag{45}$$

For critical buckling, the deadweight span can be found by solving for L in this equation:

$$\sigma = \frac{Mc}{I} = \frac{WL^2c}{8I} + \frac{PLc}{4I} = \sigma_y \tag{46}$$

The dynamic span can be found in the same way:

$$\sigma = \frac{Mc}{I} = \frac{WL^2c}{8I} = \sigma_y \tag{47}$$

where

L = allowable span, in.
M = bending moment, K·in.
P = 0.250 kip load
W = distributed weight of duct including stiffeners and insulation, K/in.
σ = bending stress, ksi
σ_y, E, t, D, C, and I are defined in Articles AA-D-2000 and AA-D-3000

The bending stress should be checked against the appropriate allowables. In the event the allowable stress for bending is below that necessary to cause buckling, then the allowable span for design purposes will be based on bending stress, not buckling. The ASME stress intensification factors traditionally used in piping analysis are not mandatory for use in ductwork analysis. The ASME piping factors are derived based on fatigue consideration due to high temperature service, and as such are not applicable to ductwork.

For ductwork analysis, the stress intensification factors k, listed below, should be used as a minimum [see Article AA-D-5000 (Sobieszanski 1970, Harp and Roberts 1971, Jones and Kitching 1966, and Seely and Smith 1962)].

k = 2.5 for duct elbows
= 3.5 for duct tees
= 1.0 for duct straight runs

Then, the stress at a point due to a bending moment becomes

$$\sigma = k\frac{Mc}{I} \tag{48}$$

when M is determined from the various analysis methods for static or dynamic loads, and k is the appropriate duct stress intensification.

If a modal analysis is performed, the analysis using the appropriate response spectra can be expedited if a dynamic span based on the methods in this Appendix is used to lay off hanger spans.

If a simplified static method is used, the same method can be used to determine the allowable spans based on the design methods of the appendix. Simplified methods differ from modal analysis in that higher vibratory modes are not examined and the results may not be conservative. Therefore, a multimode participation factor is recommended to adjust the design acceleration upward to account for the presence of higher vibratory modes that the simple method may otherwise not include. A factor K equal to 1.5 is recommended unless another value can be justified [see Article AA-D-5000 (NUREG 0800)]. Thus, for a design acceleration of A, the new design acceleration A^1 is found from:

$$A^1 = KA \tag{49}$$

where

K = multimode participation factor
= 1.5 (suggested value) [refer to Article AA-D-5000 (NUREG 0800)] the load becomes

$$W^1 = W(KA) \qquad \text{horizontal event} \tag{50}$$

$$W^1 = W(1 \pm KA) \qquad \text{vertical event} \tag{51}$$

from beam theory as before:

$$\sigma = \frac{Mc}{I} = \frac{kW^1L^2c}{8I}$$

$$L = \left[\frac{8I\sigma}{kW^1r}\right]^{1/2} \tag{52}$$

for a horizontal event:

$$L = \left[\frac{8I\sigma}{kWKAr}\right]^{1/2} \tag{53}$$

for a vertical event:

$$L = \left[\frac{8I\sigma}{kW(1 \pm KA)r}\right]^{1/2} \tag{54}$$

where

k = stress intensification factors
= 2.5 elbows
= 3.5 tees
= 1.0 straight runs
r = radius of duct
σ = allowable stress, ksi

The spans computed above can be used to determine support spacings for a circular duct system. The vertical span should be used throughout. The horizontal span, if computed differently from the vertical span, should be used to check spans against restraints required for vertical restraint. If the vertical supports do not provide horizontal restraint, then additional supports based on the horizontal span may be required.

The seismic deflections σ should also be checked. From elementary beam theory, the deflection under uniform loading of a simply supported beam is

$$\sigma = \frac{5W^1L^4}{384EI} \tag{55}$$

Using the definition for W^1 for vertical and horizontal events, the deflections are

(a) Vertical Event

$$\sigma = \frac{5\,(1 \pm KA)\,WL^4}{384EI} \tag{56}$$

(b) Horizontal Event

$$\sigma = \frac{5\,KAWL^4}{384EI} \tag{57}$$

ARTICLE AA-D-5000
REFERENCED DOCUMENTS

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Division II
Ventilation Air Cleaning and Ventilation Air Conditioning

SECTION BA
FANS AND BLOWERS

Tables

Nonmandatory Appendices

ARTICLE BA-1000 INTRODUCTION

(09) BA-1100 SCOPE

This section provides requirements for the performance, design, construction, acceptance testing, and quality assurance for single stage fans, fan drivers, drives, and related fan accessories used as components in nuclear safety-related air or gas treatment systems in nuclear facilities.

(09) BA-1110 PURPOSE

The purpose of this section is to assure that fan equipment used in nuclear facilities is acceptable in all aspects of performance, design, construction testing, and quality assurance.

BA-1120 APPLICABILITY

This section applies only to fans acting as individual components in a system and includes the driver, drive, and related fan accessories. This section does not cover equipment whose primary purpose is to compress air or gas. Although fans used in nuclear facilities may produce a change in density of air or gas being moved, hence providing compression or rarefaction, the primary purpose of the fans is to move air or gas. No limits on speed, compression, density, temperature, power, or size restrict the applicability of this section.

This section does not cover any functional system design requirements, sizing of complete air handling systems, or any operating characteristics of these systems. Additionally, ejectors, gas compressors, gravity roof ventilators, and positive displacement-type air moving units are not within the scope of this Code.

The responsibility for meeting each requirement of this section shall be assigned by the Owner or designee using Nonmandatory Appendix BA-B as a guide.

(09) BA-1130 DEFINITIONS AND TERMS

axial fans: composed of three groups of fans: propeller, tubeaxial, and vaneaxial. In all cases, the air flow is parallel to the rotating shaft.

blocked tight/shut off: a condition of fan operation accompanied by a complete closure of the inlet or outlet, permitting no air flow.

brake horsepower: the power delivered to the fan input shaft (does not include any drive losses other than the fan bearings).

centrifugal fan: a fan rotor or wheel with blades within a scroll-type housing that includes driving mechanism supports for either belt drive or direct connection. Air enters the housing through one or two inlets concentric with the rotating shaft. Air is expelled through the wheel blades into the surrounding housing and the fan outlet.

critical speed: corresponds to the first natural frequency of the rotating element (impeller and shaft assembly) when mounted on rigid supports.

design pressure: the maximum allowable pressure for which a specific component is designed.

design speed: the maximum speed RPM of the fan's continuous operation.

design temperature: the maximum air temperature at which a fan can be continually operated.

direct connected: a method of connection whereby the driver and fan wheel are positively connected in line to operate at the speed of the driver.

dynamic losses: losses in the total pressure that result from disturbances in the air flow caused by change in direction or velocity of the air stream, or both, such as an unducted fan inlet or outlet.

fans: air moving devices composed of a wheel or blade and housing. Fans transfer mechanical energy and cause the flow of air by increasing the total pressure of the moving air.

fan air density: the density of the air corresponding to the pressure and temperature at the fan inlet.

fan arrangement number: an Air Movement and Control Association definition of bearing location, means of motor support, position of motor, and method of coupling the motor to the fan. Arrangements are shown in AMCA 99-2404, 99-2410, and 99-3404.

fan flow rate: the volumetric rate at fan air density.

fan operating range: the stable portion of the performance curve where the fan will operate free of a stall or surge condition.

fan performance curves: curves that give static or total pressure and power input over a range of air volume flow rate at a stated inlet density and fan speed. Fan performance curves may include static and mechanical efficiency. The range of air volume flow rate usually extends from shutoff (zero air flow) to free delivery (zero static pressure).

fan power input: the power required to drive the fan and any elements in the drive train that are considered a part of the fan.

fan static pressure (P_s): the difference between the fan total pressure and the fan velocity pressure (corresponding to average velocity through outlet). Therefore, the fan static pressure is the difference between the static pressure at the fan outlet and the total pressure at the fan inlet.

fan total pressure (P_t): the difference between the total pressure at the fan outlet and the total pressure at the fan inlet.

free delivery condition: a condition during which the fan static pressure is zero and flow rate is at a maximum value.

inlet bell (bell mouth): fan or duct inlet opening made in the shape of a bell opening to streamline the inlet air flow, minimize air turbulence, and thereby reduce the inlet loss in air pressure.

inlet/outlet cones: conical duct sections added to the inlet or outlet of axial fans. The inlet cone minimizes air turbulence. The outlet cone provides regain in static pressure.

inlet transitions (boxes): sections of ducting added to centrifugal fans in place of standard duct elbows, designed to provide predictable fan inlet conditions. Inlet box positions are shown in AMCA 99-2405.

maximum speed: see *design speed.*

operating point: a point on the fan performance curve that represents the fan performance for a given system.

operating pressure: the pressure under normal conditions.

operating speed: the actual speed RPM at which the supplied fan is to perform. This may be a range of speeds for VFDs and VSDs.

operating temperature: the air temperature in the fan during normal conditions.

orientation: the designation of rotation and discharge of a centrifugal fan. Direction of rotation as viewed from the drive side for all fans. Rotation is defined as clockwise or counterclockwise. Discharge is defined as up blast, down blast, top horizontal, bottom horizontal, top angular up or down, and bottom angular up or down. Orientations are given in AMCA 99-2406.

peak design temperature: the maximum temperature at which a fan can operate for a specific time.

scroll casing, housing, volute: stationary protective enclosures designed to divert the flow of air into the inlet of the impeller and to direct the flow from the discharge of the impeller. The enclosure may also affect the energy transformation of the airstream.

stall/surge limit: the stall limit of an axial fan is that point near the peak of the pressure curve at a particular blade angle that corresponds to the minimum flow rate at which the fan may be operated without separation of airflow over the blades. The surge limit of a centrifugal fan is that point near the peak of the pressure curve that corresponds to the minimum flow rate at which the fan can be operated without instability.

system resistance curve: the plot of the total of all system pressure losses, such as filters, coils, dampers, and ductwork versus air flow.

variable inlet vanes: moveable vanes located in a fan inlet that form an integral part of the fan (whether added to or incorporated as part of an inlet bell) to control fan performance.

(09)

ARTICLE BA-2000
REFERENCED DOCUMENTS

The codes and standards listed below shall supplement those listed in Section AA. Unless otherwise specified, the latest edition shall apply.

AMCA 99, Standards Handbook

AMCA 201, Fan Application Manual—Fans and Systems

AMCA 210, Laboratory Methods of Testing Fans for Rating Purposes

AMCA 300, Reverberant Room Method for Sound Testing of Fans

AMCA 301-1990, Methods for Calculating Fan Sound Ratings From Laboratory Test Data

Publisher: Air Movement and Control Association International, Inc. (AMCA), 30 West University Drive, Arlington Heights, IL 60004-1893

ASHRAE 68, Laboratory Method of Testing to Determine the Sound Power in a Duct (AMCA Std. 330)

Publisher: American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329

ARTICLE BA-3000 MATERIALS

(09)

BA-3100 GENERAL

Materials for fan components and accessories shall be in conformance with the ASME or ASTM materials listed in Table BA-3100. Substitute materials shall be equivalent to or exceed the requirements in Table BA-3100 and be approved by the owner or designee.

BA-3110 MATERIAL STRESS VALUES

The ASME or ASTM designation in Table BA-3100 specifies a chemical composition and a material thickness limit. A grade designation is usually required to determine the minimum strength of the material. If the specific grade material has an assigned minimum yield and tensile strength, these values shall be used for design purposes. If values have not been established and assigned, then tests in accordance with the procedures outlined in ASTM A 370 and Article AA-5000 shall be performed to obtain these values. Results of mill certified tests performed as above designating these values may be used. Maximum allowable design stress values shall be calculated by the procedures in Article AA-4000. These procedures require the use of an allowable stress for normal structural requirements, and correction of allowable stress for conditions where buckling can take place and for the several service levels. When the minimum yield values have been established by test or by ASTM minimums, then the allowable stress S or S_a used in Article AA-4000 shall be 60% of yield.

BA-3200 SPECIAL LIMITATIONS ON MATERIALS

Aluminum and zinc shall not be used in the presence of corrosive vapors. All materials shall be compatible with operating environmental conditions.

BA-3300 DESIGNATION OF MATERIALS

The ASME or ASTM material numbers and grade for the fan components selected from BA-3410 and BA-3420 shall be identified.

BA-3400 CERTIFICATION OF MATERIALS

The Manufacturer shall make available, when required by the Design Specification, certified test reports of chemical and physical properties of material and hardware used for all stress components of fans and related accessories, including fan wheel components, fan shafts, and driver support plate, but excluding fan drivers, drives, and bearings.

BA-3410 CENTRIFUGAL FANS

A Manufacturer's Certificate of Conformance shall be provided for scrolls, housing side sheets, inlets, side plates, back (center) plate, weld filler materials, and support framing integral to the fan.

BA-3420 AXIAL FANS

A Manufacturer's Certificate of Conformance shall be provided for fan casing, guide vanes, weld filler material, and driver support components.

BA-3500 PURCHASED MATERIALS

All purchased items shall meet the requirements of BA-3100, BA-3110, BA-3200, BA-3300, and BA-3400.

BA-3600 DRIVER MATERIALS

Driver materials shall be selected such that the drivers meet the electrical and mechanical requirements of ANSI/IEEE 323, ANSI/IEEE 334, ANSI/IEEE 344, and NEMA MG-1, as required by the design specification.

TABLE BA-3100
ALLOWABLE MATERIALS

ASME Designator	ASTM Designator	Publication Title
Sheet and Strip		
. . .	A 366	Steel, Carbon, Cold-Rolled Sheet, Commercial Quality, A 1008/A 1008M
SA-414	A 414	Carbon Steel Sheets for Pressure Vessels, A 414/A 414M
. . .	A 653-97	Steel Sheet, Zinc Coated by the Hot-Dip Process, A 653/A 653M-028
. . .	A 569	Steel, Carbon, Hot-Rolled Sheet and Strip, Commercial Quality, A 1011/A 1011M
. . .	A 570	Hot-Rolled Carbon Steel Sheet and Strip, Structural Quality, A 1011/A 1011M
. . .	A 606	Steel Sheet and Strip, Hot- and Cold-Rolled, High Strength, Low-Alloy With Improved Corrosion Resistance, A 606
. . .	A 607	Steel Sheet and Strip, Hot- and Cold-Rolled, High Strength, Low-Alloy Columbium and/or Vanadium, A 1008/A 1008 M-03, and A 1011/A 1011M
. . .	A 611	Steel, Cold-Rolled Sheet, Carbon Structural, A 1008/A 1008M
SA-620	A 620	Carbon Steel Sheet, Cold-Rolled, Drawing Quality, Special Killed, A 1008/A 1008M
. . .	A 621	Steel Sheet, Hot-Rolled, Pickled and Oiled, Drawing Quality
. . .	A 743	Corrosion Resistant Chromium–Iron–Nickel Base Alloy for General Purpose, A 743/A 743M
. . .	A 744	Corrosion Resistant Iron–Chromium–Nickel and Nickel Base Alloy Casting for Severe Service, A 744/A 744M
Plate		
SA-240	A 240-97A	Heat-Resisting Chromium and Chromium–Nickel Stainless Steel Plate, Sheet, and Strip for Fusion-Welded Unfired Pressure Vessels, A 240/A 240M
. . .	A 242-93A	High-Strength Low-Alloy Type 1, A 242/A 242M
SA-283	A 283	Low- and Intermediate-Tensile Strength Carbon Steel Plates, Shapes, and Bars, Structural Quality, A 283/A 283M
SA-285	A 514-94A	High-Strength Quenched and Tempered Alloy Steel, A 514/A 514M
. . .	A 588-97	High-Strength Low-Alloy With 50,000 Min. Yield to 4 In. Thick, A 588/A 588M
SA-209	B 209-96	Aluminum Sheet or Plate, Alloys 3003, 5052, 6061, 6061-T6, B 209
Hardware		
SA-193	A 193	Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service, A 193/A 193M
SA-194	A 194-97	Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service, A 194/A 194M
SA-307	A 307	Carbon Steel Externally and Internally Threaded Fasteners, A 307
SA-354	A 449	Quenched and Tempered Steel Bolts and Studs, A 449
. . .	A 489	Carbon Steel Eyebolts, A 489
SA-563	A 563-96	Carbon Steel Nuts, A 563
SA-574	A 574-97	Alloy-Steel Socket Head Cap Screws, A 574

TABLE BA-3100
ALLOWABLE MATERIALS (CONT'D)

ASME Designator	ASTM Designator	Publication Title
Forgings and Castings		
. . .	A 27-95	Mild to Medium Strength Carbon Steel Castings for General Application, A 27/A 27M
SA-47	A 47-95	Malleable Iron Castings, A 47/A 47M
. . .	A 48-94A	Gray Iron Castings, A 48/A 48M
SA-105	A 105-97	Forgings, Carbon Steel, for Piping Components, A05/A 105M
. . .	A 126-95	Gray Iron Castings for Valves, Flanges, and Pipe Fittings, A 126-95
. . .	A 668-96	Shaft Forging, A 66B/A 668M
. . .	A 536-84	Iron, Nodular Casting, A 536-84
. . .	A 148-93B	Steel, Cast, A 148/A 148M
SB-26	B 26-97	Aluminum, Cast 40E or D 612, B 26/B 26M
SB-108	B 108-97	Aluminum, Cast A 356-T61, B 108
Structurals		
SA-36	A 36-96	Structural Steel, Structural Quality, A 36/A 36M
. . .	A 108-95	Steel Bars, Carbon, Cold-Finished, Standard Quality, A 108
. . .	A 123-97A	Angles, Hot-Dip Galvanized Coatings Used on A 36 Base Metal, A 123/A 123M
. . .	A 276-97	Stainless and Heat-Resisting Steel Bars and Shapes, A 276
SA-479	A 479-97A	Stainless and Heat Resisting Steel Bars and Shapes, Pressure Vessel Quality, A 479/A 479M
. . .	A 510-96	Wire Rods and Coarse Round Wire, Carbon Steel, A 510
. . .	A 575-96	Merchant Quality Hot-Rolled Carbon Steel Bars, A 575-96
. . .	A 576-90B	Steel Bars, Carbon, Hot-Rolled, Special Quality Aluminum, A 576-906
SB-211	B 211-95A	Aluminum Bars, Alloy 6061-T6, B 211
SB-308	B 308-96	Aluminum Angles, Alloy 6061-T6, B 308/B 308M
Pipe and Tube		
SA-53	A 53-97	Pipe Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless, A 53/A 53M
. . .	A 269-96	Seamless and Welded Austenitic Stainless Steel Tubing for General Service, A 269
SA-312	A 312-95A	Seamless and Austenitic Stainless Steel Pipe, A 312/A 312M
. . .	A 519-96	Seamless Carbon and Alloy-Steel Mechanical Tubing, A 519-96
Screening		
. . .	A 555-97	General Requirements for Stainless and Heat-Resisting Steel Wire, A 555/A 555M-97
. . .	A 581-95B	Free-Machining Stainless and Heat-Resisting Steel, A 581/A 581M-95b

GENERAL NOTE:
The latest edition of the reference shall apply unless otherwise indicated.

(09)

ARTICLE BA-4000 DESIGN

Design of fans shall be in accordance with the requirements of BA and of those portions of Section AA invoked in Section BA. Guidance on fan system design consideration is contained in Nonmandatory Appendix BA-A.

BA-4100 DESIGN CONDITIONS

BA-4110 PERFORMANCE

Fans shall be selected to provide the specified flow rate and pressure requirements while operating in the stable region of the fan curve. Fans shall not be selected to operate in the stall or unstable region of the fan curve. Details of fan inlet and discharge conditions shall be considered and documented in support of fan sizing and selection. Fans shall be sized with consideration of dynamic losses that may be encountered. System characteristics shall be considered using AMCA 201. The following fan data shall be established in support of the fan selection:

(a) fan type and blade shape
(b) airflow, actual ft^3/min (m^3/min)
(c) total pressure to be developed, in. wg (mm wg)
(d) maximum allowable discharge velocity, ft/min (m/min)
(e) air density at which the fan is to be rated, lb/ft^3 (kg/m^3)
(f) maximum air density expected, lb/ft^3 (kg/m^3)
(g) operating temperatures, °F (°C)
(h) details of intake and discharge transitions that affect fan performance
(i) parallel fan operation, if required
(j) peak design temperature
(k) fan operating range, if required

BA-4120 ENVIRONMENTAL CONDITIONS

BA-4121 General

Fans, including drivers, drives, bearings, and accessories, shall be designed to operate continuously, while exposed to the environmental conditions caused by postulated accidents for a period, as determined by the Design Specification. This applies to fans used during normal plant operation and to fans on standby status intended for operation under accident conditions only. The 30 days of continuous operation is in addition to the projected life of the plant for fans used during normal plant operation and in addition to expected operation, including operation during periodic testing and maintenance for fans on standby status.

BA-4122 Aging

The aging mechanisms listed in BA-4123 shall be applied to the equipment and components. Design qualification shall be specified in accordance with ANSI/IEEE 627. A list of recommended spare parts and their expected life shall be provided for the equipment and components that are not expected to last for the life of the plant under specific environmental conditions.

BA-4123 Environmental Considerations

The following aging mechanisms affecting life expectancy shall be considered as a minimum:

(a) radiation
(b) temperature variation range
(c) pressure variation range
(d) corrosive chemicals and moisture conditions
(e) erosive particles in air streams
(f) duty cycles

BA-4124 Environmental and Seismic Qualifications

Fans, including drivers, drives, bearings, and accessories shall be seismically and environmentally qualified in accordance with qualification requirements of this section, and imposed under Article AA-4000.

BA-4130 LOADING

BA-4131 Load Definition

Loads applicable to fan design are described in AA-4211 and AA-4212. The specific conditions indicated in BA-4131.1 through BA-4131.4 shall be considered.

BA-4131.1 Normal Loads. Normal loads consist of the following:

(a) positive or negative pressure differential transients imposed on the fan housing by maximum normal fan pressure differential

(b) forces imposed on the fan in any of its modes of operation, including a single failure of any interacting component

(c) loads imposed on fan inlet and outlet by duct connections

(d) loads imposed on fan, driver, or both, by electrical conduit connections

(e) loads imposed on the fan bearings

BA-4131.2 Loads Imposed on Driver and Fan When Starting. Loads imposed on the driver and fan may be caused by fan pinwheeling (inadvertent reverse rotation) caused by backflow of air while on standby status.

BA-4132 Missile Protection

Fans shall be designed to prevent any internally generated missiles from penetrating the fan housing unless other external protection is provided. Consideration shall be given to the orientation of the fan inlet and outlet openings with respect to the protection of other safety-related equipment that is to occupy the adjoining space.

BA-4133 Construction

As a minimum, the fan construction shall be capable of meeting the maximum conditions in which fan pressure and outlet velocity are specified.

Fans shall be designed in accordance with the structural requirements given in Article AA-4000. Structural requirements, load definitions, and structural design verification specific to fans are given in BA-4131, BA-4431, BA-4432, and BA-4433. Additionally, construction shall comply with the stress and deflection criteria associated with the loads given by BA-4433.

BA-4140 LEAKAGE

BA-4141 General

Fans are subject to the leakage criteria when the location of the fan and direction of leakage impose a contamination burden in the space housing the fan or the space supplied with air by the fan. Leakage testing shall be as given in BA-5142.

BA-4141.1 Fan Housing Leakage. Housings subject to the leakage criteria, including penetrations such as cable connections of axial fans, shall be made airtight, according to the method outlined in BA-5142.1.

BA-4141.2 Shaft Leakage. Shafts subject to leakage criteria shall be limited to 0.01% of the normal airflow per inch (25.4 mm) of fan operating pressure, or 0.5 scfm (0.0142 m^3/min), whichever is greater.

BA-4150 SUPPORT BOUNDARY

The support boundary for the fan shall be the point of attachment of the fan housing or base to its foundation.

BA-4151 Centrifugal Fan Support Boundary

The support boundary for a centrifugal fan is the attachment point for the fan base to the building, or the structural members of an air handling unit, or structural steel within the building. The following data shall be specified:

(a) size, number, and type of anchorage attachment

(b) anchorage loads to be imposed on the attachment points

BA-4152 Axial Fan Support Boundary

The support boundary for an axial fan is at the inlet and outlet mounting flanges unless the axial fan is base mounted. The support boundary for a base-mounted axial fan is the attachment point for the fan housing to the building, or the structural members of an air handling unit, or structural steel within the building. The following data shall be specified:

(a) size, number, and type of anchorage attachment

(b) anchorage loads to be imposed on the attachment points

BA-4160 VIBRATION

BA-4161 General

Fan wheels shall be dynamically balanced prior to fan assembly. Final balancing shall be performed on the completed assembly. All test results shall be documented. After installation, fans shall be checked and rebalanced, if necessary, to correct changes due to handling, shipping, and final support structure conditions.

TABLE BA-4162
MAXIMUM ALLOWABLE DISPLACEMENT

Rotational Speed, rpm	Double Amplitude Displacement, mils	(mm)
600	3.2	(0.081)
720	2.7	(0.068)
900	2.1	(0.053)
1,200	1.6	(0.040)
1,800	1.1	(0.027)
3,600	0.5	(0.012)

GENERAL NOTE: Displacement may be interpolated for other speeds.

BA-4162 Centrifugal Fans

The double amplitude radial displacement measured on the bearing caps at the designated fan speed shall not exceed the values listed in Table BA-4162, measured with a meter filtered to the fan rotational speed.

BA-4163 Axial Fans

The double amplitude radial displacement measured on the fan housing at both the inlet and discharge locations at the designated speed shall not exceed 1.0 mil (0.025 mm), measured with a meter filtered to the fan rotational speed.

BA-4200 SELECTION

BA-4210 FANS

BA-4211 General

This subarticle details principles to be used in the application of fans to systems in nuclear facilities.

BA-4211.1 Application. Each fan shall have a title and a numbering that uniquely identifies that fan.

BA-4211.2 Duty. The duty of the fan shall be described by the operating and idle time periods, their frequency, and the corresponding fan load characteristics.

BA-4211.3 Fan Configuration. The fan discharge, drive arrangement, and rotation shall be included in the design specification.

BA-4211.4 Fan Environment. The environmental conditions, including airstream and gas stream contaminants, of BA-4120 that can affect the operability, service life, maintainability, or need for special features as to construction or materials of the fan shall be included in the design specification.

BA-4211.5 Special Limitations. Special limitations, such as space, weight, outlet velocity, fan speed, sound power level, and driver nameplate horsepower, that influence fan selection shall be considered and included in the Design Specification.

BA-4212 Performance Rating

Fan performance rating shall consist of the following information for all fan operating points, as a minimum:

(a) flow rate at fan inlet, actual ft^3/min (m^3/min)
(b) fan total and fan static pressure, in. wg (mm wg)
(c) fan air density, lb/ft^3 (kg/m^3)
(d) fan air temperature, °F (°C)
(e) fan operating speed, rpm
(f) fan power input, hp (kW)

BA-4213 Pressure Relationships

Fans shall be rated using either fan static pressure or fan total pressure. Fan pressure relationships are illustrated in AMCA 201.

BA-4214 Operation at Reduced Flow

Fans shall be selected to satisfy the maximum performance requirement. Operation at reduced flow shall be evaluated during the initial fan selection to ensure stable fan operation over the entire range of expected fan operation.

BA-4220 DRIVERS

BA-4221 Information Required for Driver Selection

Information required for driver selection shall consist of the following, as a minimum:

(a) fan speed torque curve with operating brake horsepower point identified
(b) fan inertia applied to the driver shaft
(c) external forces acting on the driver shaft
(d) driver rated electrical power source
(e) environmental requirements
(f) driver and fan physical orientation
(g) applicable standards such as IEEE and NEMA requirements
(h) space heater requirements
(i) minimum air velocity over driver when required

BA-4222 Special Limitations

BA-4222.1 Centrifugal Fans. Belt drives shall be permitted only in areas that are accessible for maintenance during normal and accident conditions. The number of belts selected shall allow for a single belt failure without loss of function. In use of either direct or belt drives, the equipment shall be capable of operating under the specified conditions while performing its intended safety-related function. Drives in which gear reducers are used shall not be allowed. Systems that are air balanced using variable pitch diameter sheaves shall be provided with fixed diameter sheaves for long-term operation.

BA-4222.2 Axial Fans. Axial fans shall be selected for direct connected operation, in accordance with AMCA 99-3404, designated arrangement No. 4.

BA-4300 CONSTRUCTION

BA-4310 GENERAL

This paragraph contains general requirements for the construction of fans, fan driver, drives, and accessories.

BA-4320 FANS

BA-4321 Centrifugal Fans

BA-4321.1 General. The housing materials and design shall meet the requirements of BA-3100, BA-4100, BA-4200, and BA-6110.

Spark-resistant construction, where specified, shall meet the requirements of AMCA 99-0401.

BA-4321.2 Bearings. Bearings shall be self-aligning, antifriction, and shall have an L-10 service rating life of at least 100,000 hr in accordance with the load and speed conditions. Bearing rating life shall be established in accordance with ANSI/AFBMA 9 or 11.

When the driver bearings are also the fan bearings, an L-10 life less than 100,000 hr is permissible. This limitation shall be documented.

Bearings shall be provided with grease fittings, usable in accessible areas without interrupting fan operation.

BA-4322 Axial Fans

BA-4322.1 General. The fan construction shall include adjustable-pitch bladed wheels mounted upon the driver's extended shaft and located inside the flanged fan casing. The driver shall meet the requirements of BA-4220 and BA-4320.

When required by BA-4142, electric cables penetrating the fan housing shall meet the requirements of BA-4142.1 as to fan housing air leakage.

BA-4322.2 Fan Housing. The fan housing materials and design shall meet the requirements of BA-4100, BA-4200, and BA-6110.

BA-4322.3 Blade Angle. Adjustable pitch blades shall have corresponding blade angles indicated on the fan performance curve. Blade position designations appearing on the fan curve shall bear a correspondence with a permanent index located at the blade hub connection. After setting the blades, the locking device shall be torqued and secured in place.

BA-4322.4 Bearings. Bearings shall be antifriction type. Bearing L-10 life under actual operating conditions shall be at least 100,000 hr. Bearing life shall be established in accordance with ANSI/AFBMA 9 or 11. When the bearing size is limited by driver dimensional constraints and the driver bearings are also the fan bearings, an L-10 life of less than 100,000 hr is permissible. This limitation shall be documented.

Bearings shall be provided with grease fittings. For drivers within the fan casing, both supply and purge lines shall be extended to outside the fan casing to permit bearing lubrication without interrupting fan operation.

BA-4330 DRIVERS AND DRIVES

BA-4331 Types of Drives

The drives shall be subject to the limitation of BA-4222.

BA-4332 Drive Alignment and Adjustment

Direct drives shall make use of metal shims to provide final alignments. Belt drives shall be provided with an adjustable driver base to allow a full range of belt tension adjustment.

BA-4333 Mechanical Design Requirements for Drivers

(a) Bearings shall be antifriction type. Bearing L-10 life under actual operating conditions shall be at least 100,000 hr. An L-10 life of less than 100,000 hr may be used when limited by driver constraints. Bearing life expectancy shall be documented.

Bearings shall be provided with grease fittings. For drivers located within fan casing, both supply and purge grease lines shall be extended to outside the fan casing to permit bearing lubrication without interrupting fan operation.

(b) Maximum sheave arrangement shall be limited per NEMA MG-1.

(c) Drivers shall conform to NEMA MG-1.

BA-4334 Electrical Design Requirements

(a) All drivers shall be designed for single voltage supply.

(b) Drivers shall conform to NEMA MG-1.

(c) Provision shall be made for solid grounding of the driver.

BA-4335 Application

All fan drivers shall be selected to reach operating speed under the lowest voltage conditions as defined in the Design Specification.

BA-4340 ACCESSORIES

BA-4341 Accessories Common to Centrifugal and Axial Fans

(a) Fan lifting lugs or eye bolts shall be provided on fans and drivers 50 lb (22.7 kg) and heavier in weight.

(b) Inspection panels where called for by the Design Specification shall be provided in fan housings having wheels 12 in. (30.5 cm) and larger in diameter. Panels shall be of a size that will allow maintenance on components located within the fan housing. Quick-opening latches shall normally be used, except that when leakage criteria are required per BA-4142, bolted and gasketed seals shall be used. Latches shall be retainable on the panel or fan to prevent loss of latches in the fan housing.

(c) Arrows clearly indicating the direction of fan rotation and airflow shall be permanently displayed on each fan housing.

(d) All gaskets used shall be of a material that is capable of withstanding the normal and accident aging mechanisms of BA-4123 without loss of function for a minimum predetermined qualified life.

(e) Bearing lubricants shall be selected to withstand the aging mechanisms of BA-4123 for a minimum predetermined qualified life consistent with the term provided by provisions of accessibility and the environmental conditions of BA-4121.

(f) Provisions shall be made for the installation of thermocouples on fan and driver bearings of fans that are inaccessible for unscheduled inspection when required by the Design Specification.

BA-4342 Centrifugal Fans

BA-4342.1 Variable Inlet Vanes. Variable inlet vanes, when used, shall be capable of reducing the rated volume flow to at least 30% of design, and shall be flanged and bolted to, or built as an integral part of the fan inlet. Manual actuation shall be with a locking quadrant. Electric, pneumatic, or noncombustible electrohydraulic actuators for remote or automatic operation of variable inlet vanes shall be mounted on the fan housing or shall be provided with a common structural support base. When remote inaccessible actuation is required, the vane actuation position shall be displayed at an accessible location. Fan performance characteristics with inlet vanes shall be determined in accordance with Article BA-5000.

Vane assemblies for double inlet fans shall be connected through a common control shaft for simultaneous operation.

BA-4342.2 Inlet Screen Guards. Guards for bolting to the fan inlet or outlet shall meet the material requirements of BA-6100.

BA-4342.3 Vibration Isolators. Vibration isolators shall not be used and fans shall be mounted rigidly unless provisions are made to withstand the forces generated or amplified during a seismic event.

BA-4342.4 Guards. Shaft and bearing guards and V-belt drive guards shall be of the quick-removal design type. V-belt guards shall permit checking the fan speed without guard removal.

BA-4342.5 Inlet Transitions. The inlet and outlet connections shall be flanged. The housing connected flange shall be drilled to match the fan inlet flange.

BA-4342.6 Shaft Seals. Shaft seals, when required, shall meet the leakage criteria of BA-4142.2.

BA-4343 Axial Fans

BA-4343.1 Inlet/Outlet Cones. Flanged inlet/outlet cones shall be fabricated of the same material as the fan housing. The housing connected flange of the cone(s) shall be drilled to match the fan inlet/outlet flange(s).

BA-4343.2 Inlet Bells. Flanged inlet bells, drilled to match the fan housing inlet flange, shall meet the requirements of BA-3100. Inlet bells should always be provided for fans with nonducted inlets.

BA-4343.3 Inlet and Outlet Screen Guards. Guards for bolting to the fan inlet or outlet shall meet the material requirements of BA-6100.

BA-4343.4 Mounts. Fan mounts shall be welded to the casing and shall be designed to support the weight of the fan and driver in the specified mounting arrangement and in consideration of all internal and external dynamic forces.

BA-4343.5 Vibration Isolators. Vibration isolators shall not be used and fans shall be mounted rigidly unless provisions are made to withstand a seismic event.

BA-4343.6 Variable Inlet Vanes. Variable inlet vanes shall not be used for axial fans unless provisions are made to prevent overloading the driver.

BA-4400 REPORTS AND CALCULATIONS

BA-4410 PERFORMANCE RATING

BA-4411 Rating Calculations

Calculations and tests used to obtain fan ratings shall include the effects on performance of all shaft and bearing blockages, accessories, and other means of control associated with the fan. Fan power requirements shall include the effects of bearing friction and any other losses due to the drives that are supplied as an integral part of the fan.

BA-4412 Documentation of Final Rating Data

As a minimum, the rating data and the bases identified in BA-4212 shall be included.

In addition to the listed or tabulated point of rating, a constant-speed performance curve shall be prepared, which contains complete identification information such as fan size, type, inlet and outlet area, system and fan duty, fan speed, and fan air density. The performance curve shall show fan total pressure, fan static pressure, and fan horsepower versus flow rate from free delivery to shutoff. The operating point of rating as well as the permissible operating range over which stable operation will occur shall be clearly identified. Unstable portions of the performance curve shall be clearly labeled.

BA-4420 EQUIPMENT SOUND PRODUCTION

BA-4421 Sound Level Data Report

When required, a sound level data report shall be prepared. The sound level data in the report shall be expressed as sound power level in dB (referenced to 10^{-12} W) for eight octave bands. The report shall state whether the data were obtained from tests of the actual fan or by calculation from test data of a similar fan.

BA-4430 STRUCTURAL VERIFICATION CONSIDERATIONS

BA-4431 Verification by Analysis

When verification of design by analysis is selected, the results of the analysis shall be in the form of a design verification report (DVR). The DVR shall comply with AA-4441. Equipment shall be deemed to be designed verified if the stress conditions and deflections identified in BA-4131 and AA-4341.2 are not exceeded under the applicable load combinations.

The DVR shall address, as a minimum, the stress and deflection of the following fan components in both the normal and accident conditions:

(a) housings, including flanges and mounting supports
(b) wheel blades
(c) wheel hub
(d) shaft
(e) bearing supports
(f) driver supports
(g) weld filler material
(h) driver

Maximum shaft deflection shall not exceed 90% of the radial clearance between blade and housing. No deflection shall be allowed to exceed the limits of AA-4341.2.

BA-4432 Verification by Testing

When verification by testing is selected, a design verification test procedure (DVTP) shall be established. The test procedure, as a minimum, shall identify the specific components to be tested and the respective test methods and acceptance values. Upon completion of the tests, a DVR shall be prepared. The DVR shall comply with AA-4442. Equipment shall be deemed to have successfully passed the tests if the equipment meets the acceptance requirements identified in AA-4442 when subjected to the selected load combinations.

BA-4433 Special Considerations

(a) The maximum deflection that may be sustained without loss of equipment function during normal or accident conditions shall be determined by analysis or test. The allowable deflections in any plane for the load combinations of BA-4131 shall not exceed the limits expressed by and measured according to BA-4162 and BA-4163.

(b) Fan supports shall be designed to withstand the loads described in BA-4131. Foundation and supports shall be designed so that the natural frequency of vibration of the overall supporting structure is at least 25% lower or 25% higher than the rotational frequency of the fan or driver.

ARTICLE BA-5000
INSPECTION AND TESTING

Inspection and testing of fans shall be in accordance with the requirements of Section BA and of AA-5100, AA-5200, AA-5400, and AA-6430.

BA-5100 FAN INSPECTION AND TESTING

BA-5110 GENERAL TESTING REQUIREMENTS

(09) **BA-5111 Fans Requiring Tests**

Performance ratings may be based on test results of a fan that is identical as to type and size, or of a smaller, geometrically similar fan, that has been tested in accordance with AMCA 210. Performance ratings established for a fan may be applied to several identical fans of the same type and size, with the same nominal dimensions, irrespective of fan orientation.

BA-5112 Test Facilities

Equipment shall be tested in a facility that provides for testing in accordance with the requirements of this Code.

BA-5112.1 Facilities. The facility shall have the space, power, and instrumentation to conduct full-scale performance or mechanical operating tests without compromising the data or intent of the test.

BA-5112.2 Instrument Calibration. An updated listing of all test instrumentation and equipment shall be maintained along with a description of methods used to calibrate each instrument, the calibration interval, and the date of the last calibration. Calibration intervals shall be a maximum of 1 year or the Manufacturer's minimum requirement, whichever is less. Calibration of instruments shall be traceable to the National Bureau of Standards.

BA-5112.3 Qualification Records. Records shall be maintained in the test facility to verify that all test facility qualification requirements are met.

BA-5113 Documentation

Documentation shall be required for all performance testing, including a report that details witness test procedures and test setups.

BA-5120 PERFORMANCE ACCEPTANCE TESTS

Performance tests to determine a fan's flow rate, pressure, and power consumption shall be conducted.

BA-5121 Test Codes

All performance tests shall be conducted in accordance with AMCA 210. These tests shall include the effects of the drive, fan, and accessories.

BA-5122 Test Setups

Prior to testing, a test procedure containing details of all test setups and test methods shall be established based on AMCA 210.

BA-5123 Measurements

Test measurements shall be in accordance with AMCA 210 and shall yield results within the limits set by AMCA 210, Appendix D. A fan performance test shall consist of the following measurements.

BA-5123.1 Flow Rate. The fan flow rate shall be determined in accordance with AMCA 210 by either pitot tube traverse or AMCA nozzle method.

BA-5123.2 Pressure. Pressure shall be measured by AMCA 210 pitot tube or by piezometer rings.

BA-5123.3 Power. Measurements shall be made to determine shaft input power to the fan in accordance with AMCA 210. For the purposes of this Code, a driver with complete test results in accordance with IEEE 112A meets the requirements of a calibrated driver.

BA-5123.4 Fan Speed. The fan speed shall be measured in accordance with AMCA 210.

BA-5123.5 Other. Measurements such as temperature and barometric pressure associated with intermediate calculations shall be made in accordance with AMCA 210.

BA-5130 SOUND TESTS

Sound test data shall be obtained in accordance with either of the following methods.

BA-5131 Semireverberant Room Method

Sound power level ratings shall be taken in accordance with AMCA 300.

BA-5132 Induct Method

Sound power level ratings shall be taken in accordance with ASHRAE 68.

BA-5140 MECHANICAL TESTS

Mechanical tests shall be conducted to verify the basic integrity and function of mechanical parts. These tests include the following.

(09) BA-5141 Overspeed Tests

The impeller of each centrifugal fan shall be overspeed tested to a minimum of 15% above its operating speed for a 3 min to 10 min duration. The impeller of each axial fan shall be overspeed tested to a minimum of 25% above operating speed for a 1 min to 3 min duration. This test is done with wheel mounted on a mandrel, not on fan bearings.

(09) BA-5142 Leakage Tests

BA-5142.1 Housing. Housing leakage tests required by BA-4141 shall be conducted on the fan housing, pressurized to a level at least 1.25 times the fan operating pressure, using a soap solution at all welds and joints. The acceptance criteria shall call for the absence of any visible bubble formation.

BA-5142.2 Shaft. Shaft leakage tests required by BA-4141 shall be conducted on the fan with the shaft and seal assembled, the shaft rotating at the normal fan operating speed, the fan openings sealed closed, and the fan subjected to the normal fan operating pressure. The fan wheel shall be removed prior to the shaft leakage test, or provision shall be made to account for the increase in air temperature if the fan wheel is left in place.

BA-5143 Fan Vibration Test

Fans shall be given a vibration test as required by BA-4160. Prior to taking the vibration measurements, the fans shall be operated at the normal operating speed for a run in period of time until the bearings reach a stable equilibrium temperature, at which point the temperature no longer rises. Vibration readings taken on the bearing caps on centrifugal fans, and on the fan housing on axial fans, shall be no greater than those given in BA-4162 and BA-4163, respectively.

BA-5144 Mechanical Running Test

All fans shall be given a mechanical running test for at least 1 hr, after which all parts and accessories shall be inspected to determine any sign of excessive wear or mechanical defect.

BA-5145 Seismic Test

Seismic testing, when required, shall be performed in accordance with AA-4350.

BA-5150 TEST RESULTS AND REPORTS

All test results shall be certified and documented.

BA-5200 DRIVER INSPECTION AND TESTING

BA-5210 FIRST UNIT OF A DESIGN (09)

First units of a design shall be given a complete test per IEEE 112A. For a totally enclosed, air over (TEAO) driver, the full-load heat run shall be taken. For axial fans, TEAO motors are mounted inside of the fan housing and therefore the motor heat run must be run as part of the fan test, if required by the Design Specification. Test data shall be documented.

BA-5220 SUCCEEDING UNITS OF A DESIGN

Each subsequent driver shall be given a routine test per IEEE 112A. Test data shall be documented.

(09)

ARTICLE BA-6000
FABRICATION AND INSTALLATION OF CENTRIFUGAL AND AXIAL FANS

Fabrication and installation shall be in accordance with the requirements of Section BA and of Article AA-6000.

BA-6100 FABRICATION

Written fabrication procedures shall be established and used during the fan manufacture. All heat treating requirements shall be indicated on drawings or in the fabrication procedures.

BA-6110 SELECTION OF MATERIALS

Materials shall conform to the requirements of Article BA-3000.

The material designations shall be provided on the fabrication drawings.

BA-6200 INSTALLATION

Installation shall be in accordance with the requirements of AA-6600.

ARTICLE BA-7000 (09)
PACKAGING, SHIPPING, RECEIVING, STORAGE, AND HANDLING

BA-7100 GENERAL

Packaging, shipping, receiving, storage, and handling of fans shall be in accordance with the requirements of Section BA and of Article AA-7000 unless otherwise required by the Design Specification.

BA-7200 PACKAGING

Fans shall be prepared for shipment in accordance with ASME NQA-1, Protection Level C, when shipped direct without the driver, or when shipped with the driver installed to a supplier who will assemble the fan with another piece of equipment. When the fan is to be shipped to the jobsite with the driver installed, preparation shall be in accordance with Protection Level B.

BA-7300 SHIPPING

This paragraph relates to transportation methods from the manufacturer or supplier, to the job site. Shipping shall comply with the provisions of AA-7100, AA-7200, and AA-7300.

BA-7400 RECEIVING

Receiving at the job site or intermediate location, where additional work is to be performed or for long term storage, shall be accomplished in accordance with the provisions of Article AA-7000. It shall be the requirement, at any receiving point, to have adequate descriptions of items to permit suitable inspection for conformance, damage acknowledgement, and proper documentation.

BA-7500 STORAGE

Fans shall be stored in accordance with ASME NQA-1. When the fans are packaged to Protection Level C, they shall be stored in accordance with Storage Level 3. When packaging is Protection Level B, the fans, drivers, and accessories shall be stored in accordance with Storage Level 2.

One copy of the storage procedure shall be attached to the equipment or crate at time of shipment. The storage procedure shall cover both short term and long term (over 6 months) storage maintenance programs.

BA-7600 DRIVERS SHIPPED SEPARATELY

BA-7610 SHORT-TERM

Any driver that is to be used within 6 months of shipment shall be packaged according to good commercial practice, shipped within an enclosed carrier, and stored in a weather-tight ventilated and heated building, equivalent to ASME NQA-1, Storage Level 2.

BA-7620 LONG-TERM (OVER 6 MONTHS)

Any driver that is to be stored for a period of 6 months or longer must be packaged per ASME NQA-1, Protection Level B. If the driver is equipped with space heaters, the space heaters may be energized in storage, in lieu of providing moisture barrier wrapping and internal desiccant.

(09)

ARTICLE BA-8000
QUALITY ASSURANCE

BA-8100 GENERAL

Fans, fan drivers, drives, and related fan accessories covered under this section shall be manufactured, fabricated, installed, inspected, and tested in accordance with the provisions of a quality assurance program meeting the requirements of Article AA-8000.

BA-8200 REQUIRED DOCUMENTATION FOR FANS

BA-8210 CERTIFIED FAN PERFORMANCE CURVES

Documentation shall be established to verify that the certified fan performance curves were generated in accordance with AMCA 210.

BA-8220 MATERIAL CERTIFICATION

Material test reports are required in accordance with BA-3400.

Permanent documentation shall be established and shall include as a minimum: procurement records, receiving records, manufacturing records, inspection reports, material control records, and Certified Material Test Reports for which certification is required. Permanent documentation shall be maintained for the life of the plant.

BA-8300 DRAWINGS AND DOCUMENTATION

The Design Specification shall list the documentation requirements for the fans and list when this documentation is to be provided by the Manufacturer and supplied to the Owner or designee.

(a) Material Certifications and Test Reports

(b) Fan drawings including: Outline Drawings, Wiring diagrams, Material lists.

(c) Welding Procedures, applicable welding code, listed in AA-6300.

(d) Reports for tests and inspections required by BA-5000

(e) Seismic and Environmental Qualification Reports

(f) Operating, Installation and Maintenance Manuals

(g) Performance Curve

(h) Data Sheet

(i) Sound Report (if required)

ARTICLE BA-9000 (09)
NAMEPLATES AND OPERATING AND MAINTENANCE MANUALS

BA-9100 GENERAL

All items manufactured under the requirements of this section shall be identified to ensure compliance with the requirements of AA-8200 and Article AA-9000.

Records, as necessary to ensure compliance with AA-8200, shall be maintained by the responsible organization in accordance with the approved Quality Assurance program.

BA-9200 FANS

BA-9210 REQUIRED NAMEPLATE DATA

Each fan assembly shall be provided with a legibly marked nameplate giving the identifying name, normal fan capacity, manufacturer, fan type, size, rotation, rating, maximum speed, and mark numbers, as applicable to Section BA and Article AA-9000.

BA-9220 DRIVERS

Each driver shall have one or more engraved or embossed nameplates of stainless steel, which as a minimum shall convey the data required by NEMA MG-1.

BA-9300 ACCESSORIES

BA-9310 ACCEPTABLE MARKING METHODS

Each accessory shall be marked with the name of the Manufacturer or a distinctive marking, which may be in code, by which it is identified as the product of a particular manufacturer.

BA-9400 OPERATING AND MAINTENANCE MANUALS

The Manufacturer shall provide an operating and maintenance manual for the equipment furnished. The manual shall include

(a) recommended spare parts list, including a description of each part and a drawing that identifies the location of each part

(b) recommended maintenance procedure, including a periodic servicing schedule

(09)

NONMANDATORY APPENDIX BA-A
FAN SYSTEM CONSIDERATIONS

ARTICLE BA-A-1000
FAN SYSTEM CONSIDERATIONS

BA-A-1100 SYSTEM CHARACTERISTICS

System resistance is an expression that establishes the aerodynamic and friction losses of an air handling system in relation to the flow rate through that system. A system characteristic can be described as having a fixed system resistance or a variable system resistance. A fixed system resistance is one in which the system resistance usually varies as the square of the change in flow rate and all operating points always fall along the same system resistance line. A variable system resistance is one in which at least one active component of the system is capable of varying the ratio of flow to resistance pressure, such as a damper. The entire range of system operation should be determined before a fan selection is made in order to ensure that the fan selected will operate on the stable portion of the fan performance curve.

BA-A-1200 SYSTEM EFFECTS ON FAN PERFORMANCE

Actual system configurations often provide inlet and outlet conditions that cause uneven velocity profiles and swirls. This can seriously alter the fan's predicted performance. The amount a fan's performance is likely to be affected is called a *system effect factor* and should be added to the system resistance. System effect factors for fan systems may be estimated using AMCA 201.

BA-A-1300 FAN AND SYSTEM MATCHING

If the system resistance curve, composed of the resistance to flow of the system and the appropriate system effect factor, has been accurately determined, the fan selected will develop the equivalent and necessary pressure to meet the system requirements, and should deliver the designed CFM when installed in the system. The point of intersection of the system resistance curve and the fan performance curve determine the actual flow rate.

BA-A-1400 FAN-SYSTEM CAPACITY CONTROL

A fan and system operate at the intersection of the system resistance curve and the fan performance curve. This principle always holds true. Therefore, once a fan is installed, the only way to change the operating point is either to change the system resistance curve or the fan performance curve.

The principal method of changing the system curve is through use of a control damper. Since a control damper simply adds or removes the amount of restriction to the airflow within the system, the fan continues to operate at some point on its original performance curve. The use of an outlet or inlet damper to control an axial fan should not be permitted unless loading conditions are completely evaluated, as excessive dampering may cause

(a) the fan blades to stall, which may cause system instability and possible fan failure

(b) the driver cooling capability to be reduced, which may cause an overloading condition

(c) the fan power characteristic to increase at reduced flow rates, which may cause an overloading condition

The acceptable methods to change the fan performance curve of a fan used on nuclear safety-related systems are variable inlet vanes on a centrifugal fan and blade angle change on an axial fan.

BA-A-1500 MULTIPLE FAN SYSTEMS

When fans of equal rating operate in series, each handles the same flow rate and approximately one-half of the total system pressure. When fans of equal rating operate in parallel, each fan handles one-half the total flow rate at the same pressure. Fans and drivers should be sized so that if one fan should fail, the remaining fan remains stable and does not overload its driver.

NONMANDATORY APPENDIX BA-B DIVISION OF RESPONSIBILITY

This Nonmandatory Appendix is intended to identify the roles normally assumed by the organizations responsible for fulfilling Code requirements when not specifically addressed in an article or subarticle. These are guidelines to assist with Code compliance and are not to be construed as legal or contractual responsibilities unless so invoked by the Owner or designee.

(09) **TABLE BA-B-1000 DIVISION OF RESPONSIBILITY**

BA-	Item	Responsible Party
3200	Limitations on materials	Engineer
3400	Certificate of conformance	Manufacturer
4110	Performance	
	(a) fan type and blade shape	Engineer
	(b) airflow	Engineer
	(c) total pressure	Engineer
	(d) maximum discharge velocity	Engineer
	(e) air density at rating	Engineer
	(f) maximum air density expected	Engineer
	(g) operating temperature	Engineer
	(h) details of intake and discharge transitions	Engineer/Manufacturer
	(i) parallel fan operation	Engineer
	(j) peak design temperature	Engineer
4121	Post accepted design time	Engineer
4132	Internally generated missile analysis	Manufacturer
4133	Loading conditions	Engineer
4141	Leakage criteria, ducting	Engineer
4150	Centrifugal fan support boundary	
	(a) size and type of anchorage	Engineer/Manufacturer
	(b) anchorage loads	Manufacturer
4210	Fans	
4211.1	Title and numbering	Engineer
4211.2	Duty cycle	Engineer
4211.3	Fan configuration	Engineer
4211.4	Environment	Engineer
4211.5	Limitations	Engineer

TABLE BA-B-1000
DIVISION OF RESPONSIBILITY (CONT'D) **(09)**

BA-	Item	Responsible Party
4212	(a) Flow rate	Engineer
	(b) Fan pressure	Engineer
	(c) Air density	Engineer
	(d) Air temperature	Engineer
	(e) Fan speed	Manufacturer
	(f) Fan power input	Manufacturer
4220	Drivers	
4221	(a) Speed torque curve	Manufacturer
	(b) Inertia	Manufacturer
	(c) External forces	Manufacturer
	(d) Power source	Engineer/Manufacturer
	(e) Environmental	Engineer
	(f) Driver and fan orientation	Engineer/Manufacturer
	(g) Standards	Engineer
	(h) Heater requirements	Engineer
4341(d)	Inspection panel requirements predetermined life	Engineer
4411	Rating calculations	Manufacturer
4412	Documentation of rating	Manufacturer
4421	Sound level data report	Manufacturer/Engineer
4431	Design verification stress report	Manufacturer
4432	Design verification test procedure	Manufacturer
	Design verification test report	Manufacturer
5112.3	Periodic inspections of test facility for qualification	Engineer
5113, 5150, 5200	Final test report	Manufacturer
5122	Test procedure details	Manufacturer
6100	Fabrication procedures	Manufacturer
6100	Witness and hold points	Engineer
7000	Packaging, shipping, and storage procedures	Manufacturer
8000	Documentation for Code verification	Manufacturer/Engineer
8220	Material certification report contents	Manufacturer
9400	Operating and maintenance manuals	Manufacturer

SECTION DA
DAMPERS AND LOUVERS

Table

Mandatory Appendices

Nonmandatory Appendix

(09)

ARTICLE DA-1000
SCOPE

This section encompasses the requirements for the design, fabrication, materials, performance, acceptance testing, and quality assurance, as well as component nomenclature, for dampers and louvers used as components in nuclear safety-related air or gas treatment systems in nuclear facilities. Also included in this section are design specification requirements for actuators and other control-related accessories used in conjunction with nuclear safety-related dampers and louvers.

DA-1100 PURPOSE

The purpose of this section is to identify and establish the requirements for the design, manufacture, shop test, and installation of dampers and louvers for use in air and gas treatment systems that are associated with nuclear facilities.

This section further identifies and establishes requirements for the installation of actuators and accessories, and for the performance of a damper and louver assembly.

DA-1200 LIMIT

DA-1210 EXCLUSION OF ITEMS

Valves whose design, manufacture, test, and installation are covered by the ASME Code, Section III, or ASME B31.1, are excluded from this section even though they may be used to perform the function of a damper.

DA-1220 EXCLUSION OF SPECIFIC DESIGNS

While certain minimum functional requirements of damper actuators and accessories are included in this section, it is not intended to include specific dimensional or material design requirements for these items.

DA-1230 BOUNDARY LIMITS

The requirements of this Code are limited to those parts that comprise a damper or louver assembly as defined in DA-1310. While general requirements are included for mating flanges and similar supports, the boundary limits are the damper or louver assembly, flange, or frame.

DA-1300 DEFINITIONS AND TERMS

DA-1310 COMPONENTS

accessories: solenoid valves, position switches, indicating lights, pressure regulators, and other similar components specified as part of the damper or louver assembly.

damper: an operable device used for the purpose of controlling pressure, flow volume, or flow direction in air or gas systems.

damper assembly: an assembly consisting of a damper, integrally mounted actuator, and any accessories required for its operation. The term also refers to a combination of two or more damper assemblies with interconnecting linkage to permit operation as a single unit.

damper and louver actuators (operators)

(a) *heat or temperature operated actuator:* a device utilizing heat or temperature to release the damper blades.

(b) *manual actuators:* devices which permit the blades of a damper to be positioned by the direct or indirect application of manual force, including such devices as levers, chain falls, gearboxes, and screw jacks.

(c) *power-operated actuators:* devices utilizing an external energy source to position the damper or louver blades in response to a controlled signal.

(d) *self-contained actuators:* devices and/or forces such as counterweights, springs, gravity, or airstream pressure used to actuate the blade(s).

louver: a fixed or adjustable device comprised of multiple blades which, when mounted in an opening, permits the flow of air but inhibits the entrance of other elements, such as rain or snow.

DA-1320 FUNCTION

backdraft prevention: preventing reversal of flow.

balancing: fixing the position of one or more dampers to establish a flow or pressure relationship in a system.

fire control: interrupting airflow automatically in the event of a fire so as to restrict the passage of flame through a part of an air system in order to maintain the integrity of fire rated separation.

flow control: varying or maintaining volumetric flow within a system in response to a signal.

isolation: separating a system or a portion of a system from selected flow paths.

pressure control: varying or maintaining a pressure within a system or space in response to a signal, or varying or maintaining a differential pressure between parts of a system or between spaces in response to a signal.

pressure relief: limiting differential pressures across a duct, casing, or building wall to a predetermined value.

tornado control: controlling airflow automatically to prevent the transmission of tornado pressure surges.

(09) DA-1330 CONFIGURATION

See Appendix DA-II for illustration of the following terms.

adjustable louver: a louver in which the blades may be repositioned.

curtain-type damper: a damper with interlocking blades that fold together, and open and unfold to form a continuous restrictive barrier such as in a curtain type fire damper.

fixed louver: a louver in which the blades do not move.

opposed blade damper: a multiblade damper having blades that rotate in opposite directions.

parallel blade damper: a multiblade damper having blades that rotate in the same direction.

poppet damper: a single-blade damper with linear blade movement always perpendicular to the seat.

single-blade damper: a damper having one centrally pivoted, balanced blade or one edge-pivoted unbalanced blade.

slide gate guillotine damper: a damper with blades which move perpendicular to the airstream and are supported by parallel guides.

wing blade damper: a damper with one or more pairs of edge-pivoted blades rotating in opposite directions about a common central support member.

DA-1340 LEAKAGE AND BLADE OPERATING POSITIONING

failsafe position: the position assumed by the blades upon loss of the controlling signal.

frame leakage: the amount of air or gas that will pass through the frame (external pressure boundaries) of a damper at a specific differential pressure across the pressure boundary with the damper either open or closed.

normal operating position: the normal operating position of the louver or damper blades in response to a control signal.

seat leakage: the amount of air or gas that will pass between or around the blades when in a closed position at a specific differential pressure across the blades.

DA-1350 PRESSURE

blade design pressure: the maximum positive or negative differential pressure that may occur across the blades, which is the sum total of the operating pressure and all other possible additional pressure differentials.

frame design pressure: the maximum positive or negative differential pressure that may occur between the inside and outside of the damper frame, which is the sum total of the operating pressure and all other possible additional pressure differentials.

operating pressure: the maximum positive or negative differential pressure that may occur during normal operation. Included are pressures of normal design airflows and impact pressures from rapid changes of other devices in a system.

pressure drop: the system static pressure loss in fluid pressure caused by the flow of air or gas through a full or partially open component.

DA-1360 TEMPERATURE

ambient design temperatures: the highest and lowest temperature surrounding the exterior of the damper or louver.

internal design temperatures: the highest and lowest temperature of the air or gas passing through the damper or louver.

DA-1370 TESTS

performance test(s): a test(s) made on an individual or lot of components to verify performance in accordance with specified requirements.

qualification test(s): a test(s) that establishes the suitability of a component for a given application, generally made on either a prototype or on a sample from a typical production lot of the component.

(09) DA-1380 CONSTRUCTION

fire damper construction: construction suitable to pass the criteria of Underwriters Laboratories Standard UL-555 for Fire Dampers for Dynamic Systems and labeled under the UL Follow-Up Service Requirements for Fire Resistance Construction for 1½ hr or 3 hr.

NOTE: Such construction will satisfy the requirements of DA-3211, DA-4220, and the temperature limits of DA-3120.

gastight construction: fabrication of a component and component housing to prohibit passage of air or gas through the external pressure boundaries.

DA-1390 TORQUE

breakaway torque: the torque required to move the blades from the closed and sealed position with the operating design pressure being applied across the closed blades.

dynamic torque: the torque required to move the damper or louver blades in either direction while being acted upon by the forces, at all blade positions from full open to near closed, created by the airflow and the pressure drop.

friction torque: the torque required to overcome friction of such items as bearings, stuffing boxes, linkage, etc.

seating torque: the torque required to properly seat the seals and limit the leakage to the specified amount.

ARTICLE DA-2000 REFERENCED DOCUMENTS (09)

The codes and standards referenced below shall supplement those documents listed in Section AA. Unless otherwise specified, the date of the document in effect at the time this Code section is implemented shall apply.

AMCA 500D-98, Laboratory Methods for Testing Dampers for Ratings

AMCA 500L-99, Laboratory Methods for Testing Louvers for Ratings

Publisher: Air Movement and Control Association International, Inc. (AMCA), 30 West University Drive, Arlington Heights, IL 60004-1893

NFPA-90A-2002, Standard for the Installation of Air Conditioning and Ventilation Systems

Publisher: National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101

UL 555-1999, Standard for Safety, Fire Dampers, and Ceiling Dampers

UL 555C-1996, Standard for Safety, Ceiling Dampers

Publisher: Underwriters Laboratories, Inc. (UL), 333 Pfingsten Road, Northbrook, IL 60062-2096

ARTICLE DA-3000
MATERIALS

DA-3100 ALLOWABLE MATERIALS

DA-3110 MATERIALS OF CONSTRUCTION

Materials used in the construction of frames, blades, shafts, and linkages shall conform to requirements of specifications for materials given in Table DA-3110.

DA-3120 ALLOWABLE STRESS

Allowable stress values for the design of frames, blades, shafts, and linkages are specified in Article AA-4000.

At temperatures above 650°F (343°C) for ferrous material or 200°F (93°C) for nonferrous material, the special limitations cited in DA-3211 shall apply.

DA-3130 BEARING MATERIALS

Bearing materials shall conform to the requirements of DA-4250.

DA-3140 SEAL MATERIALS

Seal materials shall conform to the requirements of DA-4260.

DA-3200 SPECIAL LIMITATIONS ON MATERIALS

DA-3210 METALS

DA-3211 Physical Properties Reduction

The reduction in the physical properties of metals at higher temperatures must be recognized and factored into the design of dampers used in high temperature application, particularly where fire hazard is involved.

DA-3212 Galvanic Corrosion

The possibility of galvanic corrosion due to the relative potentials of aluminum, copper, and their alloys should be considered when used in conjunction with each other, or with steel or other metals and their alloys.

DA-3213 Corrosive Vapors

Aluminum and zinc shall not be used in the presence of corrosive vapors unless protected by coatings or other suitable means designed to prevent deterioration of the metal.

DA-3220 NONMETALLIC MATERIALS

The use of nonmetallic materials such as plastics, elastomers, and similar substances is permitted in the construction of components provided that in the selection of these materials, consideration is given to

(a) destruction where fire hazards exist, including toxicity

(b) degradation of properties caused by temperature increase, radiation exposure, chemical exposure, and aging

(c) maintainability

DA-3230 DETERIORATION OF MATERIALS IN SERVICE

It is the responsibility of the Owner or his designee to identify the environment in which the components must operate so that the Manufacturer can select the grade of materials to meet the conditions stated in the design specification.

DA-3300 CERTIFICATION OF MATERIALS

The Manufacturer shall make available, as a minimum, certified test reports of chemical and physical properties of material and hardware for stress components such as related accessories including frames,

TABLE DA-3110 ALLOWABLE MATERIALS (09)

ASME Designator	Publication Title
	ASME Ferrous Material Specifications
Pipe	
SA-106	Seamless Carbon Steel Pipe for High-Temperature Service
SA-134	Electric-Fusion (Arc)-Welded Steel Plate Pipe
SA-135	Electric-Resistance-Welded Steel Pipe
SA-155	Electric-Fusion-Welded Steel Pipe for High-Pressure Service
SA-312	Seamless and Welded Austenitic Stainless Steel Pipe
SA-335	Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service
SA-530	General Requirements for Specialized Carbon and Alloy-Steel Pipe
Tubing	
SA-213	Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat Exchanger Tubes
Plates	
SA-240	Chromium and Chromium–Nickel Stainless Steel Plate, Sheet, and Strip for Fusion-Welded Unfired Pressure Vessels
SA-285	Plates for Pressure Vessels
SA-515	Carbon Steel Plates for Pressure Vessels for Intermediate and High-Temperature Service
SA-516	Carbon Steel Plates for Pressure Vessels for Moderate and Low-Temperature Service
Forgings	
SA-105	Forged or Rolled Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
SA-181	Forged or Rolled Steel Pipe Flanges, Forged Fittings, and Valves and Parts for General Service
SA-182	Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
Bolts, Nuts, and Studs	
SA-193	Alloy-Steel Bolting Materials for High-Temperature Service
SA-194	Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service
SA-307	Low-Carbon Steel Externally and Internally Threaded Standard Fasteners
SA-354	Quenched and Tempered Alloy-Steel Bolts and Studs with Suitable Nuts
Castings	
SA-216	Carbon Steel Castings Suitable for Fusion Welding for High-Temperature Service
SA-217	Alloy-Steel Castings for Pressure Containing Parts Suitable for High-Temperature Service
SA-351	Ferritic and Austenitic Steel Castings for High-Temperature Service
Structural Components	
SA-36	Structural Steel
SA-283	Low- and Intermediate-Tensile Strength Carbon Steel Plates of Structural Quality
	ASME Nonferrous Material Specifications
SB-209	Aluminum Alloy Sheet and Plate

(09)

TABLE DA-3110
ALLOWABLE MATERIALS (CONT'D)

ASME Designator	Publication Title
	ASME Nonferrous Material Specifications (Cont'd)
SB-211	Aluminum Alloy Bars, Rods, and Wire
SB-221	Aluminum Alloy Extruded Bars, Rods, and Shapes
	ASTM Ferrous Material Specifications
Structural Components	
A-36	Structural Steel
A-108	Steel Bars, Carbon, Cold-Finished, Standard Quality
A-242	High-Strength, Low-Alloy Structural Steel
A-276	Stainless and Heat-Resisting Steel Bars and Shapes
A-284	Low- and Intermediate-Tensile Strength Carbon Steel Plates for Machining and General Construction
A-575	Steel Bars, Carbon, Merchant Quality "M" Grades
A-576	Steel Bars, Carbon, Hot-Wrought, Special Quality
Plate, Sheet, and Strip	
A-123	Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed, and Forged Steel Shapes, Plates, Bars, and Strip
A-240	Heat-Resisting Chromium and Chromium–Nickel Stainless Steel Plate, Sheet, and Strip for Fusion Welded Unfired Pressure Vessels
A-366	Cold-Rolled Carbon Steel Sheet, Commercial Quality
A-446	Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Structural (Physical) Quality
A-480	General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
A-484	General Requirements for Stainless and Heat-Resisting Wrought Steel Products (Except Wire)
A-525	General Requirements for Steel Sheet, Zinc-Coated by Hot-Dip Process
A-526	Steel Sheet, Zinc-Coated by Hot-Dip Process, Commercial Quality
A-527	Steel Sheet, Zinc-Coated by Hot-Dip Process, Lock-Form Quality
A-570	Hot-Rolled Carbon Steel Sheet and Strip, Structural Quality
A-582	Free-Machining Stainless and Heat-Resisting Steel Bars, Hot-Rolled or Cold-Finished
A-606	Steel Sheet and Strip, Hot- and Cold-Rolled, High-Strength, Low-Alloy with Improved Corrosion Resistance
A-607	Steel Sheet and Strip, Hot- and Cold-Rolled, High-Strength, Low-Alloy Columbium and/or Vanadium
A-611	Steel, Cold-Rolled Sheet, Carbon, Structural
A-653-02a	Standard Specification for Steel Sheet, Zinc Coated (Galvanized) or Zinc-Iron Alloy Coated (Galvannealed) by the Hot-Dip Process
A-924-99	Standard Specification for Steel Sheet, Metallic-Coated by Hot-Dip Process
	ASTM Nonferrous Material Specifications
Tubing	
B-68	Seamless Annealed Soft Copper Tubing
B-75	Seamless Copper
B-88	Seamless Copper Tube

GENERAL NOTE: Unless otherwise spcified, the date of the document in effect at the time this Code section is implemented shall apply.

blades, shafts, and linkages. For those ASTM materials which do not have physical testing required by the ASTM specification, testing should be performed per ASTM A 370.

All other components used in the construction of the damper shall be provided with a manufacturer's certificate of compliance covering the ASME or ASTM material specification, grade, and class, if applicable.

ARTICLE DA-4000
DESIGN

DA-4100 GENERAL DESIGN

Design of dampers and louvers shall be in accordance with the requirements of Section DA and of those portions of Section AA invoked in Section DA.

DA-4110 REQUIREMENTS OF DESIGN SPECIFICATIONS

Design specifications prepared by the Owner or his designee in sufficient detail to provide a complete basis for design and manufacture in accordance with this Code shall include, as applicable

(a) reference to this Code
(b) function, as defined in DA-1320
(c) configuration, as defined in DA-1330
(d) maximum allowable seat and frame leakage and the specific differential pressures, as defined in DA-1340 and Mandatory Appendix DA-I
(e) pressures, as defined in DA-1350
(f) temperatures, as defined in DA-1360
(g) volumetric flow rate at defined temperature, pressure, and density
(h) maximum relative humidity of the air or gas stream
(i) maximum design pressure drop at design volumetric flow rate
(j) composition, concentration, and nature of the entrained contaminants in the air or gas stream
(k) normal operating position and failsafe position of blades
(l) installation parameters
(m) mounting configuration and support, i.e., flange mounted, inside-of-duct mounted, wall or cantilevered mounting
(n) orientation of damper and direction of airflow
(o) blade orientation relative to frame
(p) maximum closure and opening time
(q) actuator data, as required by DA-4300
(r) anticipated number of operating cycles (e.g., specify number for two-position or state "continuous operation" for modulating service)
(s) allowable materials per Article DA-3000
(t) special requirements for blades, frames, linkages, seals, and bearings
(u) accessories required and mounting location
(v) any and all anticipated internal and external loadings other than pressures
(w) combination of loading conditions, seismic requirements, and the design transients applicable to the appropriate service level per Article AA-4000
(x) radiation integrated life dose and maximum dose rate (rad / unit time)
(y) finish and coating requirements
(z) fire resistance rating as $1\frac{1}{2}$ hr or 3 hr

DA-4120 REQUIREMENTS OF THE MANUFACTURER

When required by the design specifications, documentation provided by the Manufacturer to the Owner or his designee shall include the following, as applicable:

(a) mounting connection details
(b) weight and center of gravity
(c) service connections, size, type, and locations
(d) pressure drop at rated flow
(e) maximum seat and frame leakage at design pressures
(f) maximum closure and opening time at stated conditions
(g) materials of construction
(h) bearing design life
(i) seal design life
(j) actuator torque supplied
(k) damper or louver torque required
(l) actuator environmental and seismic qualifications
(m) verification of structural integrity, performance, and qualification in accordance with Article AA-4000
(n) actuator position or orientation
(o) UL fire resistance rating and UL installation instructions
(p) Manufacturer's Recommended Replacement Parts List **(09)**

DA-4130 PERFORMANCE REQUIREMENTS

DA-4131 Seat Leakage

Seat leakage shall be equal to or less than the amount shown in Mandatory Appendix DA-I for the class specified in the design specification.

DA-4132 Frame Leakage

Frame leakage shall be equal to or less than the amount shown in Mandatory Appendix DA-I for the class specified in the design specification.

DA-4133 Pressure Drop

Pressure drop shall be less than or equal to that stated in the design specification at the design volumetric flow rate.

DA-4134 Fire Ratings

Fire dampers shall have a $1\frac{1}{2}$ hr or 3 hr rating in accordance with UL 555 as determined by NFPA 90A and NFPA 803.

DA-4135 Fire Damper Closure

The fire damper shall close against the specified volumetric flow rate and specified operating pressure.

DA-4136 Cycle Time

The damper must cycle full open to full closed or full closed to full open within the time specified in the design specification.

DA-4200 TECHNICAL REQUIREMENTS

DA-4210 STRUCTURAL

DA-4211 General

Dampers or louvers shall be designed in accordance with the structural requirements given in Article AA-4000. Structural requirements and load definitions are given in DA-4212 through DA-4214.

DA-4212 Support Boundary

DA-4212.1 Methods of Support. A damper or louver assembly may be supported by one or more of several methods. It may be line supported as an assembly inserted into a run of duct; it may have its support at its end attachments to the duct and be totally supported by that line of duct; or it may be flange mounted to a bulkhead type of building structure or auxiliary structure.

(a) Line Supported Assembly. The support boundary for this case shall be the interface flanges or other mechanical connections designed to transfer all components of load across the joints.

(b) Bulkhead or End Supported Assembly. The support boundary for this case shall also be the interface flanges or other mechanical connections or structural connections designed to transfer all components of load.

(c) Side, Top, or Bottom Supported Assembly. The support boundary for this case shall be the attachment point for the assembly. Although support to the building superstructure, auxiliary steel, equipment foundation, or other structure represents ground for the damper, that support is not included in the scope of this section.

DA-4212.2 Documentation. The damper or louver Manufacturer shall be responsible for providing all information necessary to define the support boundary interfaces. The interface control information to be specified shall include but not necessarily be limited to the following:

(a) identification of any special support requirements as well as the configuration and size of the damper flanges.

(b) magnitudes and directions of all loads imposed on the anchorage points, including all static, dynamic, and operational loads resulting from the installed assembly. Load data shall be provided in a form that shall allow combinations to be considered as required in Article AA-4000.

(c) other information, such as bending moments, shear forces, axial loads, torsional moments, or stiffness requirements necessary to ensure that the damper or louver can perform its required safety function under all design conditions.

DA-4213 Loads

Loads to be considered are as given in AA-4211 and AA-4212 with the following clarifications.

DA-4213.1 Normal Loads. Normal loads N shall include the following:

actuator load: the load or loads imposed by the actuator to a specific area of the assembly.

deadweight load: the load imposed by the weight of all components of the assembly.

externally concentrated load: the load or loads imposed by the application of an external force to a limited area of the assembly.

normal equipment interface load: the normal externally applied load or loads from other equipment attached to the assembly.

operating pressure load: load resulting from the maximum positive or negative differential pressure that may occur during normal operation. Included are loads imposed by normal design airflows and impact pressures resulting from rapid change of other devices in a system.

DA-4213.2 Thermal Loads. Thermal loads T shall include loads resulting from constraint of forces and displacements caused by temperature variations.

DA-4213.3 Other Loads. Other specific load conditions such as shock loads due to pressure transients shall be provided in the design specification to allow loads to be combined for the service levels as required under AA-4212 and compared to the applicable service limits required under AA-4214 and AA-4230 and other criteria imposed under AA-4240 and stress limits of this section.

DA-4214 Structural Verification

The technical and documentation requirements of AA-4000 shall apply to verification of design by analysis, test, or comparison.

DA-4215 Special Considerations

(a) Frame deflection under normal and upset plant conditions (Service Levels A and B) shall not exceed $^1/_{360}$ of the span in any direction, or $^1/_8$ in. (3.175 mm), whichever is less.

(b) Blade edge or center line deflection under normal and upset plant conditions (Service Levels A and B) shall not exceed $^1/_{360}$ of the blade length (or diameter) or $^1/_8$ in. (3.175 mm), whichever is less.

(c) The blade edge and center line deflection under loads due to normal plant conditions shall not allow the leakage criteria to be exceeded.

(d) Fire damper design shall be based on loads imposed on damper blades when closing with design volumetric flow rate and pressures present.

DA-4220 THERMAL EXPANSION

To prevent binding and restraint of free movement, the design shall provide for the relative motions that occur between components due to variations of temperature and coefficients of expansion. Such provisions for differential expansion shall include, as a minimum, the following:

(a) blade end clearances
(b) bearing clearances
(c) longitudinal movement of the shafts
(d) sealing capabilities

DA-4230 TORQUE

DA-4231 Torque Determinations

In determining the torque required to actuate the blades, the Manufacturer shall consider the blade position and direction of the applied torque to produce the desired movement. At the maximum specified operating pressure this determination shall include, as a minimum, the following torque components:

(a) breakaway torque
(b) dynamic torque
(c) friction torque
(d) seating torque

DA-4232 Actuator Torque (09)

The actuator and associated linkage shall deliver to the damper or louver a minimum of $1^1/_2$ times the maximum torque as determined in DA-4231, except for self-contained actuators used to counterbalance a specific force, and shall be designed to match the required torque. Actuators shall be evaluated in both directions for the maximum torque, at the beginning of the blade movement, while stroking the blades through the full range of movement. Orientation of dampers shall be taken into consideration when selecting operators and actuators.

DA-4240 LINKAGE

DA-4241 Linkage Components

The linkage includes the arms, brackets, pivots, bars, levers, and fasteners required to perform the following functions:

(a) interconnect the blades of multibladed dampers or louvers so they act in unison

(b) interconnect the actuator and blades so as to provide the desired operation

DA-4242 Linkage Design

Linkage design shall include the following minimum requirements:

(a) Brackets, arms, and levers shall be of a length and stiffness to provide stable operation of the blades at the maximum specified operating pressure and airflow without flutter or binding at all blade positions.

(b) The linkage system shall be designed to transmit sufficient torque to each blade to set the seals of each and every blade at the maximum specified operating pressure and airflow to limit leakage to less than the specified leakage.

(c) All linkage components shall be designed to transmit a minimum of $1\frac{1}{2}$ times the torque required by DA-4231 without exceeding the allowable stress listed in Article AA-4000.

(d) If a linkage system is designed to be field adjustable, suitable locking devices such as jam nuts, etc., shall be provided.

(e) The linkage sysem shall be designed to be compatible with the actuator selected for the application.

DA-4250 BEARINGS

DA-4251 General Application

(a) Bearings shall permit axial shaft movement to provide for operating clearances and differential expansion in both vertical and horizontal installations.

(b) Bearing materials shall be selected for the loading and environmental conditions to which the bearings will be subjected.

DA-4252 Bearing Types

DA-4252.1 Metallic Sleeve Bearings. Sintered sleeve bearing material shall be lubricant-impregnated bronze or stainless steel. Solid sleeve bearing material shall be bronze or stainless steel and shall be lubricated prior to shipment, and provisions should be made for lubrication in the field.

DA-4252.2 Nonmetallic Sleeve Bearings. Nonmetallic sleeve bearings, i.e., phenolic, nylon, and similar materials, may be used subject to the limitations of DA-3220.

DA-4252.3 Rolling Element Bearings. Premounted bearing assemblies, flanges, or pillow blocks shall be self-aligning and mounted in such a manner as to be replaceable. Grease fittings shall be provided when the lubricant must be periodically renewed. Flanges and pillow blocks are to be made of steel, malleable iron, or cast iron.

DA-4253 Bearing Design

(a) Bearing running surfaces of sleeve bearings shall have a finish as recommended by the bearing Manufacturer.

(b) Sleeve bearings shall be contained to prevent axial displacement and to prevent rotational movement except between the intended bearing surfaces.

(c) Sleeve bearings shall have a bearing load surface diameter difference as recommended by the bearing Manufacturer to provide rotational clearance.

(d) Sleeve bearing wall thickness shall be as recommended by the bearing Manufacturer.

(e) Rolling element bearings shall be sized to allow bearings to be slipped onto the shaft. The maximum clearance in shaft diameter shall be as recommended by the bearing Manufacturer, plus clearance for thermal expansion.

DA-4254 Bearing Loading

(a) Sleeve bearing loading on the radial and thrust load areas shall not exceed 67% of the bearing Manufacturer's recommended static load rating.

(b) Sleeve bearing radial load area shall, as a minimum, be equal to one-quarter of the diameter times the length supported by the bearing housing or damper/louver frame.

(c) When sleeve bearings are subjected to thrust loads, a thrust washer shall be used to transmit the load to the bearing, or the load transmitting member shall meet the requirement of DA-4252.1.

(d) Maximum radial or thrust loading on rolling element bearings shall not exceed the bearing Manufacturer's recommended static load rating.

(e) The calculated load on each bearing shall consist of all design forces applied to that bearing, including that of the actuator and linkage.

DA-4260 SEALS

DA-4261 General

Seals may be utilized to reduce seat leakage and frame leakage to the degree required by the design specification. The control of seat leakage requires seals such as metal or elastomer blade edges, stops, or seats. Control of frame leakage may require shaft seals such as stuffing boxes or cover plates.

DA-4262 Design

The seal design shall maintain the specified leakage limits during the design life of the seal.

Where the design life of the assembly exceeds the life expectancy of the seal material, the seals shall be replaceable, and the means of attaching the seal or installing the packing in a stuffing box shall be so designed to facilitate their replacement. When environmental or system conditions prevent the use or the replacement of elastomer seals, metal seals or seats shall be considered.

DA-4263 Material

Selection of seal material by the damper Manufacturer shall be based on specific system design performance requirements and environmental conditions to which it is exposed.

Physical characteristics of the seal material, such as compression set, tensile strength, hardness, and elasticity, must be verified by generic or individual tests prior to determining the material to be used for a particular seal as well as determining the design life of that seal.

The design life of the seal is the length of time that the seal will function properly while the seal material experiences mild degradation of its molecular structure caused by the aging process of the environment.

DA-4270 FRAME CONSTRUCTION

DA-4271 Frame Construction Class A or B

Dampers requiring frame construction to Leakage Rate Class A or B (see Mandatory Appendix DA-I) shall be provided with stuffing boxes, gasketted cover plates, or other sealing devices to reduce frame leakage to less than or equal to that stated in the design specification.

DA-4272 Gasket and Packing Material Requirements

Gasket and packing materials shall conform to the requirements of DA-3220, DA-3230, and DA-4263.

DA-4280 MOUNTING OF ACTUATORS AND ACCESSORIES

DA-4281 Mounting Structure

Each actuator and/or accessory shall be provided with a rigid structure suitable for mounting such devices.

DA-4282 Accessibility

The arrangement of actuators and accessories shall provide accessibility for removal and replacement of each component.

DA-4283 Mounting Structure Material

The structure for mounting actuators and accessories shall be fabricated of material listed in Table DA-3110. Structures shall be designed as required by Article AA-4000.

DA-4284 Attachment of Actuators and Accessories

Actuators and accessories shall be attached to the mounting structure with removable fasteners, of materials listed in Table DA-3110, sized to conform to the stress limitations stated in Article AA-4000.

DA-4285 Linkage Adjustability

The actuator mounting or linkage shall permit adjustment to achieve the required positioning of the blades at each end of the actuator movement.

DA-4300 ACTUATORS

DA-4310 POWER-OPERATED ACTUATORS

DA-4311 Torque Required

The actuator shall be capable of providing the torque required by DA-4232.

DA-4312 Forces and Loads on Actuators

Determination of actuator capability shall include consideration of forces transmitted to the actuator directly, through the mounting, and through the linkage; especially side loads on extended rods, and impact loads caused by acceleration and deceleration of blades.

DA-4313 Acceleration and Deceleration Loads

Actuator design shall include consideration of loads caused by acceleration and deceleration of connected components such as blades, springs, and counterbalances.

DA-4314 Actuator Voltage or Pressure Load Rating

The actuator rating shall be based on the minimum specified voltage or pressure.

DA-4315 Power Actuator Specification Requirements

The design specification shall include the following as a minimum to establish requirements for actuator performance:

(*a*) function
(*1*) two-position or modulating
(*2*) fail open, closed, or last position
(*3*) power to open or power to close
(*b*) power source
(*1*) type (such as electric, pneumatic, hydraulic)
(*2*) characteristics (such as voltage, pressure, and their ranges)
(*c*) control signal characteristics
(*d*) frequency of actuation
(*e*) damper opening and closing time
(*f*) environmental conditions
(*g*) mounting location and any limitations on space and orientation
(*h*) manual override requirements
(*i*) accumulator sizing requirements
(*j*) actuator environmental and seismic qualifications
(*k*) type of motion (linear or rotary)

DA-4320 MANUAL ACTUATORS

Manual actuators should be equipped with locking devices and position indicators.

DA-4321 Torque Requirements

Manual actuators shall be capable of delivering the torque required by DA-4232. Manual actuator components shall be sized as required by Article AA-4000.

DA-4322 Forces and Loads on Actuators

Determination of manual actuator capability shall include consideration of forces transmitted to the actuator directly and through the linkage, including side loads on extended rods.

(09) DA-4323 Maximum Input Forces

Input force required to operate manual actuators shall not exceed 40 lb.

DA-4330 SELF-CONTAINED ACTUATORS

Self-contained actuators shall be capable of delivering the torque required by DA-4231.

DA-4340 HEAT- OR TEMPERATURE-OPERATED ACTUATORS

Heat- or temperature-operated actuators such as fusible links shall be in accordance with NFPA 90A.

DA-4400 ACCESSORIES

DA-4410 ACCESSORY REQUIREMENTS

As required by the design specification, the damper or louver assembly shall be provided with appropriate accessory equipment to provide proper function and performance of the assembly.

DA-4420 AUXILIARY ENERGY SOURCE

When required by the design specification, actuators shall be provided with an auxiliary energy source, such as springs, counterweights, or accumulators.

DA-4430 MODULATING ACTUATOR REQUIREMENTS

When required by the design specification, actuators for modulating service shall be provided with a pilot positioner or similar device to ensure controlled positioning of the damper in response to the control signal.

DA-4440 POSITION INDICATORS

When required by the design specification, local position indicators shall be provided to enable surveillance and operability verification.

DA-4450 ENVIRONMENTAL DESIGN REQUIREMENTS

Electrical devices such as position indicating switches, limit switches, and all other electrical components shall comply with the applicable IEEE standard(s) stated in the design specification. All other pneumatic, hydraulic, or other type of accessories shall be suitable for the environment specified in the design specification.

DA-4460 PIPING OF PNEUMATIC ACTUATORS

For pneumatically actuated dampers or louvers, the pneumatic piping system required for the operation of the assembly shall be arranged to provide a single field connection for each supply, or a control signal source for each assembly. Pneumatic piping system materials and installation shall conform to the requirements of the design specification. Pipe sizes shall be provided to ensure operation within the specified operating time.

DA-4470 ELECTRICAL WIRING REQUIREMENTS

For electrically actuated dampers or louvers, interconnecting electrical wiring required for the operation of the actuators and accessories shall not be installed, unless specifically required by the design specification. When interconnecting electrical wiring is required by the design specification, the design specification shall specifically identify all interface materials and installation requirements for each assembly.

ARTICLE DA-5000
INSPECTION AND TESTING

Inspection and testing of louvers and dampers shall be in accordance with the requirements of this Article and of AA-5100, AA-5200, AA-5300, AA-5410, AA-5500, and AA-5800. The Manufacturer shall be responsible for establishing the written visual examination procedures and necessary tolerances to ensure that the products are built to the Manufacturer's drawings. Examination procedures shall include appropriate checklists to verify that the required observations were performed. Written reports of visual inspection shall contain, as a minimum, the requirements of AA-5200.

(09) DA-5100 TESTING

The purpose of this subarticle is to ensure the performance of the damper or louver prior to its installation. Acceptance shall be based on the performance requirements of DA-4130. The use of the test shall be at the discretion of the Engineer as related to the service requirements. Specific tests required by the Engineer shall be specified in the design specification.

DA-5110 PRESSURE DROP TESTING

Pressure drop data shall be based on tests performed in accordance with AMCA Standard 500. The AMCA Standard figure number used shall be stated with the pressure drop data.

DA-5120 CYCLE TIME AND CYCLE REPETITION

DA-5121 Required Cycles

The damper or louver assembly, as applicable, shall be cycled a minimum of 10 times from the full-open to the full-closed position to verify the free operation of all parts and the correct adjustment, positioning, and seating of all blades.

DA-5122 Pneumatic Air Pressure

The minimum specified air pressure shall be used for pneumatic operators during cycling.

DA-5123 Cycle Time

The maximum time for operation of any of the cycles shall be compared with the allowable specified cycle time. If the specified time is exceeded, the necessary correction shall be made and the cycle test repeated.

DA-5124 Operational Requirements

Determine that movement of the blades, actuators, and linkage shall be smooth and without hesitation, and limit switches operate in their intended position.

DA-5130 FRAME LEAKAGE TESTING FOR FRAME LEAKAGE CLASSES A AND B

Pressure plates shall be bolted to the inlet and outlet side of the damper. The chamber created shall be pressurized to the specified frame design pressure with the blades partially open. Testing for Leakage Class A shall be in accordance with the bubble method of DA-5141, with the bubble solution applied to the frame. Testing for Leakage Class B shall use a calibrated flowmeter outlined in DA-5143. Leakage shall be equal to or less than the amount shown in Mandatory Appendix DA-I for the leakage class specified in the design specification.

DA-5140 SEAT LEAKAGE TESTING

Seat leakage testing shall be performed or verified after cycle time and cycle repetition testing and frame leakage testing. Leakage shall be equal to or less than that stated in Mandatory Appendix DA-I.

DA-5141 Seat Leakage Test for Leakage Class 0 Dampers (Bubble Method)

The damper shall be bolted to a pressure chamber which is then pressurized to the specified blade design pressure. A bubble solution (a commercial test solution or a solution consisting of equal parts liquid detergent, glycerine, and water) shall be applied to the damper seat area to be tested. A few moments later, but before the soap solution can dry, check the wetted areas and mark places where bubbles are being generated.

Unless otherwise specified, a leak indication is any bubble $^{1}\!/_{16}$ in. (1.58 mm) diameter that forms in 1 sec, or a bubble $^{9}\!/_{32}$ in. (7.14 mm) that forms in 1 min.

DA-5142 Seat Leakage Test for Leakage Class II or III Dampers or Louvers

Leakage data shall be based on tests performed in accordance with AMCA 500 or other approved methods.

DA-5143 Seat Leakage Test for Leakage Class I Dampers

The damper shall be bolted to a pressure chamber that is then pressurized to the specified blade design pressure using compressed air of instrument air quality. The inlet compressed air line shall have a calibrated flowmeter capable of resolving flow to within ±10% of allowable leakage in the line to measure all air passing through the damper.

DA-5144 Fire Damper Closure Test

The fire dampers shall be tested in accordance with AMCA 500-83 using Fig. 5.4, 5.5, or 5.7 for wall or floor transfer applications; and Fig. 5.1, 5.2, or 5.3 for applications of the damper in ducts with dampers installed in their intended position. For closure under dynamic airflow conditions, the damper shall be tested at the specified volumetric flow rate when open and to the maximum operating pressure when closed.

ARTICLE DA-6000
FABRICATION, FINISHING, AND INSTALLATION

Article AA-6000 shall apply for fabrication, finishing, and installation, except that the design and seismic qualifications of the damper assembly are based on the damper assembly being adequately supported for the appropriate loads. The Owner or his designee shall provide supports for the damper assembly to ensure that the damper is adequately supported as required by the Manufacturer's requirements and DA-4212. All of the welding codes or standards listed are allowed. In addition, installation of UL fire dampers shall be in accordance with the Manufacturer's UL installation instructions.

DA-6100 WELDING AND BRAZING

Specific welding and brazing parameters shall conform to the requirements of Article AA-6000.

(09)
ARTICLE DA-7000
PACKAGING, SHIPPING, AND STORAGE

Packaging, shipping, and storage of damper and louver assemblies shall be in accordance with the requirements of Article AA-7000. Implementation requires an ASME NQA-1 classification level for packaging, shipping, receiving, storage, and handling of all items. Such classification is as follows:

(a) dampers or louvers only: Level C
(b) electric actuator: Level B
(c) actuator, other than electric: Level C
(d) accessories: Level B
(e) dampers or louvers with electric actuators or accessories: Level B

ARTICLE DA-8000
QUALITY ASSURANCE

Quality assurance of dampers and louvers shall be in accordance with the requirements of Section DA and Article AA-8000.

DA-8100 DAMPER AND LOUVER PERFORMANCE

Documentation shall be established to verify that damper and louver performance complies with the testing criteria of Article DA-5000.

DA-8300 QUALITY ASSURANCE RECORDS

Documentation shall be prepared, maintained, and submitted to the Owner for record in accordance with the requirements of Article DA-9000.

ARTICLE DA-9000
NAMEPLATES, STAMPINGS, AND MANUALS

Article AA-9000 requirements for nameplates, stampings, and manuals shall apply, except that the nameplate shall require only the following information:

(a) Manufacturer's name

(b) equipment, tag, or mark number information as supplied by the purchaser

(c) size

DA-9100 NAMEPLATES AND STAMPINGS

In those instances when the damper or louver assembly consists of several frames that may be independently removable, each such frame shall bear required piece part markings.

Actuators and accessories included in the assembly shall be marked with the name of the Manufacturer or a distinctive marking, which may be in code, by which it is identified as a product of a particular Manufacturer.

DA-9200 MANUALS

The Manufacturer shall provide a manual or manuals for the equipment furnished. The manual shall include a recommended spare parts list and recommended installation, maintenance, and operational procedures.

MANDATORY APPENDIX DA-I
FRAME LEAKAGE

TABLE DA-I-1000
MAXIMUM PERMISSIBLE SEAT LEAKAGE RATE, scfm, OF DAMPER OR ADJUSTABLE LOUVER FACE AREA AT 1 in. wg DIFFERENTIAL PRESSURE

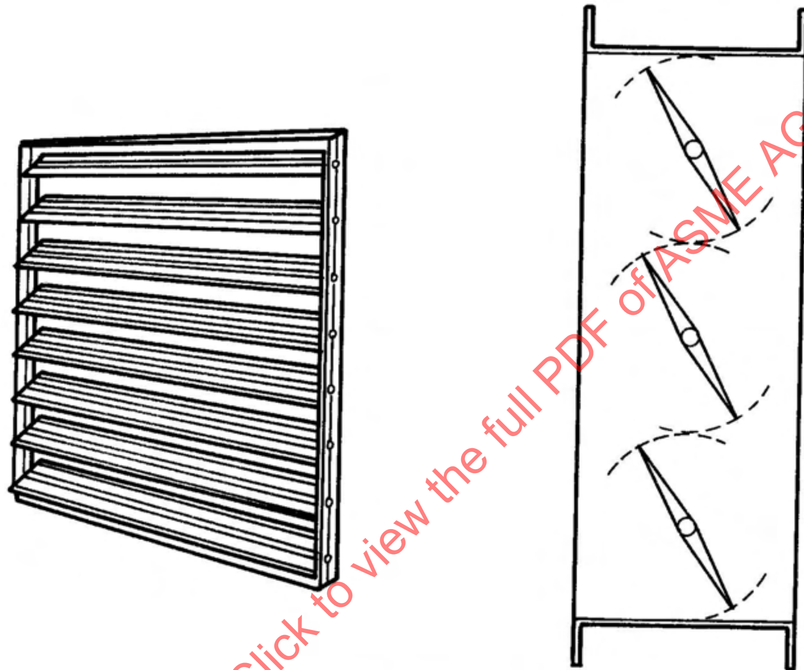
Damper Blade Length or Diameter, in.	Leakage Class (Zero Leakage)	Leakage Class I (Low Leakage)	Leakage Class II (Moderate Leakage)	Leakage Class III (Normal Leakage)	Leakage (Class IV)
Up to 12	Note (1)	Note (2)	15	60	Note (3)
Up to 24	Note (1)	Note (2)	10	40	Note (3)
Up to 36	Note (1)	Note (2)	8	32	Note (3)
Up to 48	Note (1)	Note (2)	8	32	Note (3)
Up to 60	Note (1)	Note (2)	6	27	Note (3)
Up to 72	Note (1)	Note (2)	5	25	Note (3)

GENERAL NOTES:
(a) Maximum frame leakage rate classes (at frame design pressure) are: Class A — bubble tight; Class B — 1 cfm total leakage; Class C — no consideration.
(b) The total maximum permissible leak rate is determined by multiplying the above quantities by the damper area (in square feet) times the square root of the specified blade design pressure (in inches water gage).

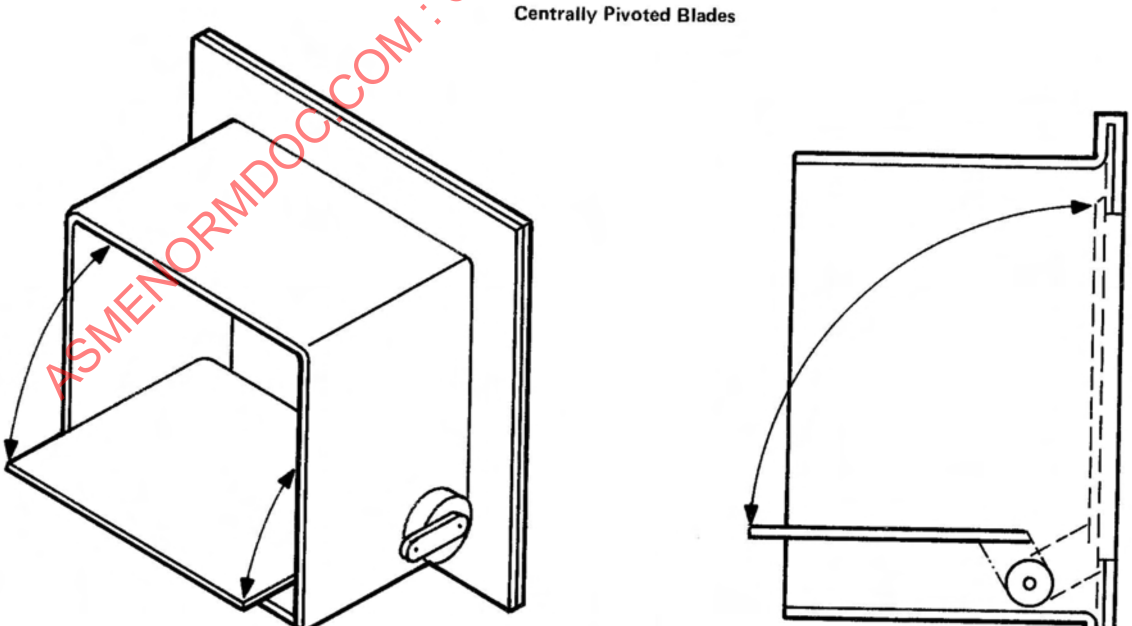
NOTES:
(1) Leakage shall be zero as determined by the bubble method damper leakage test of this Code.
(2) Low Leakage is 1 scfm/ft^2 or 1 scfm, whichever is the largest at the blade design pressure (in inches water gage).
(3) Leakage Class IV is for applications where leakage is of no consideration.

MANDATORY APPENDIX DA-II
DAMPER AND LOUVER CONFIGURATIONS

FIG. DA-II-1000-1 PARALLEL BLADE DAMPER

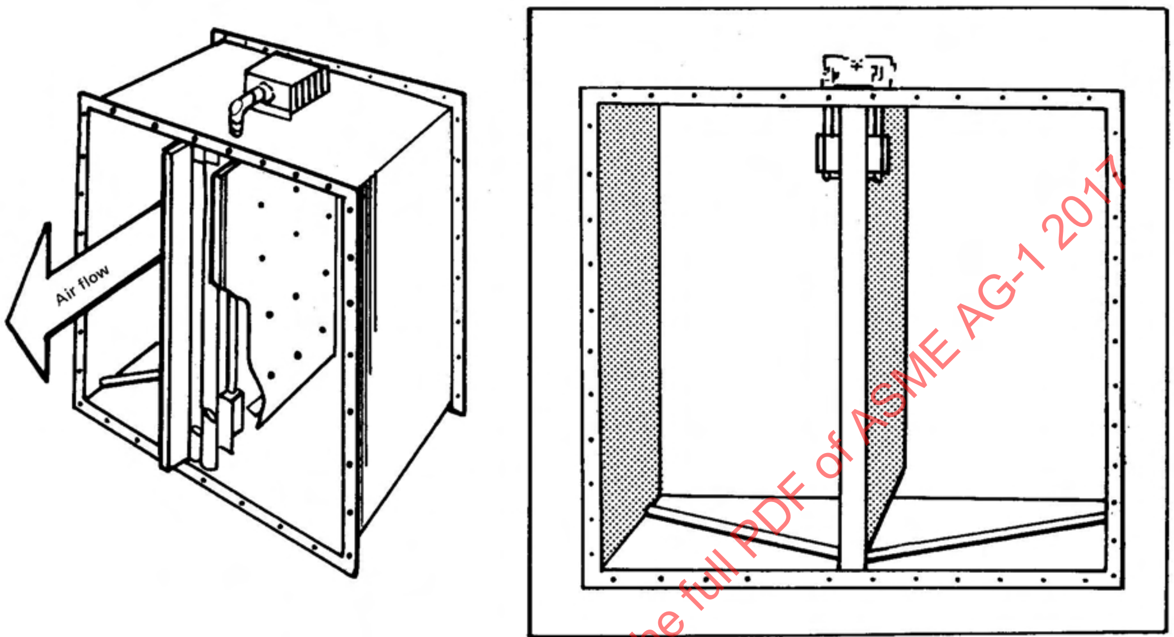


Centrally Pivoted Blades

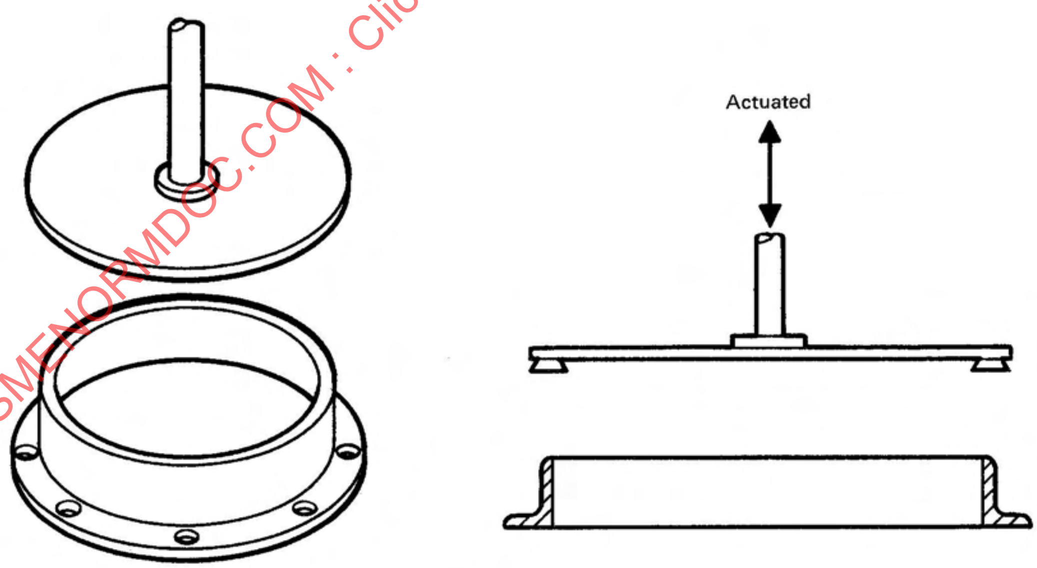


Edge Pivoted Blades

FIG. DA-II-1000-2

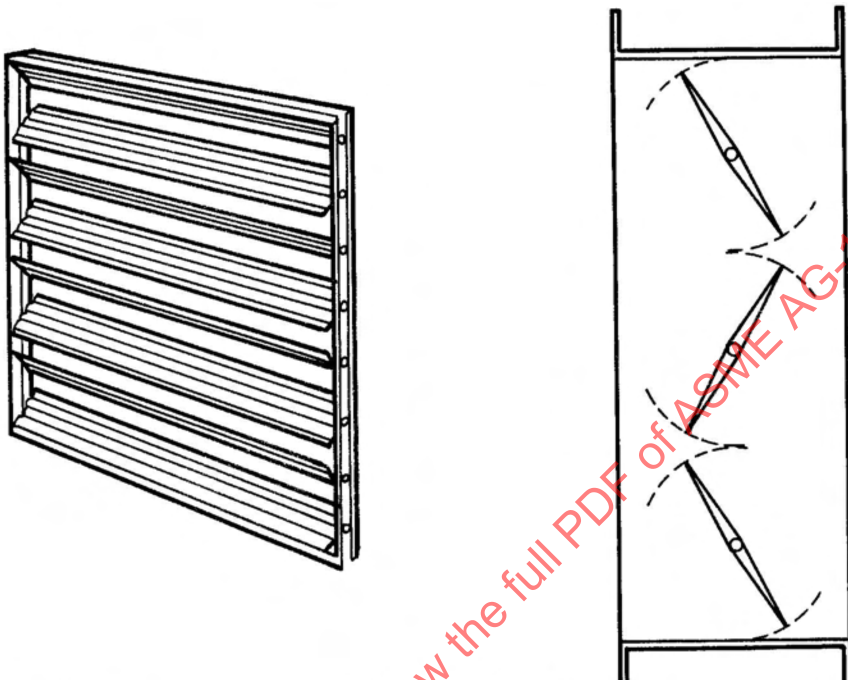


Wing Blade Damper

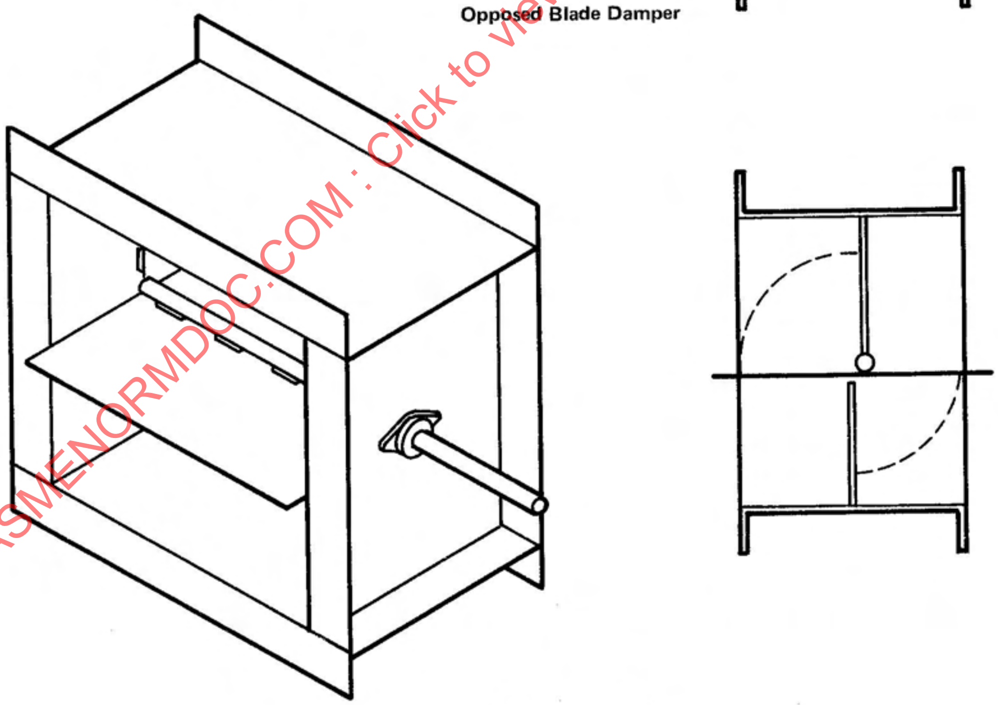


Poppet Damper

FIG. DA-II-1000-3



Opposed Blade Damper



Single-Blade Damper

FIG. DA-II-1000-4 SLIDE GATE GUILLOTINE DAMPER

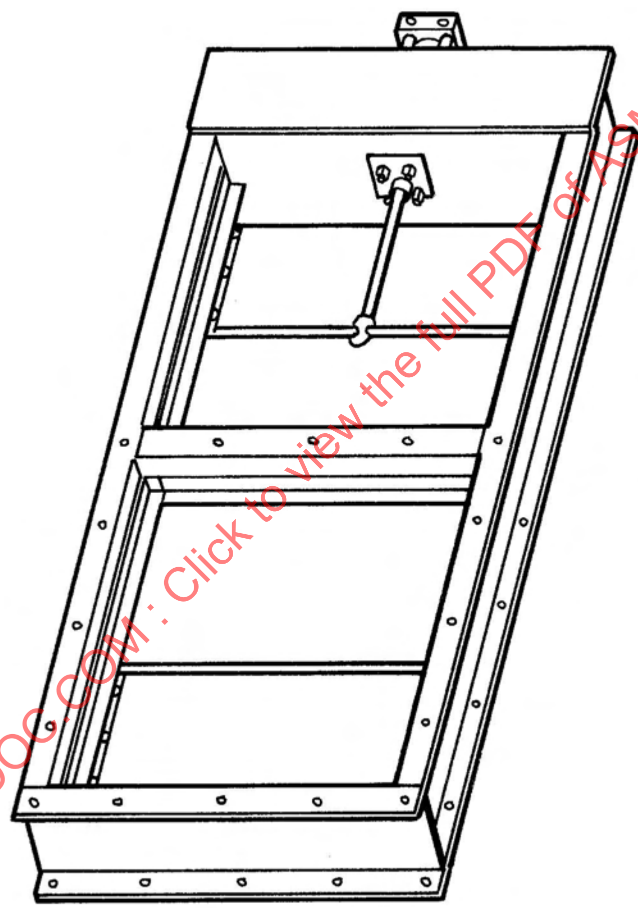


FIG. DA-II-1000-5

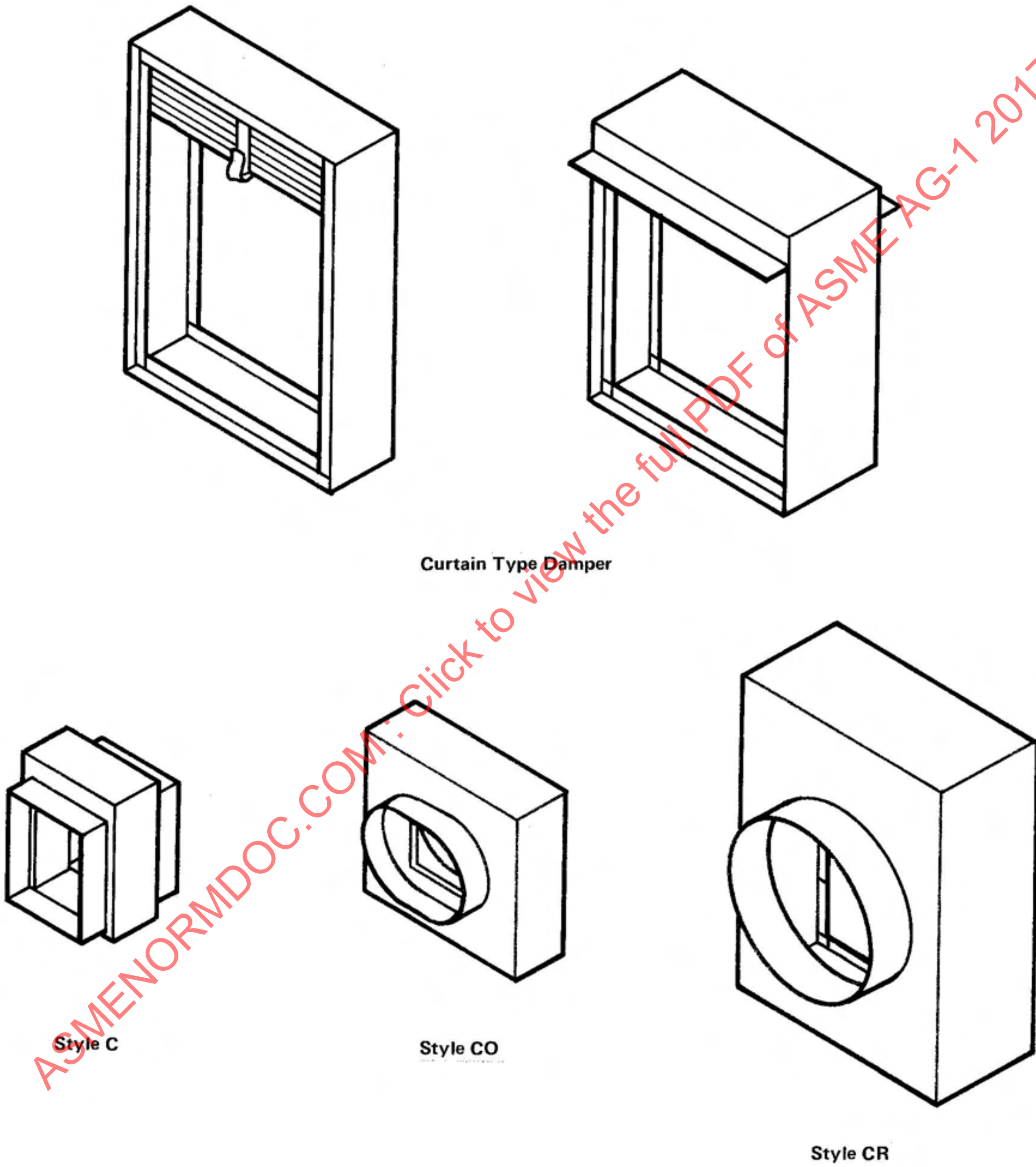
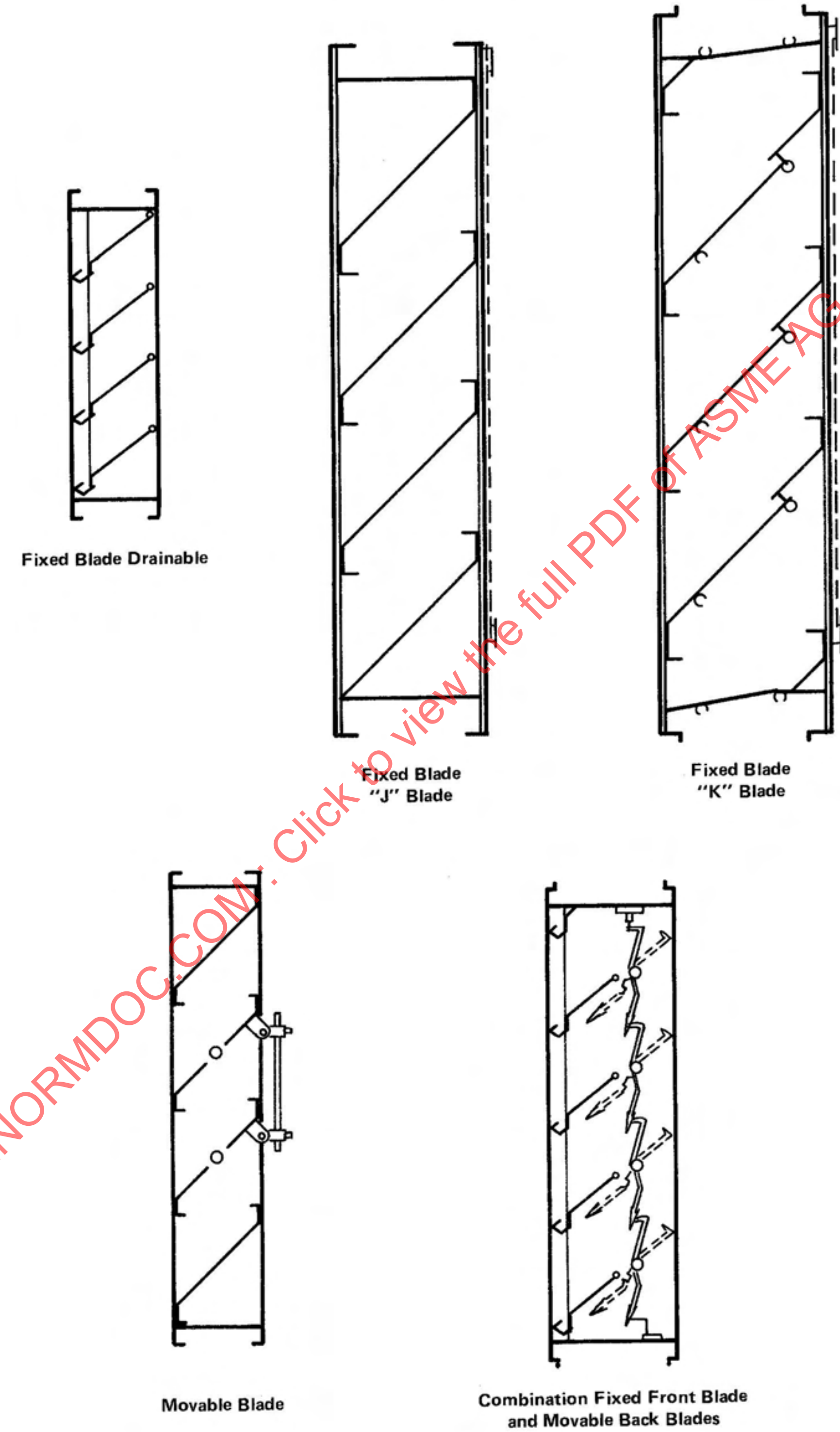


FIG. DA-II-1000-6



NONMANDATORY APPENDIX DA-A
DIVISION OF RESPONSIBILITY

This Nonmandatory Appendix is intended to identify the roles normally assumed by the organizations responsible for fulfilling Code requirements when not specifically addressed in an article or subarticle. These are guidelines to assist with Code compliance and are not to be construed as legal or contractual responsibilities unless so invoked by the owner or designee.

TABLE DA-A-1000
DIVISION OF RESPONSIBILITY

DA-	Item	Responsibility
3211	(a) Fire hazard	Owner or designee
	(b) Reduction of properties	Manufacturer
3212	Galvanic corrosion	Owner or designee
	(a) With interface	Owner or designee
	(b) With components	Manufacturer
3213	Prohibition of zinc and aluminum	Owner or designee
3220(a)	Fire hazard	Owner or designee
(b)	Degradation of properties	Manufacturer
(c)	Maintainability	Manufacturer
3230	Environment conditions affecting material selection	Owner or designee
3300	(a) CMTR	Manufacturer
	(b) Allow certificate of conformance	Owner or designee
4110(b)	Damper function	Owner or designee
(c)	Damper configuration	Owner or designee
(d)	Allowable leakage	Owner or designee
(e)	Design pressures	Owner or designee
(f)	Design temperatures	Owner or designee
(g)	Volume flow rate	Owner or designee
(h)	Relative humidity	Owner or designee
(i)	Design pressure loss	Owner or designee
(j)	Entrained contaminants	Owner or designee
(k)	(a) Normal blade position	Owner or designee
	(b) Failsafe position	Owner or designee
(l)	Dimension and space for installation	Owner or designee
(m)	Mounting configuration and support	Owner or designee
(n)	Orientation and direction of airflow	Owner or designee
(o)	Blade orientation	Owner or designee
(p)	Operating time	Owner or designee
(q)	Actuator data	Owner or designee
(r)	Seismic requirements	Owner or designee
(s)	Allowable materials	Owner or designee
(t)	Special requirements	Owner or designee
(u)	Accessories required and mounting	Owner or designee
(v)	Loads, other than pressure loads	Owner or designee
(w)	Loading combinations and design transients	Owner or designee
(x)	Radiation dose rate	Owner or designee
(y)	Finish and coating requirements	Owner or designee
(z)	Fire resistance rating	Owner or designee

TABLE DA-A-1000
DIVISION OF RESPONSIBILITY (CONT'D)

DA-	Item	Responsibility
4120(a)	Mounting connection details	Manufacturer
(b)	Weight and center of gravity	Manufacturer
(c)	Service connections	Manufacturer
(d)	Pressure loss at rated flow	Manufacturer
(e)	Leakage	Manufacturer
(f)	Operating time	Manufacturer
(g)	Materials of construction	Manufacturer
(h)	Bearing design life	Manufacturer
(i)	Seal design life	Manufacturer
(j)	Actuator torque	Manufacturer
(k)	Damper torque	Manufacturer
(l)	Actuator qualifications	Manufacturer
(m)	Verification reports	Manufacturer
(n)	Fire resistance rating	Manufacturer
4130	Gastight construction requirements	Owner or designee
4212	Damper/support boundary interface	Manufacturer
(a)	DVSR	Manufacturer
(b)	DVTP and DVTR	Manufacturer
(c)	CVCER	Manufacturer
4220	Thermal expansion clearances	Manfacturer
4240	Requirement for interconnecting wiring and interfaces	Owner or designee
4315(a)	Actuator function	Owner or designee
(b)	Actuator power source	Owner or designee
(c)	Control signal characteristics	Owner or designee
(d)	Time for operation	Owner or designee
(e)	Frequency of operation	Owner or designee
(f)	Environmental conditions	Owner or designee
(g)	Mounting location and space limitations	Owner or designee
(h)	Normal override requirements	Owner or designee
(i)	Accumulator sizing	Owner or designee
(j)	Qualification requirements	Owner or designee
4410	Requirement for accessories	Owner or designee
4420	Requirement for auxiliary energy source	Owner or designee
4430	Requirement for positioner	Owner or designee
4450	Qualification standard for electrical devices	Owner or designee
5100	Requirement for test	Owner or designee
5142	Approval of alternate test method	Owner or designee
6000	(a) Finishing of materials	Owner or designee
	(b) Structural support for dampers	Owner or designee
6100	Welding requirements	Owner or designee

SECTION SA
DUCTWORK

ARTICLE SA-1000
INTRODUCTION

SA-1100 SCOPE

This section provides requirements for the performance, design, construction, inspection, shop and field fabrication acceptance testing, and quality assurance for ductwork, including ductwork accessories, ductwork supports, and duct-mounted equipment supports, used in nuclear safety-related air treatment systems in nuclear facilities.

SA-1110 PURPOSE

This section establishes requirements for ductwork and ductwork supports to ensure system performance and reliability under all required conditions of operation and postulated events.

SA-1120 APPLICABILITY

This section applies only to ductwork and accessories, plenums, and ductwork supports. It does not cover sizing of complete air handling systems or any operating characteristics of such systems. Ductwork interface points, as applied to this section, are shown in Fig. SA-1120.

SA-1130 DEFINITIONS AND TERMS

The definitions and terms described below are specific to this section. For other definitions and terms, see subsubarticle AA-1130.

accessories: components of a duct system that are required to make the system operate in accordance with design such as turning vanes, diffusers, and gaskets.

construction documents: the drawings, specifications, installation instructions, procedures, and engineering support data produced by an engineering service organization, constructor, supplier, or contractor that are issued to the field for installation and that define the design of, or modification to, systems, structures, or components.

damper, splitter: a manually positioned single-blade damper located at duct branch connections for diverting airflow into the branch duct.

diffuser: a circular, square or rectangular air distribution outlet composed of deflecting members discharging supply air in one or more directions and planes and arranged to promote mixing of supply air with room air.

ductwork: accessories, ducts, and plenums required to convey air from one or more intake points through one or any combination of air supply, treatment, and/or conditioning equipment to one or more points of discharge.

ductwork supports: external structural members used to transmit loads between the ductwork and the designated load bearing structure.

extractor: a multivaned device located at duct branch and duct diffuser collar outlets for diverting airflow.

grille: a louvered or perforated device for transferring or directing airflow, or both.

insulation, acoustic: a material typically attached to the internal duct surface that has sound attenuating properties.

insulation, external: a material attached to the external duct surface that has heat transfer resisting properties.

insulation, internal: a material attached to the internal duct surface that has heat transfer resisting properties.

leak test pressure: the static pressure, acting in the direction of the operating pressure (positive or negative), used for establishing leakage rates. This pressure usually equals or exceeds the highest operating pressure of the item being tested but does not exceed structural capability pressure.

maximum design pressure: the static pressure to which ductwork may be subjected and required to remain intact and that is used as the starting point for structural design. This pressure shall equal or exceed the maximum operating pressure and/or test pressure, whichever is greater.

maximum operating pressure: the maximum static pressure to which the ductwork will be subjected and still be required to continue its function. Static pressure resulting from off-normal operating conditions that do not render the system inoperable (e.g., closure of branch dampers or registers) shall be considered as maximum operating pressure. The maximum operating pressure shall equal or exceed the normal operating pressure and may be equal to the maximum design pressure but may not exceed it.

normal operating pressure: the static pressure that corresponds to the normal design operating mode of the ductwork but does not include the static pressure that may be experienced in off-normal operating modes during which the system is required to continue to perform its function.

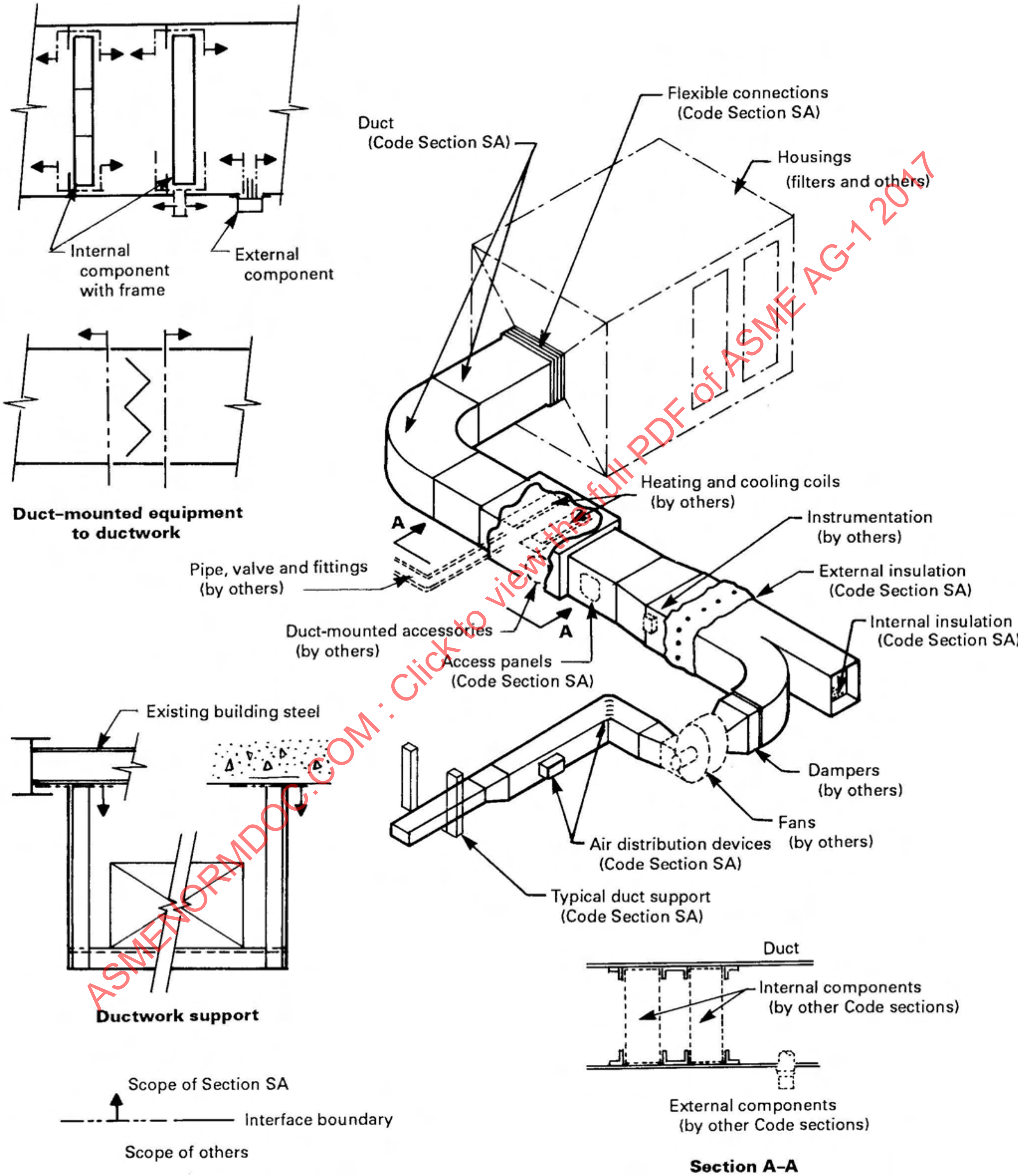
panel: a pressure boundary member of ductwork.

register: a combination of grille and damper assembly, covering an opening located in the side-wall, ceiling, floor, or duct.

silencer: a sound control device that provides acoustical attenuation.

structural capability pressure: the static pressure to which the ductwork can be safely loaded without permanent distortion. This pressure may exceed the system operational pressure transient (SOPT) due to inclusion of a margin of safety.

FIG. SA-1120 DUCTWORK AND DUCTWORK SUPPORT — INTERFACE BOUNDARY



ARTICLE SA-2000
REFERENCED DOCUMENTS

The codes and standards listed below shall supplement those listed in Section AA.

ANSI/ANS 3.3 (1980), Security for Nuclear Power Plants

Publisher: American National Standards Institute (ANSI), 25 West 43rd Street, New York, NY 10036/American Nuclear Society (ANS), 555 North Kensington Avenue, LaGrange Park, IL 60526

Certifications, Rating, and Test Manual 1062 Series, Revision 4 (1977)

Publisher: Air Diffusion Council (ADC), 1000 East Woodfield Road, Schaumburg, IL 60173-5921

Cold Formed Steel Design Manual, Specification for the Design of Cold Steel Structural Members (1986)

Publisher: American Iron and Steel Institute (AISI), 200 Town Center, Southfield, MI 48075

Handbook of Fundamentals, 1989

Publisher: American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329

Industrial Ventilation, 20th Edition, 1988

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

National Fire Codes, 1991 Edition

Publisher: National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101

Rectangular Industrial Duct Construction Standards, 1980

Round Industrial Duct Construction Standards, 1975

HVAC Duct Construction Standards, 1985

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

Specification for the Design, Fabrication and Erection of Structural Steel for Buildings, Ninth Edition

Publisher: American Institute of Steel Construction (AISC), One East Wacker Drive, Chicago, IL 60601-2001

Standard 201 (1985) Fan Application Manual — Fans and Systems

Publisher: Air Movement and Control Association International, Inc. (AMCA), 30 West University Drive, Arlington Heights, IL 60004-1893

Title 10 CFR Part 20, Standards for Protection Against Radiation

Title 10 CFR Part 50, Domestic Licensing of Production and Utilization Facilities

Publisher: U.S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pike, Rockville, MD 20852

ARTICLE SA-3000
MATERIALS

SA-3100 GENERAL

For components of ductwork and ductwork supports, the supplier shall make available, as a minimum, certified test reports of chemical and physical properties. For those ASTM materials that do not have physical testing required by the ASTM specification, tensile testing shall be performed per ASTM A 370.

All other components used in the construction of ductwork shall be provided with a manufacturer's Certificate of Compliance covering the ASME, ASTM, or other material specification, grade, and class, if applicable.

SA-3200 MATERIAL SUBSTITUTION

Measures shall be established for controlling and identifying material substitutions throughout the manufacturing and installation process.

SA-3300 MATERIAL TESTING

When required by the design specification, material shall be tested in accordance with the applicable material specification. Supplemental material testing, when required, shall be performed in accordance with Article AA-3000.

SA-3400 MATERIAL SPECIFICATIONS

Material for ductwork and ductwork supports shall be capable of meeting all requirements of Article SA-4000. Materials shall be in conformance with the ASTM materials listed in Table SA-3400. Substitute materials shall be equivalent, or exceed the requirements of Table SA-3400, as determined by the Engineer. Materials selected shall be evaluated for suitability with service conditions and compatibility with other materials used in duct construction.

The ASTM numbers in Table SA-3400 designate a chemical composition and a material thickness limit. A grade designation is usually required to determine the minimum strength of the material. If the specific grade material has an assigned minimum yield and tensile strength, these values shall be used for design purposes. If values have not been established and assigned, then tests in accordance with the procedures outlined in Article AA-3000 shall be performed to ensure that the strength of the material meets the required design stress values.

Material listed in Table SA-3400 under "Carbon Steel Plates and Sheets" when coated in accordance with "Zinc Coatings," shall be allowable under "Galvanized Steel Plates and Sheets." Materials listed under "Carbon Steel Structural Members" and "Carbon Steel Bolts and Nuts" shall be coated in accordance with "Zinc Coatings" when used in conjunction with materials listed under "Galvanized Steel Plates and Sheets."

TABLE SA-3400
ALLOWABLE MATERIALS

ASME Designator	ASTM Designator	Publication Title
Carbon Steel Plates and Sheets		
. . .	A 283	Standard Specification for Low- and Intermediate-Tensile Strength Carbon Steel Plates
. . .	A 284	Standard Specification for Low- and Intermediate-Tensile Strength, Carbon-Silicon Steel Plates for Machine Parts and General Construction
. . .	A 366	Standard Specification for Steel Sheet, Carbon, Cold-Rolled Commercial Quality
SA-414	A 414	Standard Specification for Steel Sheet, Carbon, for Pressure Vessels
. . .	A 568	Standard Specification for Steel Sheet, Carbon, and High-Strength Low-Alloy Hot-Rolled, and Cold-Rolled, General Requirements
. . .	A 569	Standard Specification for Steel, Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip, Commercial Quality
. . .	A 570	Standard Specification for Steel Sheet and Strip, Carbon, Hot-Rolled Structural Quality
. . .	A 611	Standard Specification for Steel Sheet, Carbon, Cold-Rolled Structural
SA-620	A 620	Standard Specification for Steel Sheet, Carbon, Drawing Quality, Special Kilned, Cold-Rolled
. . .	A 621	Standard Specification for Steel Sheet, Carbon, Hot-Rolled, Drawing Quality
. . .	A 635	Standard Specification for Steel Sheet and Strip, Commercial Quality, Heavy-Thickness Coils, Carbon, Hot-Rolled
. . .	A 659	Standard Specification for Steel, Carbon (0.16 Minimum to 0.25 Maximum Percent), Hot-Rolled Sheet and Strip, Commercial Quality
SA-36	A 36	Standard Specification for Structural Steel
Stainless Steel Plates and Sheets		
. . .	A 167	Standard Specification for Stainless and Heat-Resisting Chromium-nickel Steel Plate, Sheet, and Strip
SA-240	A 240	Standard Specification for Heat-Resisting Chromium and Chromium-nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels
. . .	A 666	Standard Specification for Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar
Galvanized Steel Plates and Sheets		
. . .	A 446	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process Structural (Physical) Quality
. . .	A 525	Standard Specification for General Requirements for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process
. . .	A 526	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Commercial Quality
. . .	A 527	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Lock-Form Quality
. . .	A 528	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Drawing Quality
. . .	A 591	Standard Specification for Steel Sheet, Electrolytic Zinc-Coated, for Light Coating Mass Applications
. . .	A 642	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Drawing Quality, Special Kilned

TABLE SA-3400
ALLOWABLE MATERIALS (CONT'D)

ASME Designator	ASTM Designator	Publication Title
Carbon Steel Structural Members		
SA-36	A 36	Standard Specification for Structural Steel
. . .	A 106	Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service
. . .	A 108	Standard Specification for Steel Bars, Carbon, Cold-Finished, Standard Quality
. . .	A 500	Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
. . .	A 501	Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
. . .	A 575	Standard Specification for Steel Bars, Carbon, Merchant Quality, M-grades
. . .	A 576	Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality
Stainless Steel Structural Members		
. . .	A 276	Standard Specification for Stainless and Heat-Resisting Steel Bars and Shapes
SA-312	A 312	Standard Specification for Seamless and Welded Austenitic Stainless Steel Pipes
SA-476	A 479	Standard Specification for Stainless and Heat-Resisting Steel Bars, and Shapes for Use in Boilers and Other Pressure Vessels
. . .	A 511	Standard Specification for Seamless Stainless Steel Mechanical Tubing
. . .	A 554	Standard Specification for Welded Stainless Steel Mechanical Tubing
Galvanized Steel Pipe and Conduit		
. . .	A 53	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
. . .	ANSI C80.3	Electrical Metallic Tubing, Zinc-Coated
Stainless Steel Bolts and Nuts		
SA-193	A 193	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
SA-194	A 194	Standard Specification for Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service
. . .	A 320	Standard Specification for Alloy-Steel Bolting Materials for Low-Temperature Service
. . .	A 493	Standard Specification for Stainless and Heat-Resisting Steel for Cold Heading and Cold Forging
. . .	ANSI B18.21.1	Lockwashers (Inch series)
. . .	ANSI B18.22.1	Plain Washers

TABLE SA-3400
ALLOWABLE MATERIALS (CONT'D)

ASME Designator	ASTM Designator	Publication Title
Carbon Steel Bolts and Nuts		
SA-193	A 193	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
SA-194	A 194	Standard Specification for Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service
SA-307	A 307	Standard Specification for Carbon Steel Bolts and Studs
SA-325	A 325	Standard Specification for High-Strength Bolts for Structural Steel Joints
SA-449	A 449	Standard Specification for Quenched and Tempered Steel Bolts and Studs
. . .	A 548	Standard Specification for Steel Wire, Carbon, Cold-Heading Quality, for Tapping and Sheet Metal Screws
. . .	A 563	Standard Specification for Carbon and Alloy-Steel, Steel Nuts
. . .	ANSI B18.21.1	Lockwashers (Inch Series)
. . .	ANSI B18.22.1	Plain Washers
Aluminum Material — Grilles, Registers, Diffusers		
. . .	B 209	Standard Specification for Aluminum and Aluminum Alloy Sheet and Plate
. . .	B 221	Standard Aluminum and Specification for Aluminum Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes
SB-308	B 308	Standard Specification for Aluminum Alloy, 6061-T6 Standard Structural Shapes
Zinc Coatings		
. . .	A 123	Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
. . .	A 153	Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
. . .	B 633	Standard Specification for Electro-deposited Coatings of Zinc on Iron and Steel

GENERAL NOTE: Unless specified otherwise, the effective date of specifications listed above is the latest approved revision. Where ASTM materials are specified, the equivalent ASME material specification may be substituted.

ARTICLE SA-4000
DESIGN

SA-4100 GENERAL

Ductwork and ductwork supports shall be designed in accordance with the requirements of Article AA-4000 and this section.

SA-4200 DESIGN CRITERIA

SA-4210 LOAD CRITERIA

SA-4211 Ductwork Loads

The following loads and load definitions shall be considered:

(a) Additional Dynamic Loads (ADL), Deadweight (DW), Design Pressure Differential (DPD), Design Wind (W), External Loads (EL), Normal Operating Pressure Differential (NOPD), and *System Operational Pressure Transient (SOPT)* as defined in AA-4211.

(b) Constraints of Free End Displacement Load (*T*). These are loads caused by thermal movements. When duct construction utilizes gasketed companion angle construction, effects of (T) for normal operations may be ignored. For postulated accident conditions, a review of the effect of (T) is necessary.

(c) Fluid Momentum Load (*FML*). This is as defined in AA-4211 with the following clarification:

Ductwork shall be designed to withstand FM loads resulting from air turbulence, often found in sections following fan discharges, with or without fan accessories, and certain dampers and duct fittings. The termination of such sections is marked by the length of straight ductwork required to regain uniform airflow as given by AMCA 201 Fig. 20:

$$D_f = \frac{VD}{1000} \qquad \frac{(VD)}{(3281)}$$

for round and equivalent rectangular ducts

where

D = duct diameter, ft (m)

D_f = length of straight ductwork connected to fan or component discharge, ft (m)

V = velocity, ft/min (m/sec)

The equivalent diameter (D_e) for rectangular duct, with side dimensions of a and b, is given by:

$$D_e = 1.30\left[\frac{(ab)^{0.625}}{(a+b)^{0.25}}\right]$$

(d) Live Load (*L*). Live loads shall be defined in the design specification (SA-4600). The live load shall not be less than a construction manload of 250 lb (113.4 kg). The load shall be applied at the mid-span of the duct, or midpoint of a stiffener, or within a panel. When applied to a panel, the load shall be assumed to be distributed over 10 in.^{2} (64.5 cm^2).

(e) Normal Operating Pressure Differential (*NOPD*). This is as defined in para. AA-4211 with the following clarification: For ease of design, a duct system may be designed using one pressure value that envelops NOPD and SOPT (para. AA-4211). NOPD and SOPT may be positive or negative pressures. Worst case shall be considered in design.

(f) Seismic Loads (*SL*). Loads that are the result of the envelope of the operating basis earthquake (OBE) and the safe shutdown earthquake (SSE). As overall system functionalism is not generally compromised by loads from the OBE, the SSE will govern the design. As an option, the OBE and SSE may be considered separately with the OBE loads used for the Level B load combination. The horizontal and vertical components of the seismic excitation shall be applied simultaneously in the direction that will produce worst-case stresses and deflections. These components may be combined by the square root of the sum of the squares (SRSS) method.

(g) Hydrostatic Loads From Accumulated Condensate, Water Deluge Systems, or Moisture Separators. The hydrostatic load shall be conservatively established

by documented analysis based on ductwork configuration, accessories, and component function. Hydrostatic load (HY) shall be added to the deadweight (DW) case as applicable.

(h) Design Pressure Differential (*DPD*). The dynamic external pressure loads resulting from a design basis accident (DBA), intermediate break accident (IBA), or small break accident (SBA). Generally, HVAC should be routed outside the local pipe break affected area. If HVAC is subjected to these loads, the design specification (SA-4600) shall address the station specific design requirements considering a Service Level D load combination.

(i) For component load criteria, see the following sections:

(1) HEPA filters: FC-4300
(2) Mounting frames: FG-4200
(3) Fans: Article BA-4000
(4) Dampers: Article DA-4000
(5) Refrigeration equipment: Article RA-4000
(6) Conditioning: Article CA-4000
(7) Moisture separators: Article FA-4000
(8) Prefilters: Article FB-4000
(9) Instrumentation: Article IA-4000

SA-4212 Ductwork Load Combinations

The applicable component loading shall be combined in accordance with Table SA-4212.

SA-4213 Service Conditions

The requirements of AA-4213 apply.

SA-4214 Design and Service Limits

The requirements of AA-4214 apply.

SA-4215 Ductwork Support Loads

The definition of loads per SA-4211 for live load (L), normal operating pressure differential (NOPD), seismic load (SL) shall also be used for duct supports. The definition of loads per AA-4211 for dead weight (DW), external loads (EL), and additional dynamic loads (ADL) shall also be used for duct supports. Hydrostatic loads as defined in SA-4211(g) shall be treated as a DW load when the loads have an effect on the supports. The fluid momentum load as defined in SA-4211(c) is not typically a significant load for supports and may be neglected.

TABLE SA-4212
LOAD COMBINATIONS

Component Service Level	Load Combinations
A	DW + NOPD + FML + EL + L + T + W
B	Not required
C	DW + NOPD + FML + EL + SL + ADL + W
D	Not required unless DPD is applicable

TABLE SA-4216
LOAD COMBINATIONS FOR SUPPORTS

Service Level	Load Combinations
A	DW + NOPD + EL + L + T
B	Not required
C	DW + NOPD + EL + SL + ADL
D	Not required unless DPD is applicable

SA-4216 Ductwork Support Load Combinations

The applicable support loading shall be combined in accordance with Table SA-4216.

SA-4220 STRESS CRITERIA

The ductwork stress shall be based upon the AISI *Specifications for the Design of Cold-Formed Steel Structural Members.* The ductwork support stress shall be based upon the AISC *Specification for the Design, Fabrication and Erection of Structural Steel for Buildings.*

The basic general membrane design stress for the Service Level A condition shall not exceed 0.6 Fy and shall be reduced as appropriate to consider lateral-torsional buckling of bending members and effective lengths of compression members. The basic general membrane design stress for the Level C condition shall not exceed 1.2 × 0.6 Fy per AA-4321.

The combined membrane and bending design stress for Service Level C shall not exceed 0.9 Fy and shall be reduced as appropriate to consider lateral-torsional buckling of bending members and effective lengths of compression members. The combined membrane and bending design stress for the Level A condition shall not exceed 1.8 × 0.6 Fy per AA-4321.

SA-4230 DEFLECTION CRITERIA

SA-4231 Deflection Limits

The maximum deflection (d_{max}), that may be sustained so that the duct function is not impaired shall be determined by analysis, test, or both. The allowable deflections are as defined in AA-4231 for various service level conditions.

SA-4232 Deflection Limits for Panels, Flanges, and Stiffeners

The maximum deflection (*d*), which occurs as the result of the applicable load combinations of SA-4212 is the lesser of two values derived from SA-4232.1 and SA-4232.2.

SA-4232.1 Criterion No. 1. Deflection shall not exceed the following criteria:

(a) Plate or sheet: $\frac{1}{8}$ in. per foot of the maximum unsupported panel span in direction of airflow but not more than $\frac{3}{4}$ in.

(b) Stiffeners and flange connections: Not to exceed $\frac{1}{8}$ in. per foot of span but not more than $\frac{3}{4}$ in.

(c) Flange connection to components: $\frac{1}{360}$ of the span but not to exceed $\frac{1}{8}$ in.

SA-4232.2 Criterion No. 2. Deflections shall be limited to ensure that the following will not occur:

(a) distortion of airflow path cross section in excess of tolerances specified in SA-6400.

(b) damage to safety related items such as instrumentation or accessories.

(c) impingement of deflected elements on adjacent services, such as equipment, pipe, cables, tubing, etc.

(d) loss of leak-tightness (in excess of leakage limit). See SA-4500.

(e) functional failure of components attached to the duct (e.g., instrument lines).

SA-4233 Deflection Limits for Mounting Frames and Equipment Interfaces

(a) See FG-4310 for mounting frame deflection limits.

(b) See applicable equipment section for other deflection limits.

SA-4240 OTHER CRITERIA

SA-4241 Vibration Isolation

The vibration isolation type and efficiencies, primarily between duct and equipment, shall be as designated in the design specification. The vibration isolation equipment shall be designed with restraints to resist the loads generated under any service condition.

SA-4242 Provisions for Relative Movement

Clearances shall be provided to allow for the relative motion between equipment, ductwork, and supports. When clearances or travel ranges or both are required to accommodate movements of ductwork or supports, design margins shall be introduced to allow for variations due to fabrication and installation. Design clearances and travel ranges shall be based on the maximum range that might occur between two operating conditions and not necessarily the maximum cold-to-hot range. All parts of supports shall be fabricated and assembled so that they will not be disengaged by the movements of ductwork.

SA-4243 Tolerances

Installation and fabrication tolerances for ductwork shall be accounted for in the design of the ductwork and supports. Fabrication tolerances shall comply with SA-6400.

SA-4244 Permanent Attachments

The attachment design shall include all service conditions and load combinations set forth in SA-4212 and SA-4213, or as required by the design specification.

The permissible types of welded joints shall be in accordance with AWS D1.1, or AWS D1.3, as applicable.

Attachments may be either the welded or bolted type and shall be considered as indicated in SA-4244.1 and SA-4244.2.

SA-4244.1 Welded Attachments. Consideration shall be given to local stresses induced in the ductwork by integral attachments as defined in AA-4243.

For items used as part of an assembly for the support or guiding of the ductwork, the materials shall be compatible for welding, see Article AA-6000.

SA-4244.2 Bolted Attachments. Consideration shall be given to the mechanical connection and local stresses induced in the ductwork by nonintegral attachments as defined in AA-4243.

The design of bolts for structural supports shall meet the requirements of AA-4360.

SA-4300 DUCTWORK JOINTS AND SEAMS

SA-4310 GENERAL

Selection of joints and seams used in the assembly of ductwork sections shall be based on the required structural integrity, leak-tightness, and the fluid flow within the system. Duct-housing interconnections shall be designed with consideration of the air distribution uniformity.

SA-4320 DUCT JOINTS AND SEAMS

SA-4321 Longitudinal Seams

The following longitudinal seams are acceptable for use in ductwork sections subject to the limitations of SA-4324.

(a) groove weld

(b) lock type

(c) Pittsburgh lock

(d) fillet weld

SA-4322 Transverse Joints

The following types of transverse joints are acceptable for use in ductwork sections:

(a) welded flange

(b) companion angle

(c) Vanstone flange

(d) welded coupling

SA-4323 Other Types of Connections

Other types of rigid transverse connections may be acceptable provided that the structural characteristics are documented by engineering evaluation and tested per SA-5400.

SA-4324 Limitations of Ductwork Joints and Seams

Longitudinal seams and transverse joints whose structural integrity is dependent on the folded or punched metal, shall be pressure tested. Test pressure shall be the structural capability pressure.

Longitudinal seams using sealants or elastomers to meet the leakage requirements shall be qualified by test, analysis, or test and analysis to ensure meeting the design criteria of SA-4600. Brazed welding may be used for sealing purposes.

SA-4325 Bolts and Fasteners

Requirements for bolted connections of duct-to-duct and duct-to-housing, with a design pressure differential less than 15 in. wg (3 735 Pa), shall be as follows:

(a) Maximum bolt spacing shall be 4 in. on center unless otherwise specified by the design specification. The adequacy of bolt spacing greater than 4 in. on center, for pressure boundary integrity, shall be documented by calculation or testing.

(b) Minimum bolt diameter shall be $^3/_8$ in. (9.52 mm) unless otherwise specified by the design specification. The adequacy of bolt diameters less than $^3/_8$ in. shall be documented by calculations or testing.

Requirements for bolted connections for duct with design pressure differentials exceeding 15 in. wg (3 735 Pa) shall be determined by calculations or testing.

Nonbolted, nonwelded-type fastening devices (e.g., screws, rivets) shall have their adequacy demonstrated for the load combinations of SA-4212 and documented by calculation or testing.

Bolted connections shall be verified as being capable of sustaining all loading combinations by using an appropriate stress intensification factor.

SA-4400 COMPONENTS

SA-4410 FLEXIBLE CONNECTIONS

(a) Flexible connections shall be designed to meet the requirements for design given by SA-4212, SA-4500, and NFPA 90A. Allowable leakage (fabric leakage and joint leakage) shall be determined in accordance with SA-4500.

(b) Flexible connections shall be rated by pressure and qualified life. The qualified life shall be determined by testing, or calculation, or both and be based on the environmental conditions provided by the design specification. Minimum physical properties (i.e., tensile strength), subject to degradation due to the environments required to satisfy design, shall be the basis of qualified life.

(c) Flexible connection pressure rating shall be determined by an ultimate strength test. The pressure rating of the connection shall be no greater than 50% of burst pressure. Calculation of burst pressure can be done in lieu of the test. Burst pressure shall exceed structural capability pressure.

(d) If adhesive is used in fabrication or installation of flexible connections, it shall be environmentally qualified for use in expected environmental conditions.

SA-4420 GASKETS

Gaskets shall be made of materials that are compatible with the service conditions (see SA-4600). Gasket material dimensions shall be based on joint design. An acceptable criterion for compression of gasket material shall be established on the basis of the gasket chosen. This acceptance criterion and the service life of the gasket material shall be documented by an engineering evaluation or testing.

SA-4430 ACCESS DOORS AND PANELS

Construction of doors/panels and door frames shall be selected to meet the allowable leakage determined in SA-4500. Sealing surfaces between the door/panel frame shall be designed for compression sealing. The design shall incorporate means for adjusting compression forces, gasket compression, and alignment.

Spacing of hinges, latches, and bolts shall be determined by calculation or test to ensure a uniform compression of the gasket. Spacing shall enable a compression of at least 50% of nominal gasket thickness and provide a gasket compression uniformity of ±20%.

Door hinges shall be designed to minimize damage to compression seals due to friction and shear forces during opening and closing of the doors.

Dogs, hinges, latches, etc., shall be designed such that lubrication materials shall not enter the interior of the ductwork.

See Nonmandatory Appendix SA-C (SA-C-1210) for additional guidance on the design of access doors.

SA-4440 PROVISIONS FOR TESTING AND MAINTENANCE

SA-4441 Test Ports

The Engineer shall evaluate the design function of the equipment to determine where test ports (including injection and sampling ports) are required.

SA-4450 MISCELLANEOUS

SA-4451 Drains

(a) Consideration shall be given to drains depending on requirements, services, or components within ductwork.

(b) Drains form an integral part of the ductwork system pressure boundary and are subject to air leakage requirements established in SA-4500.

(c) For additional guidance on the design of drains, see Nonmandatory Appendix SA-C (SA-C-1220).

SA-4452 Insulation

(a) Insulation shall be provided as required to ensure air conditioning function, limit condensation, or provide acoustic noise reduction.

(b) Acoustic linings and thermal insulation shall not be applied to the inside of ducts that may become contaminated during normal plant operations.

(c) Insulation applied to the outside of ducts shall not prevent access to doors, access hatches, or other components requiring adjustment or maintenance.

(d) The fire hazard classification of applied insulation, adhesive, and sealer shall not exceed a flame spread of 25 and smoke developed of 50 in accordance with NFPA-90A.

(e) Insulation shall be attached to ductwork using a method that will not adversely affect the system/component safety function.

SA-4453 Air Distribution Devices

Design of air distribution devices and their attachments shall comply with SA-4200 and AA-4300.

The performance rating of air distribution devices shall be determined by actual tests performed in accordance with the Air Diffusion Council standard listed in Article SA-2000.

SA-4454 Security Barriers

The requirements for internal and bullet-resistant barriers installed for the purpose of security shall be consistent with appropriate federal regulations.

Consideration shall be given to the impact (pressure, noise, etc.) the installation of security and bullet-resistant barriers will have on the overall performance of the air treatment system in which they are installed. The deadweight of the security and bullet-resistant barriers shall be included in the design of ductwork supports.

SA-4500 PRESSURE BOUNDARY LEAKAGE

SA-4510 GENERAL

Pressure boundary leakage shall be limited to that allowed by the system functional and environmental design requirements.

Allowable leakage for a system, or portion of a system, shall be determined considering the following factors (as a minimum):

(a) control of airborne contamination
(b) control of space pressure
(c) control of space temperature
(d) control of space humidity

SA-4520 APPLICABILITY

Pressure boundary leakage shall apply to air cleaning, air cooling, and ventilation systems. Each system's pressure boundary shall include, but not be limited to, the following items as applicable:

(a) ductwork as defined in SA-1130
(b) fan housings

(c) damper frames and valve bodies (and seats, where used for pressure boundary isolation)
(d) heating and cooling coil housings (or frames for duct mounted coils)
(e) mounting frames for components used for the reduction of radioactive contamination
(f) instrumentation or other components connected to the ductwork
(g) air cleaning unit housings

SA-4530 EVALUATION

SA-4531 Responsibility

The Engineer shall evaluate each system to establish the allowable leakage to ensure its design ventilation, temperature, and contamination control function is achievable.

SA-4532 Allowable Leakage Determination

The following criteria shall be utilized in the determination of allowable leakage:
(a) application of governing codes, regulations, and plant specific requirements
(b) consideration of each system's operating mode, including anticipated system upset conditions such as rapid closure of dampers
(c) normal and maximum operating static pressures throughout the pressure boundary
(d) system internal and external environmental conditions

Guidance for determination of allowable leakage is given in Nonmandatory Appendix SA-B.

SA-4533 Exceptions to Leakage Requirements

Portions of air cleaning, air cooling, and ventilation systems exhibiting one of the following conditions need not be subjected to quantitative measurement of leakage unless otherwise required by the design specification [however, the system shall be pressurized to normal operating pressure differential (NOPD) to locate and seal all audible leaks]:
(a) all ducts serving the protected space and located within a protected space, regardless of length
(b) plant vent stacks or ducts outside plant buildings, when high-level or mixed-mode release credit is not required to meet off-site dose limits
(c) systems which provide air cooling or heating function only located entirely in a clean interspace
(d) other exceptions to quantitative measurement of leakage requirements shall be technically justified and specifically documented with basis by the Owner or his agent

SA-4534 Documentation

Evaluation for allowable leakage of each system, or portion thereof, shall be documented. This documentation shall include the following:
(a) identification of system or portion of system
(b) governing codes, regulations, and plant specific requirements
(c) purpose of leakage control (see SA-4510)
(d) system modes of operation
(e) normal operating pressure differential (NOPD) and system operating pressure transient (SOPT)
(f) method of derivation of allowable leakage
(g) test pressures and associated allowable leakage

SA-4540 LEAKAGE TESTING

Where leakage testing is specified for a system, as a result of the Engineer's evaluation, it shall be performed in accordance with SA-5300 and Section TA of this Code.

SA-4600 DESIGN SPECIFICATION

A design specification shall be prepared which consists, as a minimum, of the following information regarding the ductwork and ductwork supports covered by this section:
(a) loads as defined by SA-4211
(b) environmental conditions
(1) ductwork external-design environmental conditions including pressure, temperature, relative humidity, radiation exposure, and hostile environmental factors for all plant conditions
(2) ductwork internal design environmental conditions for all system operating conditions
(c) service conditions as defined by AA-4213
(d) design and service limits as defined by AA-4214
(e) allowable ductwork leakage, as defined by SA-4500
(f) system safety-related function: Identify the fuction of the ductwork system for each plant condition. The function shall consist of purpose and operational parameters (i.e. flow, leakage, pressure, temperature). Plant conditions and service limits are defined by AA-4213 and AA-4214.

ARTICLE SA-5000
INSPECTION AND TESTING

SA-5100 GENERAL

Inspection and testing shall be in accordance with the requirements of AA-5100, AA-5200, AA-5300, TA-3300, and the additional requirements of this section.

SA-5110 SCOPE AND APPLICABILITY

This section contains general requirements for the inspection and testing of ductwork and ductwork supports.

SA-5120 RESPONSIBILITY FOR PROCEDURES

When an inspection or test is required herein, written inspection or testing procedures shall be developed, by the parties performing the test or inspection, to the specific requirements of this section. The inspection or testing shall be performed by personnel qualified in accordance with ASNT SNT-TC-1A as amended by ASME NQA-1 and AA-6433.

SA-5200 VISUAL INSPECTION

SA-5210 GENERAL REQUIREMENTS

Visual inspections shall be performed in accordance with AA-5200 and TA-3510.

SA-5220 WELDED CONNECTIONS

Inspection and testing of welds shall be performed in accordance with AA-5300 and Article AA-6000.

SA-5230 DUCTWORK

Ductwork shall be visually inspected for proper dimensions including tolerances, as required by SA-6500 and governing construction documents. Ductwork fabrication shall meet the applicable requirements of Article SA-6000.

SA-5231 Joints and Seams

Joints and seams shall be visually inspected. Acceptance criteria shall be as follows:

(a) Joints and seams shall comply with the requirements of SA-6400 and SA-6500.

(b) Gasketed joints shall provide uniform gasket compression. Gaskets shall be installed per construction documents.

(c) Brazed joints shall comply with the requirements of AA-6430.

(d) Longitudinal or transverse welded joints shall comply with the requirements of SA-5220.

(e) Threaded fasteners shall be provided with locking devices in accordance with AA-6258.

SA-5232 Stiffeners

Stiffeners shall be visually inspected to ensure compliance with the following acceptance criteria:

(a) Stiffeners shall comply with the fabrication and installation requirements of Article SA-6000.

(b) Welds shall comply with the requirements of SA-5220.

(c) Threaded fasteners shall be provided with locking devices in accordance with AA-6258.

(d) Removal of temporary attachments shall be confirmed.

SA-5240 DUCTWORK SUPPORTS

Supports shall be visually inspected during installation, after installation, or both in accordance with the following acceptance criteria:

(a) Supports shall comply with the fabrication and installation requirements of SA-6400 and SA-6500.

(b) Welded joints shall comply with the requirements of SA-5220.

(c) Threaded fasteners shall be provided with locking devices in accordance with AA-6258.

(d) Removal of temporary attachments shall be confirmed.

SA-5300 PRESSURE BOUNDARY LEAKAGE TESTING

SA-5310 GENERAL

The ductwork system shall be tested to demonstrate compliance with the design leakage requirements identified in SA-4500, unless exempted by SA-4533.

SA-5320 SYSTEMS COMPLETENESS

Prior to testing, the system shall be complete including all pressure boundary items identified in SA-4520, with the following exceptions:

(a) Terminal air distribution devices may be excluded from the test.

(b) Pressure boundary items not yet installed may be excluded from testing with approval of the Engineer. In such cases, prototype testing shall be performed to determine the typical leakage rate for the installation method. Detailed procedures shall be prepared to control installation of items not tested with the system. Procedures shall specify any hold points, special surface preparation or finish, and final inspection requirements to ensure that the item is installed similar to the prototype. Typical leak test values shall be increased by a factor of 10% and added to the actual leakage in the test report, and noted as such.

(c) Systems may be tested in sections, if necessary, as allowed by SA-5330. Testing shall be in accordance with SA-5300.

SA-5330 ALLOWANCES FOR TESTING SYSTEM LEAKAGE RATES BY SECTIONS

Temporary isolation at a transverse joint shall be allowed subject to the following requirements:

(a) Transverse joints not subjected to a quantitative leak test shall be companion angle type or other types which enable visual inspection of the sealing mechanism between mating ductwork sections.

(b) Assembled joints utilizing gasketing shall be visually inspected to ensure uniformity of gasket compression.

(c) Assembled joints utilizing mastic or liquid sealant shall be visually inspected to ensure that such material has been applied in accordance with the procedure approved by the Engineer.

(d) The reduced allowable leakage (L_r) of ductwork sections shall be as follows:

$$L_r = L_S - R$$

$$R = (C_J / C_T)\, L_S$$

where

C_J = total perimeter of capped end joints of test section

C_T = total perimeter of all joints in tested section, including capped end joints

L_S = section allowable leakage

R = reduction in allowable leakage in cfm/ft^2 (L/m^2)

SA-5340 TESTING PROCEDURES

Prior to pressure boundary leakage testing, test procedures shall be developed in accordance with TA-3400. All test equipment shall be specified with the proper range and required accuracy. Test procedures shall include acceptance criteria determined by SA-4500, SA-5320, and SA-5330.

SA-5350 DOCUMENTATION

A test report shall be prepared to document the pressure boundary leakage test. This report shall include, as a minimum, the following information:

(a) system or portion of system tested

(b) specified allowable leakage and test pressure

(c) calculations for ductwork square footage for systems tested by sections

(d) adjustments to allowable leakage per SA-5330(d)

(e) measured leak rates

(f) list of pressure boundary components that were not installed during the pressure boundary leakage test

(g) test equipment used, including model no., serial no., and evidence of calibration

(h) names of test personnel

(i) date of test

SA-5360 ACCEPTANCE CRITERIA

SA-5361 Quantitative Leakage Tests

Acceptance criteria for quantitative leakage tests shall comply with SA-4500 and SA-5350(d).

SA-5362 Nonquantitative Leakage Tests

For nonquantitative leakage tests allowed by SA-4533, the acceptance criteria shall be that audible leaks have been sealed.

SA-5400 STRUCTURAL CAPABILITY TESTS

SA-5410 DUCTWORK PRESSURE TEST

A pressure test shall be performed at the structural capability pressure per TA-3522. This test pressure shall be maintained for the duration of the inspection. Upon completion of this pressure test, ductwork and equipment exhibiting permanent distortion or breach of integrity shall be repaired or replaced. The pressure test shall be repeated after repair or replacement until no permanent distortion or breach of integrity is observed.

This test is not required if duct construction specified is equal to or greater than the duct construction allowed in the SMACNA standards listed in Article SA-2000 for the system operational pressure transient (SOPT).

SA-5420 LONGITUDINAL SEAM QUALIFICATION TEST

Ductwork, utilizing folded or punched metal longitudinal seams, shall be pressure tested to qualify the structural design capability of those seams. This pressure test shall be conducted at the beginning of fabrication and before any ductwork with these seams is installed in the facility. The pressure test shall be conducted on each sheet-metal gauge utilizing these seams. Seams shall be tested at the structural capability pressure for the system(s).

ARTICLE SA-6000
FABRICATION AND INSTALLATION

SA-6100 GENERAL

Ductwork and supports shall be fabricated and installed in accordance with this section and Article AA-6000.

SA-6110 SCOPE AND APPLICABILITY

This section contains specific requirements for the fabrication and installation of ductwork and its supports.

SA-6120 MATERIALS

SA-6121 Material Selection

Material used in fabrication and installation performed under this section shall conform to the requirements of Article SA-3000.

SA-6122 Material Identification

Materials to be utilized in the fabrication and installation of components, parts, and appurtenances shall be identified on fabrication or installation plans, or both and in the specifications, as required in Article AA-8000.

SA-6123 Repair of Material With Defects

Material with defects that are discovered or produced during the fabrication and installation process may be used, provided the defects are repaired in accordance with the requirements of Article AA-8000, and for weld repairs, in accordance with AA-6300.

SA-6130 CONTROL OF INSTALLATION AND FABRICATION PROCESS

Quality control procedures shall be prepared and kept current for all fabrication and installation processes in accordance with the requirements of Article AA-8000.

SA-6140 WELDING

The welding of ductwork and ductwork supports shall comply with the requirements of AWS D1.1, AWS D1.3, AWS-D9.1 and ASME Code, Section IX, as applicable.

Welding and brazing performed in accordance with this section shall meet the requirements of AA-6300 and AA-6400.

SA-6200 FABRICATION PROCESS

SA-6210 CUTTING, FORMING, BENDING, ALIGNING, AND FITTING

(a) Uncoated metal may be cut, formed, or bent by any means that does not degrade the mechanical or chemical properties of the material.

(b) Coated metal may be cut, formed, or bent as described in para. SA-6211. Coating damaged by scratches, gouge marks, or the removal of coating shall be repaired in accordance with AA-6540.

(c) Inside bend radii shall not be less than the values given in the appropriate ASTM standard for the material grade.

(d) Parts that are to be joined may be fitted, aligned and retained in position during the joining operation by the use of bars, jacks, clamps, drift pins, tack welds or other temporary attachment. The fitting and aligning process shall not cause damage to the joined parts, or their surfaces, or cause enlargement of bolt holes greater than 20% of hole diameter, or $^1/_8$ in. (3.2 mm), whichever is greater.

(e) Temporary welded attachments may be used in the fabrication or installation of ductwork but shall be completely removed after use. Where such temporary attachments are used, they shall be subject to the following requirements:

(1) Material shall be suitable for welding with no reduction in the structural integrity of the member to which the attachment is secured.

(2) Attachment material shall be identified as required by Article SA-3000.

(3) The welder and welding procedure shall be qualified in accordance with SA-6140.

(4) The immediate area around and including the temporary attachment shall be marked in a suitable manner so that after attachment removal, the area can be examined in accordance with Article SA-5000.

(f) Access doors and access panels shall be fabricated and designed to meet the design requirements of Article SA-4000.

(g) Grilles, registers, diffusers, and their accessories shall be designed to meet the design requirements of Article SA-4000.

SA-6300 MECHANICAL FASTENING

SA-6310 GENERAL

(a) Nuts for all bolts and studs shall be engaged for the full length of the nut thread. Margin shall be allotted to prevent nut from engaging the unthreaded portion of bolt or stud.

(b) High-strength bolts, used in making bolted joints, shall be installed in accordance with the requirements of the "Specification for Structural Joints Using A325 or A490 Bolts" AISC Code.

Standard bolts used in making bolted joints shall be installed in accordance with the requirements of paras. 1.4.4 and 1.5.2 of the "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings" AISC Code.

(c) Self-drilling or self-threading screws are permissible if they are qualified in accordance with the design criteria in Article SA-4000.

(d) Rivets must be qualified in accordance with Article SA-4000.

(e) Pins for securing insulation should be secured to the metal surface by welding. Other attachment methods are acceptable, if allowed by the design specification. Justification of the method of attachment used shall be supported by evaluation or calculation, considering the requirements of SA-4600.

(f) Flange faces shall be free of joint crevices at corners. These defects shall be eliminated by welding and grinding.

SA-6400 FABRICATION TOLERANCES

SA-6410 GENERAL

The fabrication of ductwork shall be accomplished within the tolerances detailed in the following tables. These fabrication tolerances provide a method of quality control. Installation tolerances shall take precedence over fabrication tolerances. Tolerances listed below are maximum deviations permitted from design dimensions. Greater deviations, due to rolling mill tolerances, are not permitted.

(a) Rectangular ducts, measured inside the duct at the joint end or stiffener, shall conform to Table SA-6410-1.

(b) Circular ducts, measured by outside circumference or two interior diameters at 90 deg (±5) to each other, shall conform to Table SA-6410-2.

(c) After fabrication is complete, flat sheet or plate surfaces shall not have a waviness, or bulge, greater than the flatness tolerance given in Table SA-6410-3.

(d) The tolerances given in Tables SA-6410-1, SA-6410-2, and SA-6410-3 are for manufacturing. Maximum operating deflections are given in SA-4230.

(e) Holes prepared for joining mating flanges shall not exceed the required bolt diameter by more than 20%, or $\frac{1}{8}$ in. (3.2 mm), whichever is larger, of bolt diameter. The center-to-center alignment of holes must be held to meet this tolerance or one flange must be drilled. Hole spacing shall be a maximum of 4 in. (102.4 mm) center-to-center, with holes at corners of the flange.

(f) Grilles, registers, and diffusers shall be fabricated to manufacturer's dimensions and tolerances.

SA-6500 INSTALLATION TOLERANCES

Ductwork and their supports shall be installed within the tolerance specified by approved construction documents. These tolerances shall comply with the design requirements of Article SA-4000.

SA-6600 CLEANING, FINISHING, AND COATING

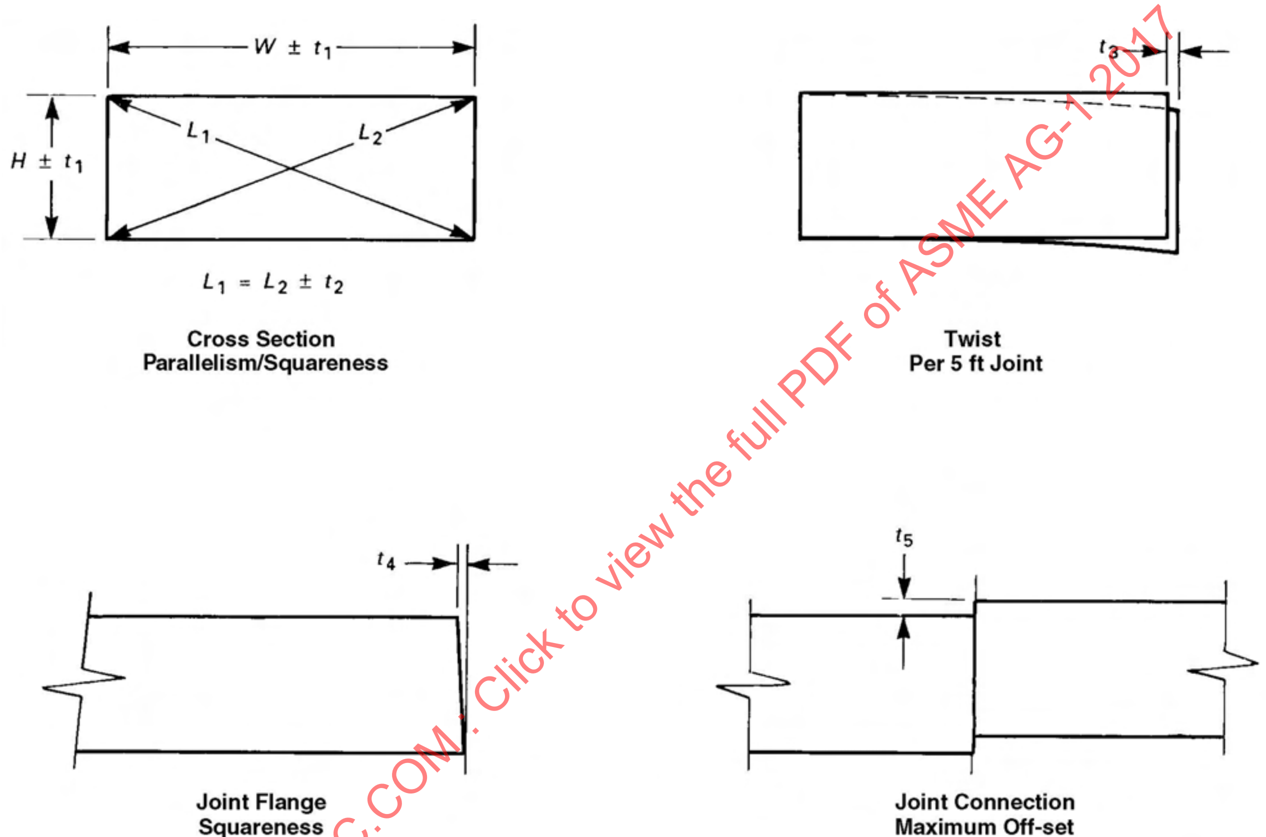
Galvanized surfaces shall be free of damage that impairs the effectiveness of the coating. Surfaces shall be repaired in accordance with AA-6540.

Painted surfaces shall be prepared and finished as described in Article AA-6000.

Painted surfaces shall be free of scratches and welding damage. Surfaces shall be repaired and repainted in accordance with Article AA-6000.

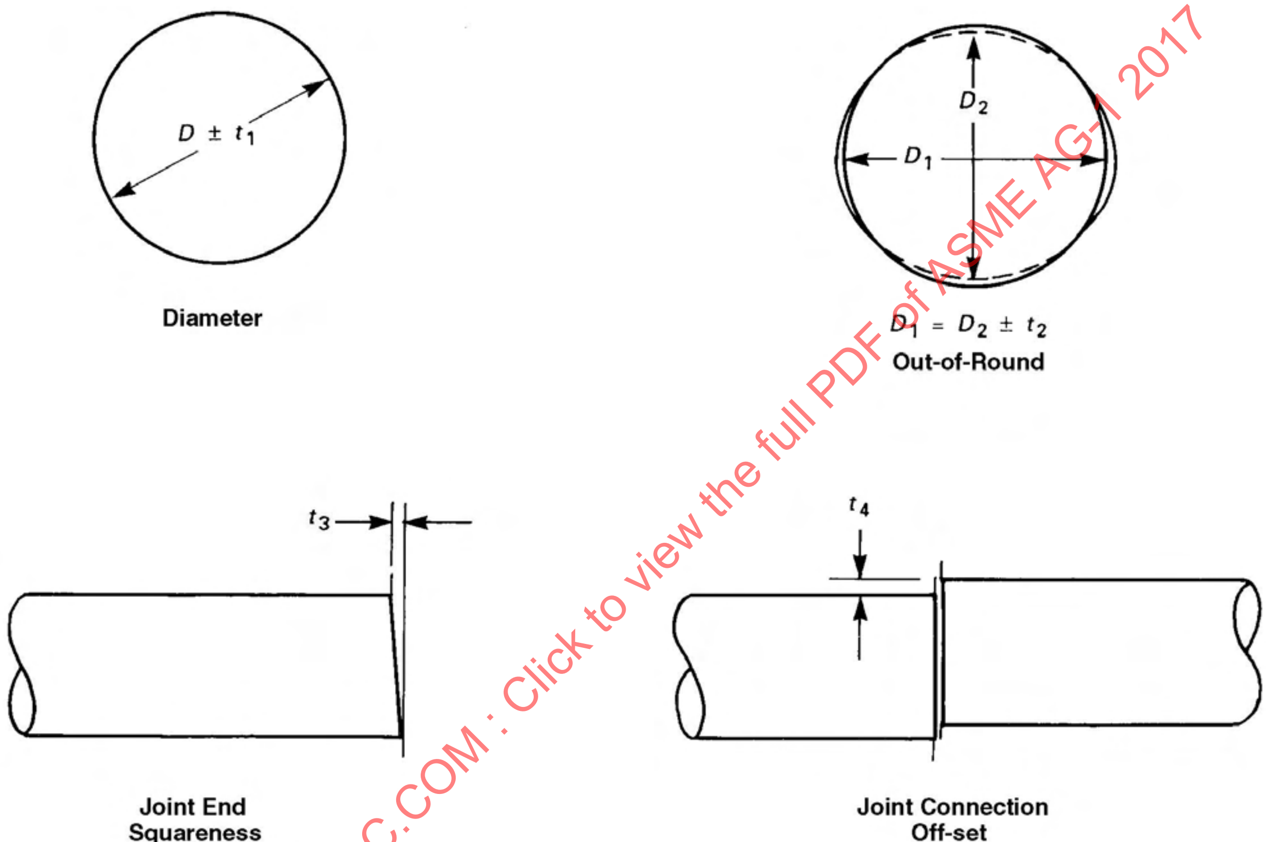
Required marking for identification shall be on the exterior of each section.

TABLE SA-6410-1 RECTANGULAR DUCTS: MAXIMUM ALLOWABLE TOLERANCES



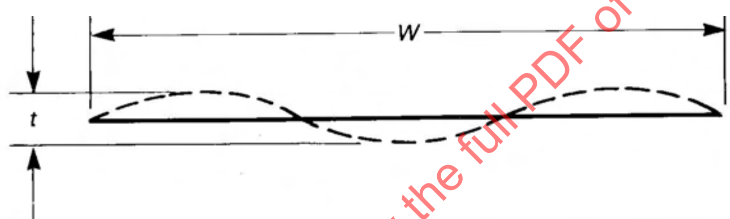
	Maximum Allowable Tolerances, in. (mm)				
W* or *H	t_1	t_2	t_3	t_4	t_5
less 12	1/16 (1.6)	1/4 (6.4)	1/8 (3.2)	1/8 (3.2)	1/16 (1.6)
12 to 18	1/8 (3.2)	1/4 (6.4)	3/16 (4.8)	1/8 (3.2)	1/8 (3.2)
18 to 24	1/8 (3.2)	3/8 (9.5)	3/16 (4.8)	1/8 (3.2)	1/8 (3.2)
24 to 48	1/8 (3.2)	3/8 (9.5)	3/16 (4.8)	1/8 (3.2)	1/8 (3.2)
48 and up	1/8 (3.2)	1/2 (12.7)	1/4 (6.4)	1/8 (3.2)	3/16 (4.8)

TABLE SA-6410-2 CIRCULAR DUCTS: MAXIMUM ALLOWABLE TOLERANCES



Maximum Allowable Tolerances, in. (mm)				
Diameter	t_1	t_2	t_3	t_4
less 18	$^1/_{16}$ (1.6)	$^1/_4$ (6.4)	$^1/_8$ (3.2)	$^1/_{16}$ (1.6)
12 to 18	$^1/_8$ (3.2)	$^3/_8$ (9.5)	$^1/_8$ (3.2)	$^1/_8$ (3.2)
18 to 24	$^1/_8$ (3.2)	$^1/_2$ (12.7)	$^1/_8$ (3.2)	$^1/_8$ (3.2)
24 to 48	$^1/_8$ (3.2)	$^3/_4$ (19.1)	$^1/_8$ (3.2)	$^1/_8$ (3.2)
48 and up	$^1/_8$ (3.2)	1 (25.4)	$^1/_8$ (3.2)	$^3/_{16}$ (4.8)

TABLE SA-6410-3 FLATNESS OF SURFACE: MAXIMUM ALLOWABLE WAVINESS TOLERANCE



Maximum Allowable Waviness Tolerance	
t = waviness tolerance of flat surfaces between duct edges and/or adjoining stiffeners. It shall not exceed 125% of allowed Manufacturers' tolerance as specified by:	
Cold-rolled steel sheet	ASTM-A568
Cold-rolled steel plate	ASTM-A6 Table 14
Hot-rolled steel sheet	ASTM-A568
Hot-rolled steel plate	ASTM-A6 Table 15
Galvanized steel sheet	ASTM-A525 Table II

ARTICLE SA-7000 PACKAGING, SHIPPING, RECEIVING, STORAGE, AND HANDLING

SA-7100 GENERAL

Packaging, shipping, receiving, storage, and handling requirements shall be in accordance with Article AA-7000 and this section.

SA-7200 PACKAGING

SA-7210 GENERAL

Ductwork and accessory item packaging requirements are dependent upon the protection level as described by AA-7230. Additional clarification or exceptions are provided below.

(a) Individual duct sections, assembled or unassembled, shall not require special packaging or end closures. These individually identified items may be pelletized for convenience. Protection equal to Level D, of ASME NQA-1 Subpart 2.2, para. 202.4, is required.

(b) Acoustically lined or insulated duct sections shall have protective wrapping to prevent water damage. Protection equal to Level C, of ASME NQA-1 Subpart 2.2, para. 202.4, is required.

(c) Grilles, registers, and diffusers shall be packaged individually by the Manufacturer to prevent any degradation. Protection equal to Level C, of ASME NQA-1 Subpart 2.2, para. 202.4, is required.

(d) Extractors, turning vanes, and splitter dampers shall be packaged individually by the Manufacturer to prevent damage and degradation until installation. Protection equal to Level C, of ASME NQA-1, is required. Should these devices be installed into the ductwork sections before shipment, all moving parts shall be secured and all sliding or operation points shall be protected from degradation by methods equal to Level C. The basic duct section level shall remain D, of ASME NQA-1 Subpart 2.2, para. 202.4.

SA-7300 SHIPPING

This section relates to all transportation methods from the original manufacturer, or supplier, to the job site. In addition to the applicable Federal and State transport regulations, the provisions of Article AA-7000 shall also apply.

SA-7400 RECEIVING

Receiving at the job site or intermediate location, where additional work is to be performed or for long-term storage, shall be accomplished in accordance with the provisions of Article AA-7000. It shall be the requirement, at any receiving point, to have adequate descriptions of items to permit suitable inspection for conformance, damage acknowledgement, and proper documentation. Records of such inspections shall be maintained until the item is reshipped or installed.

SA-7500 STORAGE

SA-7510 GENERAL

Ductwork and accessory item storage requirements are dependent upon the protection level described by AA-7230. These levels shall be the required storage requirements except in certain circumstances as listed below.

(a) Duct sections shall be stored, on adequate dunnage, in accordance with Level D requirements. Lined or insulated ductwork, unless water-proofed at time of fabrication, shall be stored in accordance with Level C requirements. Extractor and splitter dampers shall have moving parts protected in accordance with Level C requirements.

(b) Extractors, turning vanes, and splitter dampers shall be stored in accordance with the applicable levels of para. SA-7214.

(c) Ductwork supports shall be stored in accordance with Level C requirements for uncoated carbon steel and Level D requirements for other ductwork support materials.

(d) Components covered by other sections of this Code that are installed into an integral assembly that is covered by this section shall be stored in accordance with AA-7230.

ARTICLE SA-8000
QUALITY ASSURANCE

SA-8100 GENERAL

Equipment and material covered under this section shall be manufactured, fabricated, installed, inspected, and tested in accordance with the provisions of a quality assurance program meeting the requirements of Article AA-8000.

SA-8200 MATERIAL IDENTIFICATION

Measures shall be established for controlling and identifying material throughout the manufacturing process and during shipment in accordance with Article AA-8000.

SA-8300 DRAWINGS AND DOCUMENTATION

As a minimum, the following drawings and documentation shall be provided to the Owner:

(a) design parameters
(b) material certifications
(c) maximum operating pressure
(d) structural capability pressure
(e) test pressures
(f) basis and quantity for maximum allowable leakage
(g) system layout drawings
(h) welding procedures
(i) visual inspection reports
(j) test acceptance criteria
(k) leak test reports
(l) environmental qualification reports
(m) ductwork and ductwork support fabrication details

ARTICLE SA-9000
NAMEPLATES AND STAMPING

SA-9100 GENERAL

All items manufactured under the requirements of this section shall be identified to ensure compliance with the requirements of AA-8200, AA-9130, and AA-9140.

Records, as necessary to assure compliance with AA-8200, shall be maintained by the responsible organization in accordance with the approved quality assurance program.

SA-9110 STAMPING/MARKING

Stamping/marking, as used herein, provides a means of maintaining identification of finished products for the purpose of retaining traceability of material.

SA-9111 Ducts

Each duct section shall have noncorrosive, permanent identification markings. Identification markings shall relate each duct section to the applicable design and fabrication documents. Markings shall be located on the exterior of the duct. Markings need not be visible after installation is complete; however, markings shall be retrievable. It is recommended that the identification markings be placed on the ‘‘incoming air’’ end of the duct joint, as close to the end of the joint as possible, and not in such position as to be hidden or nonreadable.

SA-9112 Ductwork Supports

Each ductwork support shall have noncorrosive, permanent identification markings. Identification markings shall relate each ductwork support to the applicable design and fabrication documents.

SA-9113 Air Distribution Accessories

Air distribution devices (i.e., grilles, registers, diffusers, louvers, etc.) shall be marked, stamped, or provided with a nameplate that shall relate to the design and fabrication documents. Identification shall be retrievable after completed installation.

NONMANDATORY APPENDIX SA-A
DIVISION OF RESPONSIBILITY

This Nonmandatory Appendix defines primary responsibility for individual sections of this Code section.

TABLE SA-A-1000
DIVISION OF RESPONSIBILITY

SA-	Item	Responsible Party
3100	Certification of material	Manufacturer/Supplier
3200	Material substitution	Manufacturer/Supplier/Contractor/Engineer
3300	Material testing	Manufacturer/Supplier
4210	Load criteria	Engineer
4220	Stress criteria	Engineer
4230	Deflection criteria	Engineer
4240	Other criteria	Engineer
4320	Duct joints and seams	Contractor/Engineer
4410	Flexible connections	Manufacturer/Contractor/Engineer
4420	Gaskets	Manufacturer/Contractor/Engineer
4430	Access doors and panels	Manufacturer/Contractor/Engineer
4440	Provisions for testing and maintenance	Manufacturer/Contractor/Engineer
4450	Miscellaneous	Manufacturer/Contractor/Engineer
4530	Pressure boundary leakage evaluation	Engineer
4540	Leakage testing	Engineer/Owner/Contractor
4600	Design specification	Engineer
5120	Responsibility for procedures	Manufacturer/Contractor/Owner/Engineer
5200	Visual inspection	Contractor/Manufacturer/Owner
5320	Systems completeness	Engineer/Contractor
5330	Allowance for testing system leakage rates by sections	Engineer/Contractor

TABLE SA-A-1000
DIVISION OF RESPONSIBILITY (CONT'D)

SA-	Item	Responsible Party
5340	Testing procedures	Engineer/Contractor
5350	Documentation	Contractor
5361	Acceptance criteria — quantitative leakage tests	Contractor/Engineer
5362	Acceptance criteria — nonquantitative leakage tests	Contractor
5410	Ductwork pressure test	Contractor
5420	Longitudinal seam qualification test	Contractor
6000	Fabrication and installation	Manufacturer/Contractor
7000	Packaging, shipping, receiving, storage, and handling	Manufacturer/Supplier/Contractor/Owner
8000	Quality assurance	All Parties
9000	Nameplates and stamping	Manufacturer/Supplier/Contractor

NONMANDATORY APPENDIX SA-B
PROCEDURES TO DETERMINE ALLOWABLE LEAKAGE FOR DUCTWORK

ARTICLE SA-B-1000

SA-B-1100 PURPOSE

The purpose of this Appendix is to provide additional guidance in order to determine the allowable leakage for air cleaning, air conditioning, and ventilation systems that can be used to determine duct construction, installation, and test requirements.

This Appendix presents a method for determining allowable leakage based on health physics requirements (such as radioactivity concentration, maximum permissible concentration, and iodine protection factor), and provides typical sample problems.

Optional guidance is also provided for determining alternate leakage criteria based on air cleaning and air cooling system effectiveness and expected system installation qualities.

SA-B-1200 ALLOWABLE LEAKAGE BY HEALTH PHYSICS CRITERIA

SA-B-1210 GENERAL

10 CFR Part 20 sets limits on the airborne radioactive material concentrations in areas of nuclear facilities in which plant personnel may be present. These limits are given by 10 CFR 20 Appendix B, Table 1.

This section provides procedures to determine the maximum duct outleakage based on the maximum permissible concentration (MPC) as determined by 10 CFR 20.103, paras. a and b.

SA-B-1220 PROCEDURE TO DETERMINE ALLOWABLE LEAKAGE BY MAXIMUM PERMISSIBLE CONCENTRATION METHOD

SA-B-1221

The following describes a procedure for determining allowable leakage, in cfm per square foot (L/s per square meter) of duct surface, under positive pressure in either normal or transient conditions, which are located in a clean interspace.

(a) Determine the approximate radioactivity concentration (C_d) in MPC expected inside the duct.

(b) Determine the approximate radioactivity concentration (C_r) in MPC that can be expected in the room. For continuous occupancy, C_r is less than 1.

(c) Enter Fig. SA-B-1221 with the C_r/C_d ratio and determine the allowable unit leakage in cfm/ft^2 (L/s/m^2) of duct surface. The value taken from the chart will be applicable at the operating pressure.

where

A = duct surface area, ft^2 (m^2)

AC = room ventilation rate, air changes per hour or 60qv/Hlw (3.6 qv/Hlw)

b = duct width, in. (mm)

C_d = radioactive concentration in duct, μCi/cc

C_r = radioactive concentration in room, μCi/cc

D = duct diameter, in. (mm)

G = contamination source term, μCi/hr

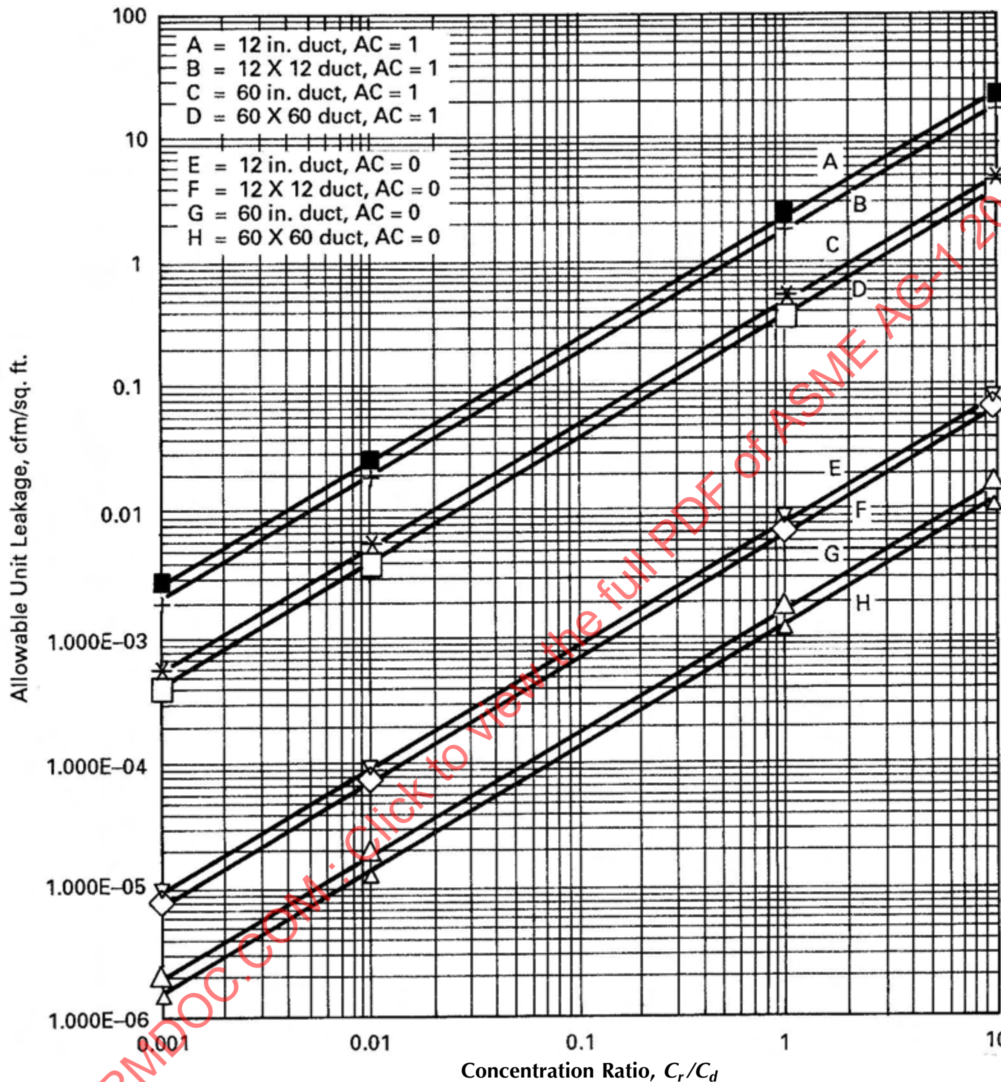
H = room height, ft (m)

h = duct height, in. (mm)

L = allowable duct leakage per unit surface area, cfm/ft^2

ℓ = room length, ft (m)

FIG. SA-B-1221 ALLOWABLE UNIT LEAKAGE FROM DUCT OR HOUSING TO OCCUPIED SPACE



GENERAL NOTES:

(a) Based on eq. (B-1) in para. B.2.1(d) and a 25 ft^2 room × 20 ft high. For other duct (and room) lengths and heights, prorate chart values by

$$L = L_{chart} \times \frac{\text{duct length}}{25} \times \frac{\text{room height}}{20}$$

(b) Contamination assumed to mix uniformly in space.

(c) 1-131 assumed to be contaminating nuclide.

(d) Allowable unit leakage applies to maximum operating pressure P_d as defined in para. 4.6.3.

l_d = duct length, ft (m)
MPC = maximum permissible concentrations
qv = room ventilation rate, cfm (L/s)
$T^1\!/_2$ = nuclide half-life, hr
V_r = room volume, ft^3 (m^3)
w = room width, ft (m)
λ = radioactivity decay constant, hr^{-1}

Duct-to-room contamination source term:

$$G = 1.7 \times 10^6 C_d LA \tag{1}$$

$$(G = 3.6 \times 10^6 C_d LA)$$

Equilibrium concentration in the room that results from outleakage is:

$$C_r = \frac{G}{28320\ V_r\left\{\lambda + \dfrac{60\ qv}{V_r}\right\}} \tag{2}$$

$$\left\{C_r = \frac{G}{1 \times 10^6\ V_r\left\{\lambda + \dfrac{3.6\ qv}{V_r}\right\}}\right\}$$

Equations (1) and (2) conservatively assume no reduction in C_r due to exfiltration of air from room at the duct leakage rate. Room volume is

$$V_r = H\ell w \tag{3}$$

For a rectangular duct, the surface area is

$$A = \frac{\ell_d}{6}(h + b) \tag{4}$$

$$\left\{A = \frac{\ell_d}{500}(h + b)\right\}$$

Substituting eqs. (1), (3), and (4) into eq. (2) and transposing, the general equation for a rectangular duct is

$$L = \frac{H\ell w}{10\ \ell_d\ (h + b)}\left\{\frac{C_r}{C_d}\right\}\left\{\frac{0.693}{T^1\!/_2} + \overline{\text{AC}}\right\} \tag{5}$$

$$\left\{L = \frac{138\ H\ell w}{\ell_d\ (h + b)}\left\{\frac{C_r}{C_d}\right\}\left\{\frac{0.693}{T^1\!/_2} + \overline{\text{AC}}\right\}\right\}$$

Assuming that the duct cross section is square ($b = h$) and that the room is square ($w = \ell$), eq. (5) reduces to

$$L = \frac{1}{20}\left\{\frac{C_r}{C_d}\right\}\frac{H\ell^2}{h\ell_d}\left\{\frac{0.693}{T^1\!/_2} + \overline{\text{AC}}\right\} \tag{6}$$

$$\left\{L = \frac{69\ H\ell^2}{h\ell_d}\left\{\frac{C_r}{C_d}\right\}\left\{\frac{0.693}{T^1\!/_2} + \overline{\text{AC}}\right\}\right\}$$

Further assuming that the room height is 20 ft (6.1 m):

$$L = \left\{\frac{C_r}{C_d}\right\}\frac{\ell^2}{h\ell_d}\left\{\frac{0.693}{T^1\!/_2} + \overline{\text{AC}}\right\} \tag{7}$$

$$\left\{L = \frac{420\ \ell^2}{h\ell_d}\left\{\frac{C_r}{C_d}\right\}\left\{\frac{0.693}{T^1\!/_2} + \overline{\text{AC}}\right\}\right\}$$

If the contaminating nuclide is I-131 ($T^1\!/_2$ = 193.6 hr) and 1 = 25 ft and ℓd = 25 ft (7.6 m):

$$L = \left\{\frac{C_r}{C_d}\right\}\frac{25}{h}(0.00358 + \overline{\text{AC}}) \tag{8}$$

$$\left\{L = \left\{\frac{C_r}{C_d}\right\}\frac{25}{h}(0.00358 + \overline{\text{AC}})\right\}$$

For a sealed room, $\overline{\text{AC}}$ = 0:

$$L = \frac{1}{11.17}\left\{\frac{C_r}{C_d}\right\}\frac{1}{h} \tag{9}$$

$$\left\{L = \frac{11.43}{h}\left\{\frac{C_r}{C_d}\right\}\right\}$$

For a room with $\overline{\text{AC}}$ = 1:

$$L = \left\{\frac{C_r}{C_d}\right\}\frac{25.09}{h} \tag{10}$$

$$\left\{L = \frac{3202}{h}\left\{\frac{C_r}{C_d}\right\}\right\}$$

For a round duct, eq. (6) is replaced by

$$A = \pi \left\{\frac{D}{12}\right\} \ell_d \qquad (11)$$

$$\left\{A = \pi \left\{\frac{D}{1000}\right\} \ell_d\right\}$$

and general eq. (7) becomes

$$\left\{L = \frac{1}{15.7} \left\{\frac{C_r}{C_d}\right\} \left\{\frac{H\ell w}{\ell_d D} \left\{\frac{0.693}{T^{1/2}} + \overline{AC}\right\}\right\}\right\} \qquad (12)$$

$$L = 88.4 \left\{\frac{C_r}{C_d}\right\} \left\{\frac{H\ell w}{\ell_d D} \left\{\frac{0.693}{T^{1/2}} + \overline{AC}\right\}\right\}$$

Where N nuclides are present in the duct, it can be shown that

$$L = \frac{H\ell w}{10\ell_d(h + b)} \; \frac{\sum_{n=1}^{N} C_r n/MNPCn}{\sum_{n=1}^{N} \frac{C_d n/MPCn}{0.693/T^{1/2}/2n + \overline{AC}}} \qquad (13)$$

In most nuclide groupings, the term $(0.693/T^{1/2})$ is negligible when compared to even minimal ventilation air change rates used in practice. Hence, eq. (13) simplifies to

$$\left\{L = \frac{138\, H\ell w}{\ell_d\,(h + b)} \; \frac{\sum_{n=1}^{N} C_r n/MPCn}{\sum_{n=1}^{N} \frac{C_d n/MPCn}{0.693/T^{1/2}/2n + \overline{AC}}}\right\}$$

$$L = \frac{H\ell w\, \overline{AC}}{10\ell_d\,(h + b)} \; \frac{\sum (C_r n/MPCn)}{\sum (C_d n/MPCn)} \qquad (14)$$

$$\left\{L = \frac{138\, H\ell w\, \overline{AC}}{\ell_d\,(h + b)} \; \frac{\sum (C_r n/MPCn)}{\sum (C_d n/MPCn)}\right\}$$

Since

$$\sum_{n=1}^{N} (C_r n/MPCn)$$

$C_r n/MPCn$ is by 10 CFR 20, the equivalent concentration in MPC, it can be seen that for a ventilated room eqs. (14) and (5) are essentially the same. It can be concluded that eq. (5) is applicable to multi-nuclide duct leakage as well. Finally, the ratio

$$\sum_{n=1}^{N} (C_r n/MPCn)$$

represents the fraction of maximum permissible dose for the stated period of exposure, usually a 40 hr week.

Determine the leak test requirements from SA-4500. If testing is required, determine test method from TA-4300 and the required test pressure. Adjust allowable leak rate for test pressure in accordance with SA-B-1222(h).

SA-B-1222

For spaces required to be maintained at a negative pressure with respect to surrounding areas, the effect of inleakage into negative pressure ducts, outside of the space served, must be evaluated to determine the reduction in air exchange rate and corresponding increase in room MPC. The procedure is as follows:

(a) Determine source terms and parameters for the event (e.g., pump seal leak rate, concentration of leaking fluid space volume, required MPC).

(b) Determine the minimum air exchange rate (air flow rate/room volume) required to maintain minimum MPC based on ALARA program.

(c) Determine the minimum flow rate to maintain space at design negative pressure.

(d) Determine design flow rate (this may be selected to ventilate space and maintain environmental conditions).

(e) Determine minimum airflow tolerance [item (d) − item (b) or item (d) − item (c)].

(f) Determine surface area of duct under negative pressure outside the space served.

(g) Determine allowable leakage rate (cfm/ft^2) (L/s/m^2) by dividing item (e) by item (f).

(h) Determine pressure boundary leakage requirements in accordance with SA-4500. If testing is required, adjust allowable leakage for test pressure in accordance with the following formula:

$$L_t = L_o\,(P_t/P_o)^{1/2} \qquad (15)$$

where

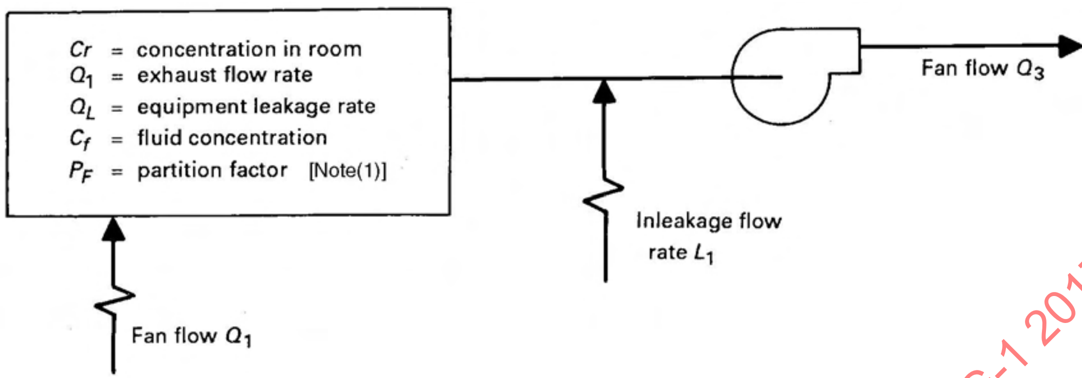
L_o = leak rate at operating pressure, cfm/ft^2 (L/s/m^2)

L_t = leak rate at test pressure, cfm/ft^2 (L/s/m^2)

P_o = operating pressure, in. wg (kPa)

P_t = test pressure, in. wg (kPa)

FIG. SA-B-1222 SYSTEM PARAMETERS



NOTE:
(1) The partition factor is the fraction of radioactivity in the process fluid that will become airborne when that process fluid is leaked into ambient air.

(i) This procedure may not be required if the system is designed, tested, and adjusted such that the minimum design flow from the space served can be achieved and the fan sized to handle the minimum flow plus the infiltration.

See Fig. SA-B-1222.

SA-B-1222.1 Sample Problems

(a) **Given:** A 30 in. × 12 in. × 50 ft (762 mm × 305 mm × 15.2 m) long duct section at the fan discharge, represented by Scheme No. 7 of Fig. SA-B-1410-1, has a rated flow of 10,000 cfm (4720 L/s). The total surface area of the duct system is 1,050 ft^2 (97.5 m^2). This duct is under 4 in. wg (1.0 kPa) positive pressure and passes through an occupied area 25 ft × 25 ft × 20 ft high (7.6 m × 7.6 m × 61 m), where the C_r shall not exceed 0.32 MPC. The discharge for this ductwork is credited with high-level release. The air change rate in the surrounding room is at least 1 air change per hour.

Determine:

Allowable leakage based on health physics requirements.

Solution:

If the same duct is exhausting a contaminated space with an effective radioactivity concentration of 1,000 MPC, it is assumed to have a concentration, C_d, of 100 MPC after passing through the filters. If the occupied space around the duct is to be limited to a concentration, C_r, of 0.32 MPC, then $C_r/C_d = 0.0032$.

Solving eq. (5) of SA-B-1221,

$$L = \frac{H\ell w}{10\ell_d\,(h+b)} \left\{\frac{C_r}{C_d}\right\} \left(\frac{0.693}{T^{1/2}} + \overline{AC}\right)$$

where

$T^{1/2} = 193.6$ hr

$$\left\{L = \frac{138\ H\ell w}{\ell_d\,(h+b)} \left\{\frac{C_r}{C_d}\right\} \left\{\frac{0.693}{T^{1/2}} + \overline{AC}\right\}\right\}$$

$$L = \frac{20 \times 25 \times 25}{10(50)(30+12)}\ 0.0032 \left(\frac{0.693}{193.6} + 1\right)$$

$$\left\{L = \frac{138(6.1 \times 7.6 \times 7.6)}{(15.2)(762+305)}\ (0.0032) \left\{\frac{0.693}{193.6} + 1\right\}\right\}$$

where

L = 0.0019 cfm/ft^2 or 0.002 cfm/ft^2

L = 0.0096 L/s/m^2 or 0.010 L/s/m^2

(b) **Given:** A cubicle containing a normally operating pump with a leak rate of 1 gal/hr (3.8 L/hr) at a concentration of 0.15 Ci/cc. (The MPC I131 is 9 × 10^{-9} Ci/cc.)

Determine:

(1) The required minimum room ventilation rate to maintain $^1/_3$ MPC.

(2) The allowable duct inleakage if the exhaust fan is rated at 1,500 cfm (708 L/s).

(3) The unit leakage if duct system consists of 100 ft (30.5 m) of 12 in. × 12 in. ductwork outside of the cubicle (305 mm × 305 mm).

Solution:
Consider a case with the following parameters:

$$C_f = 0.15\ \mu\text{Ci/cc (I-131)}$$

$$\text{allowable } C_r = \tfrac{1}{3}\ \text{MPC} = \tfrac{1}{3}\ 9 \times 10^{-9}\ \text{Ci/cc}$$

$$= 3 \times 10^{-9}\ \text{Ci/cc}$$

P_F = 0.0075 (Reference NUREG-0017, para. 2.2.5.2, Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents for PWR's, April 1976)
qL = 1 gal/hr × 1 hr/60 min × 3,785 cc/gal
qL = (3.8 L/hr) × 1 hr/60 min × 1,000 cc/L
= 63 cc/min
To meet C_r under the above conditions,

$$Q_1 = qL \times C_f \times P_F / C_r$$

= 63 cc/min × 0.15 Ci/cc × 0.0075/(3 × 10^{-9} Ci/ cc)
= 2.363 × 107 cc/min × (1 ft/30.48 cm)3 = 834 cfm
(= 2.363 × 107 cc/min × (1 L/1,000 cc) × (1 min/60 sec) = 394 L/s)

If the fan is sized to handle 1,500 cfm (708 L/s) for this system, then the allowable clean inleakage (Q_i) is:

$$Q_i = 1{,}500\ \text{cfm} - 834\ \text{cfm} = 666\ \text{cfm}$$

$$(Q_i = 708\ \text{L/s} - 394\ \text{L/s} = 314\ \text{L/s})$$

However, it is also a design consideration to maintain a linear air velocity of 50 ft/min (0.254 m/s) while the 25 ft^2 (2.3 m^2) door is open. (This criterion is set forth to maintain control of airborne radioactivity even though the door is open.) In order to meet this criterion, a flow rate (Q_1) of 50 ft/min × 25 ft^2 = 1250* cfm is required. The allowable clean air inleakage is then 1,500 − 1,250 (708 − 584) or 250 cfm (124 L/s). The unit duct leakage is therefore equal to:
*0.254 m/s × 2.3 m^2 × (1 L/0.001 m^3) = 584 L/s

$$\frac{250\ \text{cfm}}{\text{duct length} \times \text{perimeter}} = \frac{250\ \text{cfm}}{\dfrac{(50)2(30) + 2(12)}{12}}$$

$$\frac{124\ \text{L/s}}{\text{duct length} \times \text{duct perimeter}} = \frac{124\ \text{L/s}}{\dfrac{(15.2)2(762) + 2(305)}{1{,}000}}$$

L = 0.7 cfm/ft^2
(L = 3.8 L/s/m^2)

SA-B-1230 ALLOWABLE LEAKAGE BY IODINE PROTECTION FACTOR REDUCTION

SA-B-1231 General

The iodine protection factor (IPF) is used to quantify the protection offered to plant personnel by air cleaning systems in protected areas of nuclear facilities that are required to remain habitable during and following design basis accidents.

The location of the air cooling, ventilation, and air cleaning system components, whether inside or outside of the habitability envelope, will affect the value of the IPF. When portions of these systems are located outside the habitability envelope, the effect of duct inleakage or outleakage is a reduction of the IPF value.

SA-B-1232 Determination of IPF

SA-B-1232.1 IPF — All System Components Inside Habitability Envelope

The location of all components of the habitability area air cooling, ventilation, and air cleaning systems, within the habitability envelope, is considered here as the ideal case and basis of evaluating duct leakage.

The IPF is defined as follows:

$$\text{IPF}^1 = \frac{\text{Dose* Without Protection}}{\text{Dose with Protection}}$$

* - due to radioactive iodine

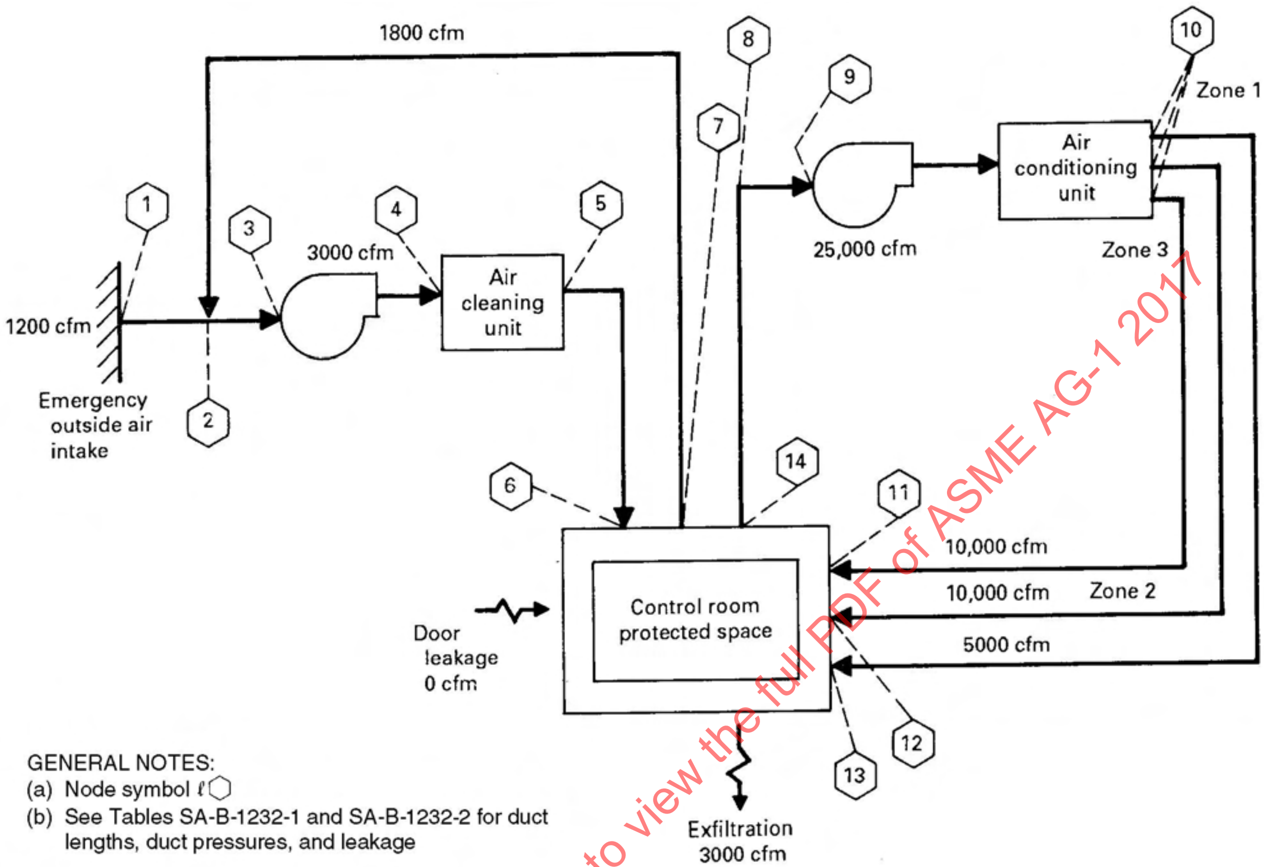
The value of the IPF for the configuration shown by Fig. SA-B-1232.1 is determined by the following:

$$\text{IPF} = \frac{F_1 + n\,F_2 + F_3}{F_1(1 - n) + F_3} \tag{16}$$

where
F_1 = rate of outside make-up air, cfm (L/s)
F_2 = rate of filtered air recirculation, cfm (L/s)
F_3 = rate of unfiltered air infiltration through walls, doors, etc., cfm (L/s)
n = radioiodine removal efficiency (per regulatory requirements)

[1] Murphy, Campe, ''Nuclear Power Plant Control Room Ventilation System Design for Meeting GDC-19,'' 13th AEC Air Cleaning Conference.

FIG. SA-B-1232.1 CONTROL ROOM SYSTEM FLOW DIAGRAM



GENERAL NOTES:
(a) Node symbol ℓ⬡
(b) See Tables SA-B-1232-1 and SA-B-1232-2 for duct lengths, duct pressures, and leakage

SA-B-1232.2 IPF — Components Inside and Outside the Habitability Envelope

When all or part of the components of the habitability air cooling, ventilation, and air cleaning systems are located outside of the habitability zone, the leakage of these components will alter the IPF. The following equation takes into account duct leakage for the system configuration shown by Fig. SA-B-1232.2:

$$\text{IPF} = \frac{F_5{}^1 + nF_2 + F_3}{F_1(1 - n) + F_3} \quad (17)$$

where

$$F_1{}^1 = F_1 + (L_f - L_o1), \text{ cfm (L/s)} \quad (18)$$

$$F_5{}^1 = F_5 + (L_o2 - L_u) - F_3, \text{ cfm (L/s)} \quad (19)$$

$$F_1 = F_5 + (L_o1 - L_f) + (L_o2 - L_u) - F_3, \text{ cfm (L/s)} \quad (20)$$

where

L_f = duct and housing inleakage with subsequent filtration, cfm (L/s)

L_o1 = outleakage from positive pressure air cleaning ducts and housings, cfm (L/s)

L_o2 = duct and housing outleakage from positive pressure air conditioning system, cfm (L/s)

L_u = duct and housing inleakage without filtration, cfm (L/s)

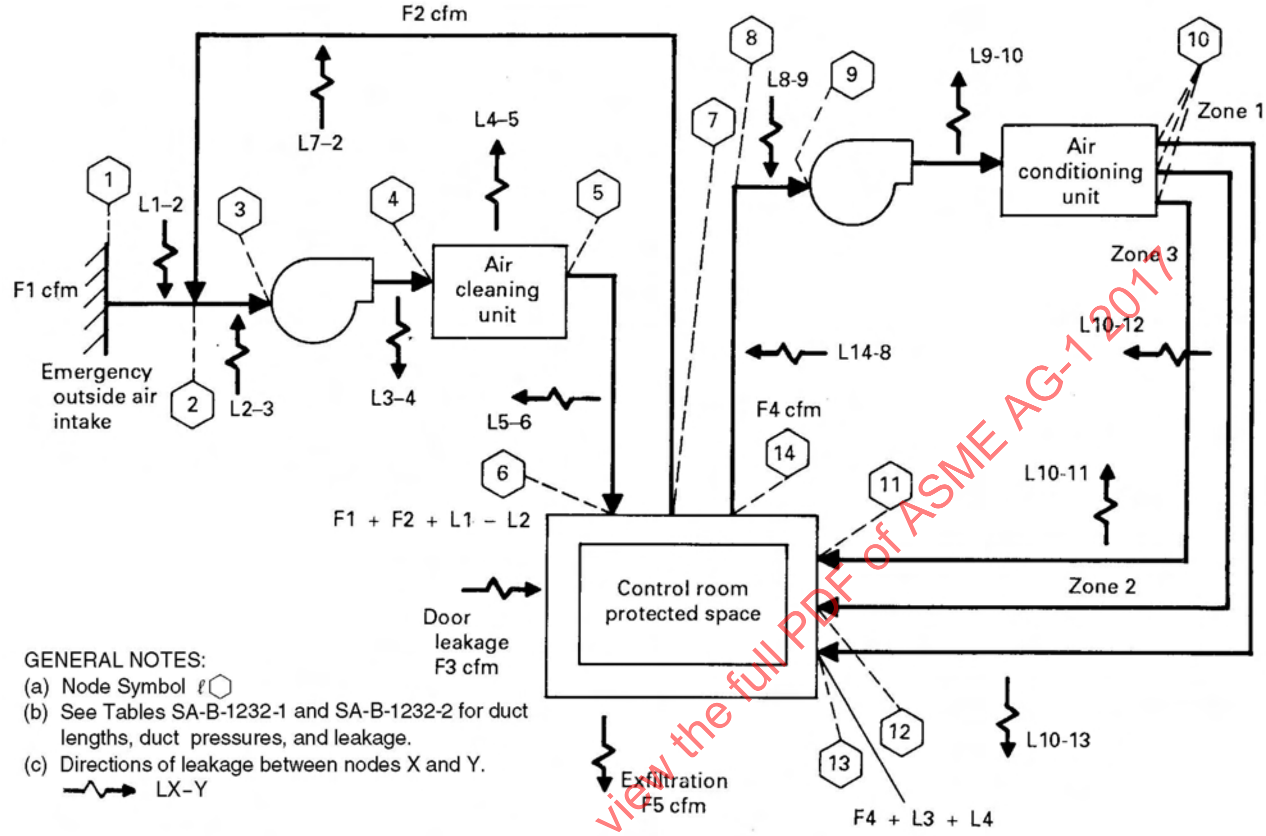
F_5 = control room boundary exfiltration, cfm (L/s)

NOTE: $(L_o1 - L_f) + (L_o2 - L_u)$ represents the additional make-up air required in order to maintain control room pressurization due to air conditioning duct and housing leakage.

SA-B-1233 Procedure to Determine Allowable Leakage by IPF Value Reduction

The following procedure quantifies the reduction of the effectiveness of the habitability area air cleaning system due to duct leakage, in terms of IPF value reduction. By limiting the percent reduction of IPF value, with respect to duct leakage, the effectiveness

FIG. SA-B-1232.2 CONTROL ROOM SYSTEM FLOW DIAGRAM WITH LEAKAGE PATHS



of the air cleaning system in limiting personnel dose is maintained.

(a) The determination of the air cleaning system flow rate usually involves an iterative process because it is based on

(1) the amount of airflow required to maintain a positive pressure differential [approximately 0.125 in. wg) (0.031 kPa)] across the control boundary, including leakage through the duct system

(2) the amount of filtered recirculation air required to achieve the required IPF

(b) The air required to pressurize the control room is first calculated, and an assumed quantity for duct leakage is added to it. After duct and housing leakage calculations have been performed for the system configuration and layout, the original assumption is revised accordingly. The make-up airflow rate should be equal to the control room exfiltration air plus duct outleakage less the duct inleakage and control room infiltration (if any).

(c) The filtered recirculation air quantity is determined by calculating the ratio of recirculated air to outside air to meet a conservative IPF. The conservative IPF is determined by calculating the minimum acceptable IPF required to meet General Design Criterion 19 (10 CFR 50, Appendix A) limits and multiplying this by a safety factor that will allow for a decrease in IPF due-to-duct leakage. The recirculation air quantity is then rechecked and revised, as necessary, when evaluating the IPF reduction factor due to duct leakage.

(d) After the outside and recirculated air quantities are initially determined and the equipment located, the ductwork can be sized and routed. The pressure in the duct, relative to the surrounding area, must be determined for the purpose of duct leakage calculations.

(e) Next, calculate duct surface areas outside the habitable zone, classify as positive pressure, filtered recirculation, unfiltered recirculation.

(f) Based on a parametric analysis, using eqs. (17) through (20), determine the maximum allowable leak rates for L_f, L_1, L_2, L_u such that the IPF is achieved.

(g) Determine unit leak rate by dividing allowable leak rates [item (f)] by surface areas [item (e)]. This is the unit leak rate at operating pressure.

(h) Determine the leak test method to be used, and determine the test pressure.

(i) Adjust the allowable unit leak rate for test pressure, in accordance with eq. (15).

SA-B-1234 Sample Problems

Given: A control room complex is provided with a safety-related air cleaning and cooling system. Figure SA-B-1232.2 shows the configuration of the system. During accident conditions, the air cleaning system is required to provide a minimum IPF value of 150.

The air cleaning unit and the air cooling unit are located outside of the protected area (i.e., the habitability envelope) in a contaminated interspace. System parameters are given by Tables SA-B-1232-1 and SA-B-1232-2.

Determine:

Allowable leakage for L_f, L_1, L_2, and L_u to meet or exceed the minimum IPF.

Ductwork and Housing Leakage Classifications

From Fig. SA-B-1410-2, Scheme No. 19, the leakage classes for the recirculation air cleaning system are determined as Class II. Note, since the make-up air is not filtered prior to entering the return duct, the return duct is assigned leakage Class I.

The leakage class of the air conditioning units are, leakage Class I for the negative pressure return air duct (because any inleakage would be unfiltered), and leakage Class II for the positive pressure supply duct (assuming control room pressure boundary requirements can be maintained).

Solution:

For this example, an air cleaning system of 3,000 cfm (1,416 L/s) flow capacity has been selected based on 1,200 cfm (566 L/s) required for pressurization and a ratio of recirculation airflow to outside airflow of 1.5. This ratio has been selected to obtain an initial conservative IPF of 248. For this hypothetical case, a minimum acceptable IPF of 150 will be assumed. In addition to the air cleaning system, the control room also requires a recirculating type air conditioning system with an assumed capacity of 25,000 cfm (11 800 L/s) [approximately 100 tons (351 685 W) of cooling capacity]. The exfiltration has been determined to be 1,000 cfm (472 L/s) maximum at 0.125 in. wg (0.031 kPa).

The maximum allowable duct leakage that will satisfy the health physics requirements is determined for this example by evaluating the reduction in the IPF. The IPF is used to express the reduction in radioiodine concentration within the control room as a result of filtration and recirculation.

For this example, the IPF is determined using eq. (17):

$$\text{IPF} = \frac{F_1 + nF_2 + F_3}{(1 - n)F_{1} + F_3}$$

where

F_1 = filtered outside air, 1,200 cfm (566 L/s)
F_2 = filtered recirculated air, 1,800 cfm (850 L/s)
F_3 = unfiltered air infiltration, 0 cfm (0 L/s)
n = filtration efficiency/100

Assuming an unfiltered inleakage (through the control room boundary) of zero, since all doors have airlock vestibules, and a filter efficiency of 99% gives:

$$\text{IPF} = \frac{1200 + (0.99)(1{,}800) + 0}{(1 - 0.99)(1{,}200) + 0}\ 248.5$$

$$\text{IPF} = \frac{566 + (0.99)(850) + 0}{(1 - 0.99)(566) + 0}\ 248.7$$

For this particular example, a minimum IPF of 150 is required in order to meet the dose requirements of General Design Criterion 19.

In this case, as long as there is no duct leakage, the minimum required IPF is exceeded. However, the IPF is reduced when the duct inleakage and outleakage are taken into account. Therefore, this must be evaluated to determine if the reduced IPF is still acceptable.

The surface area for the air cleaning duct and housing under negative pressure, which would experience inleakage with subsequent filtration (L_f), is

Nodes	Surface Area, ft^2 (m^2)	
1–2	131	(12.2)
2–3	84	(7.8)
7–2	236	(21.9)
	Total 451	(41.9)

The surface area of the air cleaning system under a positive pressure is

Nodes	Surface Area, ft^2 (m^2)	
3–4	28	(2.6)
4–5	842	(78.2)
5–6	283	(26.3)
	Total 1,153	(107.1)

TABLE SA-B-1232-1
CONTROL ROOM AIR CLEANING SYSTEM
PARAMETERS FOR LEAKAGE ANALYSIS

Nodes From–To	Duct Size, in. (mm)	Duct Length, ft (m)	Duct Surface Area, ft^2 (m^2)	Duct Pressure, in. wg (kPa)	Leakage Class
1–2	10 O.D. (254)	50 (15.2)	131 (12.1)*	−1.0 (−0.25)	II
2–3	16 O.D. (406)	20 (6.1)	84 (7.9)*	−2.0 (−0.50)	II
3–4	22 × 12 (559 × 305)	5 (1.5)	28 (2.6)**	+10.0 (2.5)	I
4–5	36 × 84 (914 × 2134)	40 (12.2)	842 (78.2)***	+10.0 (2.5)	I
5–6	22 × 12 (559 × 305)	50 (15.2)	283 (26.3)**	2.0 (0.50)	II
7–2	12 O.D. (305)	75 (22.9)	236 (21.9)*	1.0 (0.25)	I

*Calculated using $A = \pi \frac{(D)}{1000} Id$

**Calculated using $A = \frac{Id}{500}(h + b)$

***Straight conversion, ft^2 to m^2

TABLE SA-B-1232-2
CONTROL ROOM AIR CONDITIONING SYSTEM
PARAMETERS FOR LEAKAGE ANALYSIS

Nodes From–To	Duct Size, in. (mm)	Duct Length, ft (m)	Duct Surface Area, ft^2 (m^2)	Duct Pressure, in. wg (kPa)	Leakage Class
14–8	60 × 30 (1524 × 762) (15.2)	50	750 (69.5)*	−2.0 (−0.50)	I
8–9	60 × 30 (1524 × 762) (7.6)	25	375 (34.7)*	−3.0 (−0.75)	I
9–10	72 × 96 [Note (1)] (1829 × 2438)	10 (3.0)	376 (34.9)**	+5.0 (+1.2)	I
10–11	40 × 20 (1016 × 508 (12.2)	40	400 (37.2)*	+4.0 (+1.0)	II
10–12	40 × 20 (1016 × 508) (12.2)	40	400 (37.2)*	+4.0 (+1.0)	II
10–13	26 × 12 (660 × 305) (12.2)	40	250 (23.5)*	+4.0 (+1.0)	II

NOTE:
(1) Housing Dimensions.

*Calculated using $A = \frac{Id}{500}(h + b)$

**Straight conversion, ft^2 to m^2

The surface of the air conditioning system under a negative pressure is

Nodes	Surface Area, ft^2 (m^2)
14–8	750 (69.7)
8–9	375 (34.8)
	Total 1,125 (104.5)

The surface area of the air conditioning system under a positive pressure is

Nodes	Surface Area, ft^2 (m^2)
9–10	376 (34.9)
10–11	400 (37.2)
10–12	400 (37.2)
10–13	250 (23.2)
	Total 1,426 (132.5)

For the air cleaning system, we will assume, based on prior test experience and the type of duct construction used, that the unit leak rate, in the operating pressure range specified, will be 0.025 cfm/ft^2. This results in

(0.127 L/s/m^2)

$$L_f = 451 \text{ ft}^2 \times 0.025 \text{ cfm/ft}^2 = 11.3 \text{ cfm}$$
$$(41.9 \text{ m}^2) \times (0.127 \text{ L/s/m}^2) = (5.32 \text{ L/s})$$

$$L_o1 = 1153 \text{ ft}^2 \times 0.025 \text{ cfm/ft}^2 = 28.8 \text{ cfm}$$
$$(107.1 \text{ m}^2) \times (0.127 \text{ L/s/m}^2) = (13.6 \text{ L/s})$$

$$\text{Air cleaning system net leakage} = L_o1 - L_f$$

$$= 28.8 \text{ cfm} - 11.3 \text{ cfm}$$
$$(13.6 \text{ L/s}) - (5.32 \text{ L/s})$$

$$= 17.5 \text{ cfm}$$
$$(8.28 \text{ L/s}) \text{ exfiltration}$$

For air conditioning systems, assume the leak rate to be 0.07 cfm/ft^2 (0.36 L/s/m^2)

$$L_u = 1{,}125 \text{ ft}^2 \times 0.07 \text{ cfm/ft}^2 = 78.8 \text{ cfm}$$
$$(104.5 \text{ m}^2) \times (0.36 \text{ L/s/m}^2) = (37.6 \text{ L/s})$$

$$L_o2 = 1{,}426 \text{ ft}^2 \times 0.07 \text{ cfm/ft}^2 = 99.8 \text{ cfm}$$
$$(132.5 \text{ m}^2) \times (0.36 \text{ L/s/m}^2) = (47.7 \text{ L/s})$$

$$\text{Net air conditioning system leakage} = L_o2 - L_u$$

$$= 99.8 \text{ cfm} - 78.8 \text{ cfm } (47.7 \text{ L/s}) - (37.6 \text{ L/s})$$

$$= 21 \text{ cfm exfiltration } (10.1 \text{ L/s})$$

With airlock vestibules, $F_3 = 0$; inserting into eqs. (18) and (19) gives

$$F'_1 = F_1 + (L_f - L_o1)$$
$$= 1{,}200 + (11.3 - 28.8)$$
$$(566) + (5.32 - 13.6)$$
$$= 1{,}182.5 \text{ cfm}$$
$$(557.7 \text{ L/s})$$

$$F'_5 = F_5 + (L_o2 - L_u) - F_3$$
$$= 1{,}000 + (99.8 - 78.8) - 0$$
$$(472 + (47.7 - 37.6) - 0$$
$$= 1{,}021 \text{ cfm}$$
$$(482.1 \text{ L/s})$$

$$\text{IPF} = \frac{1{,}021 + (0.99 \times 1{,}800) + 0}{(1 - 0.99)(1{,}182.5) + 0}$$
$$= 237$$

$$\text{IPF} = \frac{482.1 + (0.99 \times 850) + 0}{(1 - 0.99)(557.7) + 0}$$
$$= 237$$

Since this is greater than the required IPF with margin, the duct leakage is acceptable.

Based on this analysis, the actual leakage from each duct segment and housing should be calculated, based on actual operating pressure, to determine the actual allowable leakage. This value should then be corrected for test pressure to establish acceptance criteria for duct/housing leak testing.

Subsequently, if actual test results indicated that the inleakage was:

L_f = 50 cfm (23.6 L/s) L_o1 = 30 cfm (14.2 L/s)
L_u = 200 cfm (94.4 L/s) L_o2 = 50 cfm (23.6 L/s)

the IPF would become:

$$F'_1 = 1{,}200 + (50 - 30) = 1{,}220 \text{ cfm}$$
$$(566) + (23.6 - 14.2) = 575.4 \text{ L/s}$$

$$F'_5 = 1{,}000 + (50 - 200) = 850 \text{ cfm}$$
$$(472) + (23.6 - 94.4) = 401.2 \text{ L/s}$$

$$\text{IPF} = \frac{850 + (0.99)(1{,}800)}{(1220)(0.01)} = 215.7$$
$$\text{IPF} = \frac{401.2 + (0.99)(850)}{(575.4)(0.01)}$$
$$\text{IPF} = 216.0$$

which is still above the minimum IPF and still provides a margin.

SA-B-1300 ADDITIONAL LEAKAGE CRITERIA

Additional leakage criteria may be developed to meet plant specific ALARA criteria. Additional criteria may take the form of specifying air cleaning system effectiveness or system quality parameters. It is recommended that the basis for these additional criteria be documented to allow future evaluation of test data. Examples of criteria, which have been previously established in industry standards, are identified below.

SA-B-1310 AIR CLEANING SYSTEM EFFECTIVENESS

One approach to establishing values for allowable leakage rates based on air cleaning system effectiveness is to provide arbitrary values for percent of system flow rate based on leakage classification. (See SA-B-1400.) The values in Table SA-B-1310 have been historically used.

However, these rates may not be representative of actual system design margin since system design flow rates may be established due to nonair cleaning requirements. For these cases, the procedure for establishing unit leakage rates should follow the format used in SA-B-1232.2. Determine the minimum requirements, establish the flow rate tolerance, and proportion across duct surface area.

SA-B-1320 AIR COOLING EFFECTIVENESS

When space temperatures must be maintained to ensure the functioning of nuclear safety-related equipment, the air cooling system design must have sufficient margin to account for allowable pressure boundary leakage. An evaluation to ensure that the maximum space heat gains are accounted for in the design, shall be performed.

SA-B-1330 SYSTEM QUALITY

There may be a desire to establish bench mark leakage rates for various leakage classes, or types of construction, or both, in order to determine quality during the installation process.

The Owner or system designer should establish the leak rate associated with the type of construction by previous test experience, calculation, or by a shop or field test at the beginning of the installation.

The Owner, or his designee, should randomly select sections of ducts or individual housings to leak test in situ. Selection of duct sections may be chosen based on ANSI/ASQC Z1.4 or other equivalent method, however, this is not mandatory.

SA-B-1400 AIR CLEANING SYSTEM CONFIGURATIONS AND LEAKAGE CLASSES

An air cleaning system can be defined schematically in terms of three spaces and two components.

(a) The three spaces may be either exterior or interior and are

(1) the contaminated space

(2) the protected space

(3) the interspace

(a) contaminated relative to the air cleaning system located within the interspace.

(b) clean relative to the air cleaning system located within the interspace

(b) The two components are

(1) fan

(2) air cleaning unit

All spaces noted above represent possible locations for the different parts of the air cleaning system. The

TABLE SA-B-1310
MAXIMUM ALLOWABLE LEAKAGE FOR AIR CLEANING EFFECTIVENESS
(PERCENT OF RATED FLOW)

Leakage Class [Note (1)]	Duct [Note (2)]	Housing	Total [Note (3)]	Non-ESF Duct [Note (2)]	Housing	Total [Note (3)]
I	0.10	0.10	. . .	0.50	0.10	0.60
II	1.00	0.20	1.20	5.00	1.00	6.00

NOTES:
(1) Refer to SA-B-1400 for configuration that determines leakage class. Leakage is apportioned to surface area by:

$$L_s = \frac{a}{A} \times \frac{P \times Q}{100}$$

where
A = surface area of the total system ductwork per leakage class, ft^2 (m^2)
a = surface area of the duct section, ft^2 (m^2)
L_s = allowable leakage in duct section, scfm (sL/s)
$\frac{L_s}{a}$ = the allowable unit leakage by this criteria, cfm/ft^2 (L/s/m^2)
P = allowable percent leakage
Q = system rated flow (cfm) (L/s)

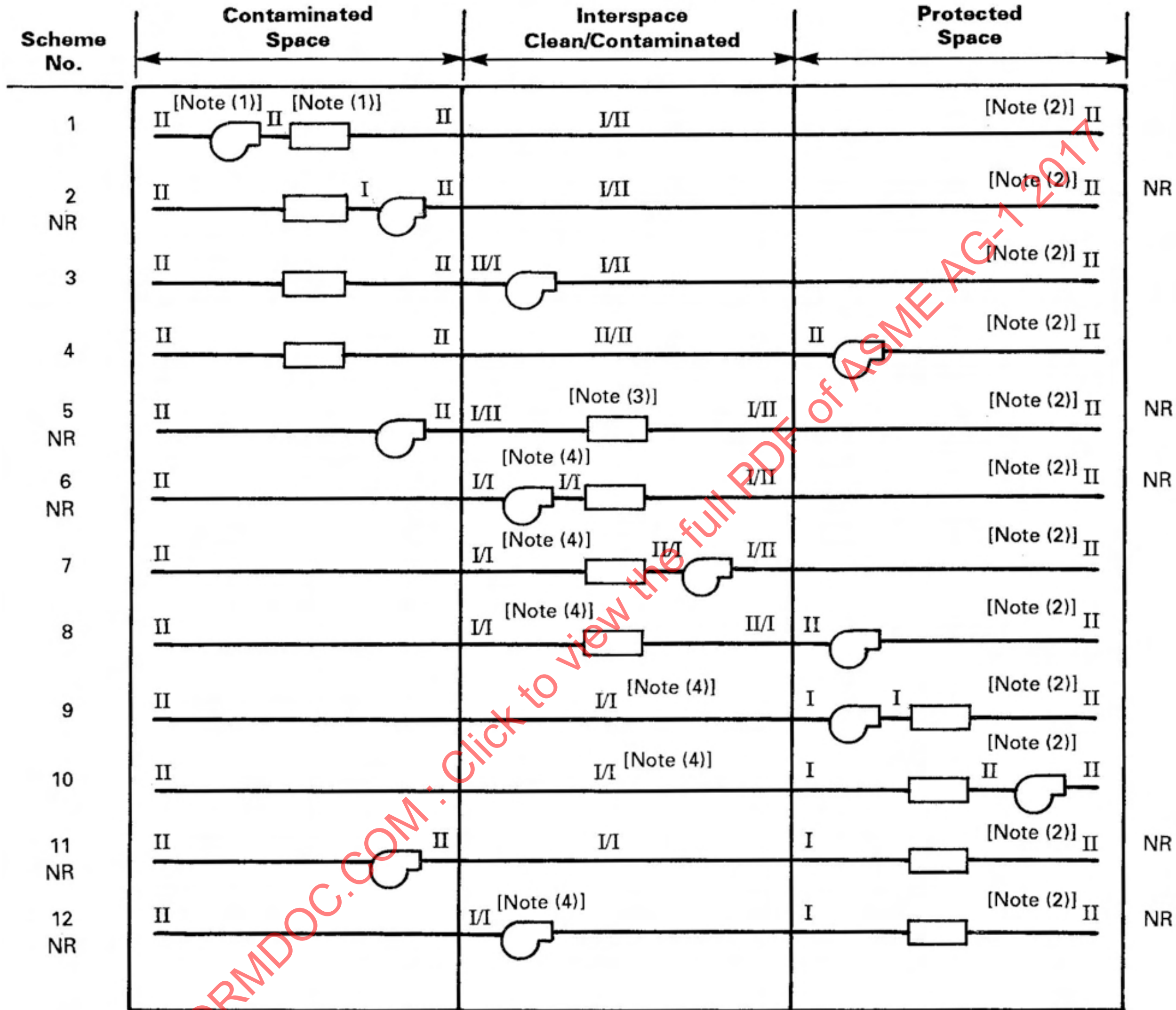
(2) All ducts under positive pressure that discharge into the plant stack for high-level release credit shall be leakage Class I.
(3) Assumes housing surface area is 20% of duct surface area. Duct and housing leakages shall be adjusted for actual housing and duct surface area ratios, but the total percent leakage shall not exceed the sum of the listed percent leakages for duct and housing.

contaminated and protected spaces also include the points of system origin and termination respectively. The interspace refers to all other spaces — contaminated or clean — where the air cleaning system or its parts may be located.

SA-B-1410 LEAKAGE CLASSES

Leakage Classes I and II have been assigned to the various sections of each air cleaning system to represent the qualitative effect of leakage on the air cleaning system function. Thus, a leakage Class II classification indicates that due to system configuration and location, a higher leakage rate may be allowable. Conversely, a leakage Class I classification indicates a more stringent leakage rate is required. Leakage classes are shown on Figs. SA-B-1410-1, SA-B-1410-2, and SA-B-1410-3.

FIG. SA-B-1410-1 SINGLE-PASS AIR CLEANING SYSTEM CONFIGURATION



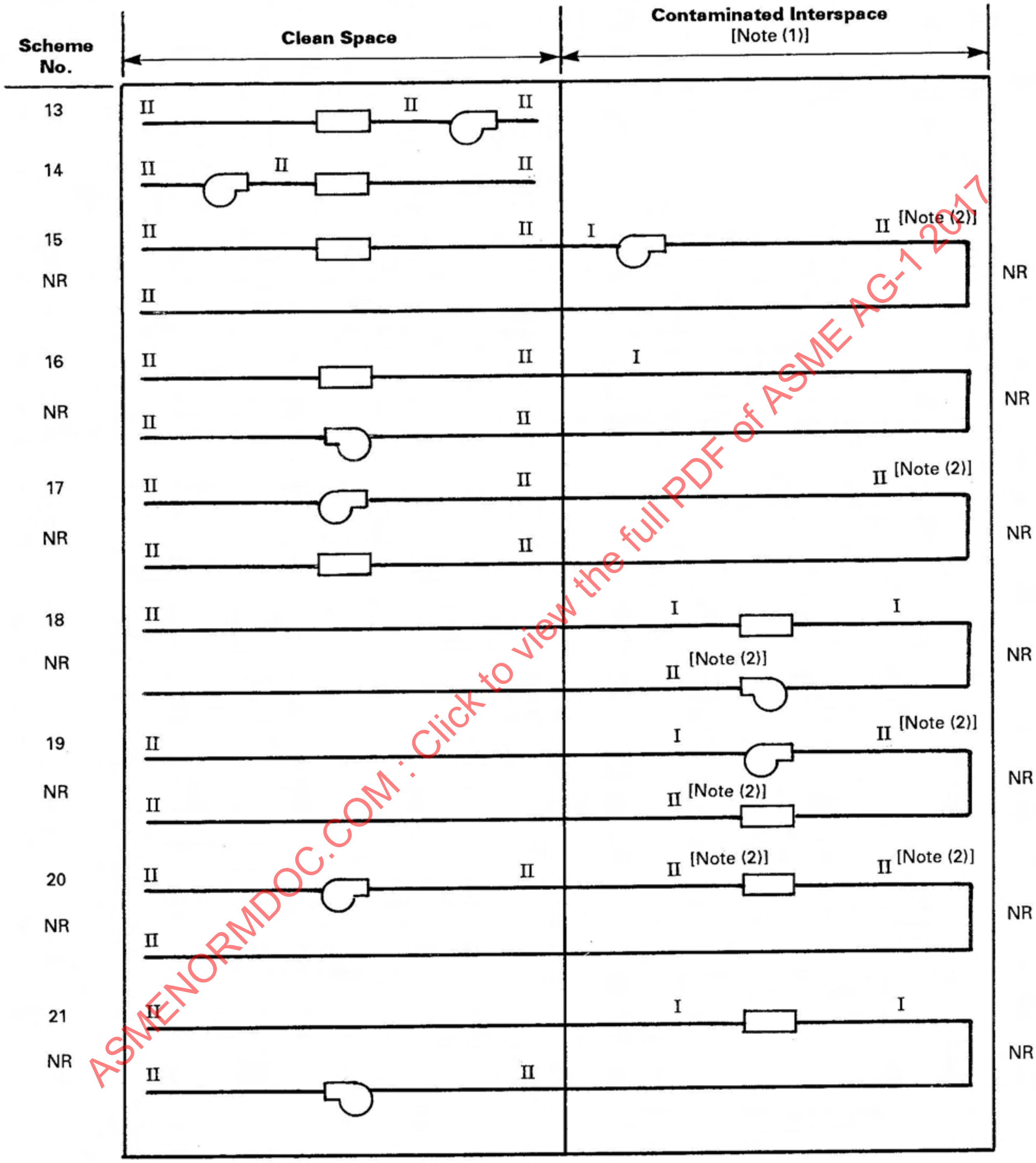
NOTES:
(1) Symbols–
NR — Not recommended

Air Cleaning Unit

Fan

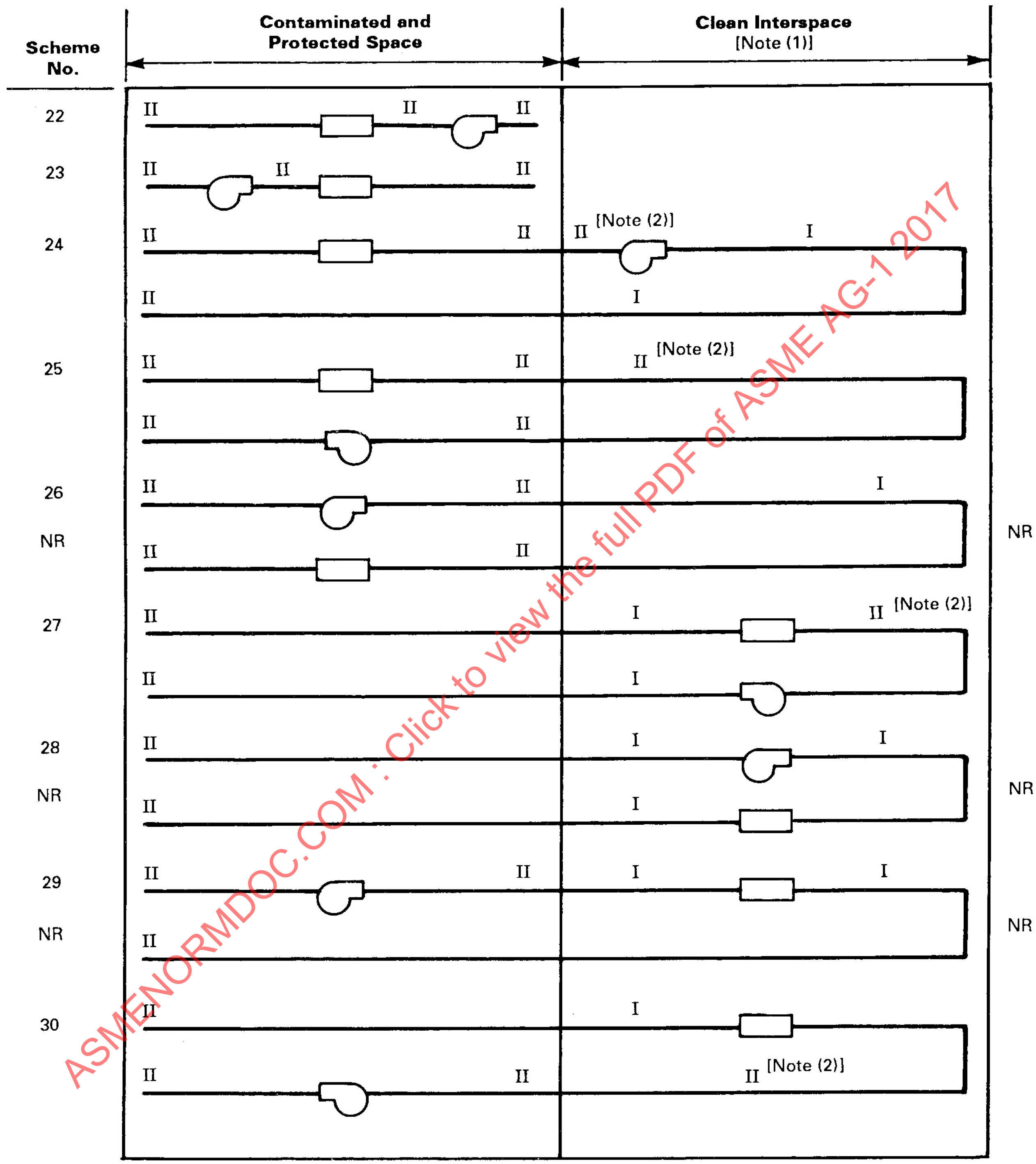
(2) All ducts under positive pressure which discharge into the plant stack for high-level release credit shall be leakage Class I.
(3) Space classification is based on the relative concentration of the space with respect to the duct (e.g. *Contaminated Interspace* means concentration within space is greater than duct or housing at that point). Thus, as duct concentration changes due to filtration, the space classification will change in a given area.
(4) Noted duct sections which pass through a Clean Interspace and which are under a negative pressure for all modes of operation may be leakage Class II.

FIG. SA-B-1410-2 RECIRCULATING AIR CLEANING SYSTEM CONFIGURATIONS



NOTES:
(1) Contamination level of fluid within ductwork < contamination level of interspace.
(2) Leakage Class I shall be used if ductwork is under negative pressure with respect to interspace during normal or transient system operation.

FIG. SA-B-1410-3 RECIRCULATING AIR CLEANING SYSTEM CONFIGURATIONS



NOTES:
(1) Contamination level of fluid within ductwork > > contamination level of interspace.
(2) Leakage Class I shall be used if ductwork is under positive pressure with respect to interspace during normal or transient system operation.

NONMANDATORY APPENDIX SA-C
ADDITIONAL GUIDELINES FOR DUCT DESIGN AND CONSTRUCTION

ARTICLE SA-C-1000

SA-C-1100 FUNCTIONAL DESIGN

Procedures and data for sizing of ductwork to provide the desired air quantities and distribution are presented in the ASHRAE Handbook, Fundamentals 1989, and in the SMACNA HVAC Duct System Design manual. Principles of room-air distribution and duct system layout are also described in those publications. Exhaust system concepts are described in Industrial Ventilation, 20th Edition, 1988 published by the American Conference of Governmental Industrial Hygienists.

SA-C-1200 GENERAL

SA-C-1210 ACCESS DOORS

SA-C-1211 General

(a) Seals

(1) Gaskets should be installed on door and a "knife-edge" sealing surface for the gasket should be provided. Gasket should be neoprene or silicone rubber with a recommended 30-40 "Shore A Durometer." Spacing shall enable a compression of at least 50% of nominal gasket thickness and provide a gasket compression uniformity of 20%.

(2) The gasket should be installed in as few pieces as possible to minimize number of joints. Gasket joints should be dove-tailed-type to prevent leakage due to misfitting butt joints.

(3) The gasket should be protected from possible damage when the door is opened by installing gasket within a channel or with a metal bar between door edge and gasket to protect it in an equivalent manner.

(b) Hinges and Latches

(1) Latches shall seal in less than 270 deg motion. Latches shall not have more than one handle per location; that is, there shall not be a handle to position the inside clamp and a separate handle to tighten the clamp down.

(2) Latches shall be configured so that when open, gravity will hold them in the open position.

(3) Latch assemblies shall have a minimum number of components and be designed so no loose components can fall off.

(c) Additional Guidance

(1) Sufficient clearance should be provided so that doors can be opened to enable access for testing, component replacement, repair, or inspection.

(2) Drawings for each type and size of door should be submitted to the Owner for review prior to fabrication. Door drawings should show location and details of hinges, latching lugs, and gaskets.

SA-C-1220 DRAINS

The number of normally open drains should be kept to a minimum (i.e., drains should be manually valved off when not needed during operation) to reduce the possibilities of degrading the pressure boundary or bypassing the air cleaning unit or filter banks.

(a) Air bypass can occur around filtration components;

(b) Cooling/heating coil capacity is negatively impacted; or

(c) Contaminated (radioactive or otherwise) air is transferred through the piping to a protected environment (either into or out of housing).

Drain lines shall be valved, sealed, trapped, or otherwise protected to prevent the following adverse conditions:

Traps or loop seals when used should be designed for the maximum operating (static) pressure the duct may experience during system startup, normal operation, system transients, or system shutdown. Provision should be made for manual or automatic fill systems to ensure water loop seals do not evaporate. If manual filling is utilized, a periodic inspection or filling procedure shall be implemented. A sight glass should be considered to aid in inspection. The same applies if a local sump is included in the design.

The drain system should be designed so that unacceptable backup of liquids into the duct will not occur. Hydraulic calculations should be prepared to document this feature of drain system design. Provision should be made in plant radwaste system to treat maximum coincident flow rate.

Initial testing of the drain system should be performed by the Owner on site, after installation, to demonstrate operability.

When shutoff valves or check valves are utilized, they should be initially tested on site, after installation, and periodically thereafter for operability and leakage.

Valve leakage should be considered as part of the allowable housing leakage criteria derived in para. 4.14.

SA-C-1230 DUCT

Round duct is generally preferred because it is stronger (particularly when internal pressures are negative and collapse would be the failure mode), is frequently more economical for high pressure construction, and is easier to join and seal than rectangular duct. However, round duct occupies more space than rectangular duct, and it is more difficult to fabricate some types of round branch fittings.

Additional duct design guidance is given in Nonmandatory Appendix AA-D.

TABLE SA-C-1300

SMACNA Manuals	Max. Design Static Pressure, in. wg	
	Positive	Negative
HVAC Duct Construction Standards	10 (2.5 kPa)	3 (.75 kPa)
Round Industrial Duct Construction Standards	30 (7.5 kPa)	30 (7.5 kPa)
Rectangular Industrial Duct Construction Standards	30 (7.5 kPa)	30 (7.5 kPa)

SA-C-1240 ACCESS FOR SERVICE, TESTING, AND INSPECTION

Ducts that will have to be cleaned out periodically should be equipped with low-leakage access hatches at strategic points.

SA-C-1300 DUCT CONSTRUCTION STANDARDS

Table SA-C-1300 lists standards that may be used in the mechanical design of ductwork. The SMACNA HVAC Duct Construction Standards contain design data for both indicated in the Table. Although design data in the SMACNA Round and Rectangular Industrial Duct Construction Standards have been developed for negative-pressure applications, they may also be used for positive-pressure design. Positive-pressure designs using the HVAC Duct Construction Standards are less conservative than positive pressure designs using the Round and Rectangular Industrial Duct Construction Standards.

When using either the Round or Rectangular Industrial Duct Construction Standards for nuclear power plant system design, the system may be considered as "Class 1," as defined by SMACNA.

These duct design references do not incorporate structural design requirements. Guidance given in these references must be evaluated for structural capability and revised as necessary to meet the requirements of Article SA-4000 and the nuclear facility specific parameters.

SECTION HA
HOUSINGS

ARTICLE HA-1000
INTRODUCTION

HA-1100 SCOPE

This section provides requirements for the design, construction, performance, fabrication, inspection, acceptance testing, and quality assurance for housings and housing supports in nuclear safety-related air treatment systems.

HA-1110 PURPOSE

The purpose of this section is to ensure that the housings have acceptable design, performance, and construction.

HA-1120 APPLICABILITY

This section applies to housings containing air cleaning, air handling, and air conditioning components. Internal components of housings including, but not necessarily limited to, HEPA filters, refilters, adsorbers, moisture separators, cooling and heating coils, dampers, mounting frames, and fans are covered in other Division II Code sections.

This section does not apply to sizing of housings, nor does it apply to the design of the nuclear air cleaning, air conditioning, or air handling systems in which the housings are installed.

Housing interface boundaries, as applied to this section are shown on Figs. HA-1120-1, HA-1120-2, and HA-1120-3. Interface boundaries occur between housing penetrations and external piping, instrumentation, and conduit. Interface boundaries also occur between internal and external components and structural support members directly attached to the housing.

HA-1130 DEFINITIONS AND TERMS

The definitions and terms described below are specific to this section. For other definitions and terms, see AA-1130.

air cleaning unit: a self-contained assembly that includes all components whose primary function is to remove particulate matter (filter) or gas phase contaminants such as radioactive iodine (adsorber). A unit includes a housing plus internal air cleaning components. An air cleaning unit may be walk-in or side-load-type design.

air conditioning unit: a self-contained assembly of all components whose primary function is to change air temperature or relative humidity. Unit may include housing, fan(s), heating and/or cooling coil(s), filters, etc.

air handling unit: a self-contained assembly of all components whose primary function is to move air. Units that perform both cleaning and handling shall be classified as air cleaning.

housing: the portion of an air cleaning, air conditioning, or air handling unit that encloses, and provides access to their respective components, and provides connections to adjacent ductwork, instrumentation, and ancillary systems.

manifold: a device to uniformly disperse test agent over a defined area from a single pipe or tube or to uniformly collect test agent mixed with air from a defined area into a single pipe or tube.

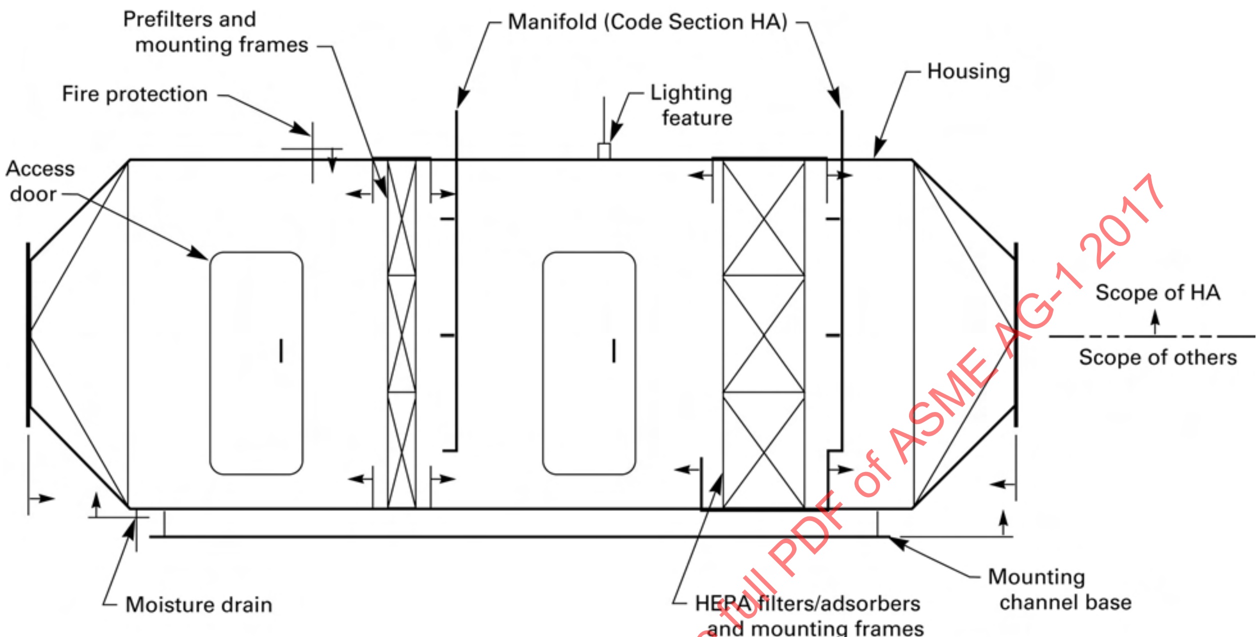


FIG. HA-1120-1 HOUSING, AIR CLEANING UNIT: WALK-IN TYPE

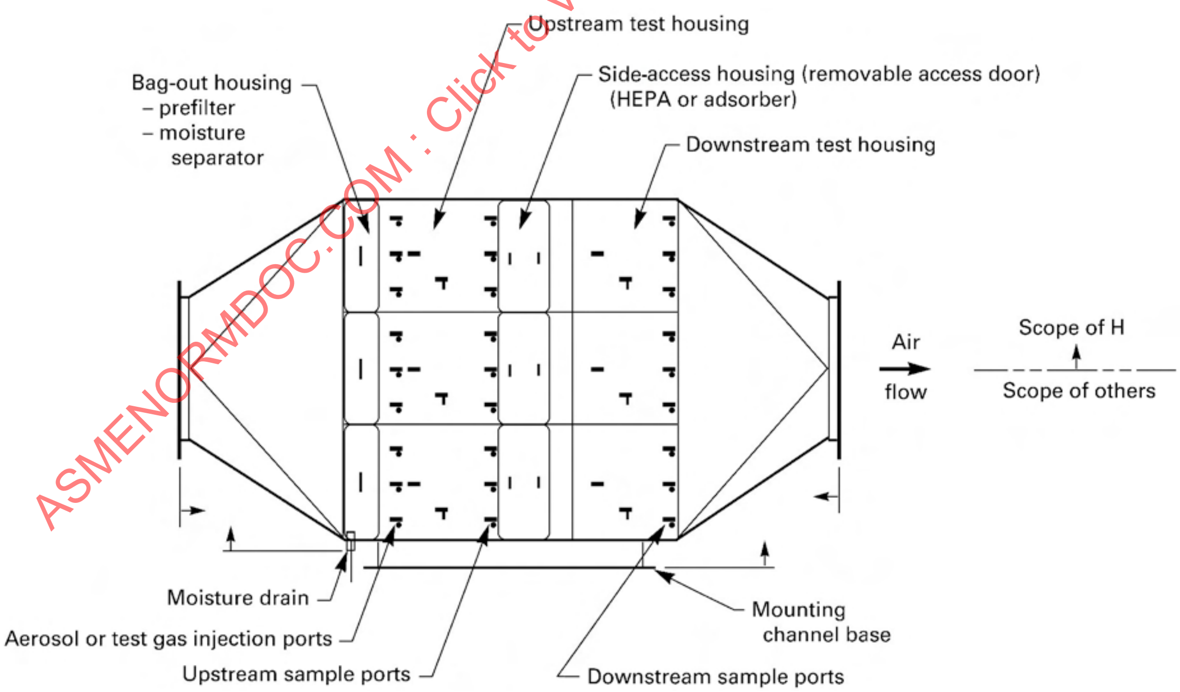
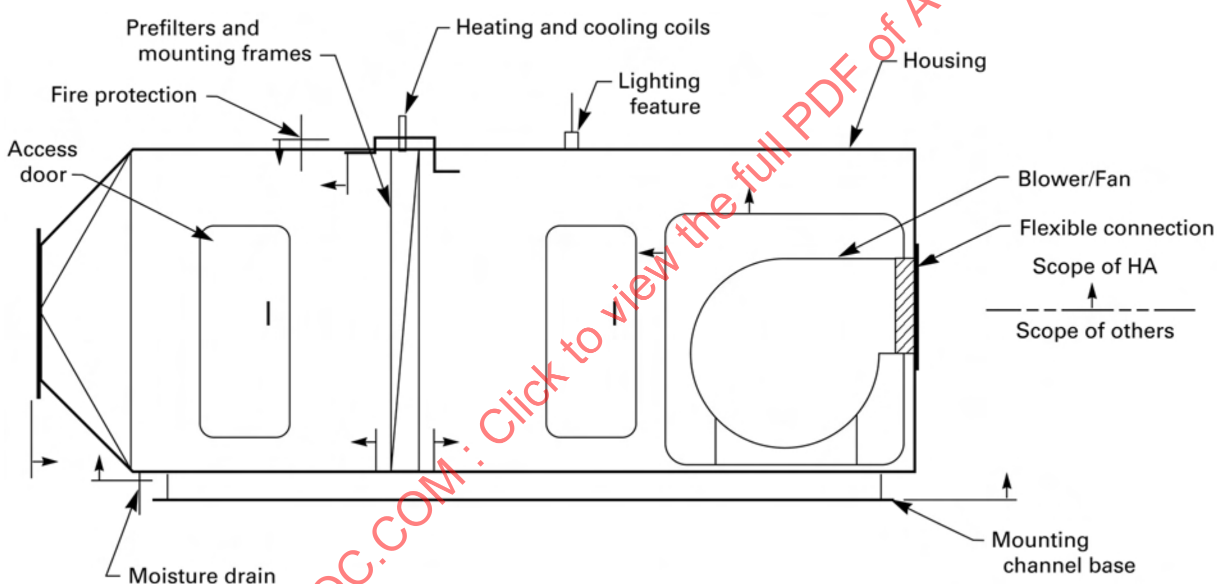


FIG. HA-1120-2 HOUSING, AIR CLEANING UNIT: SIDE-ACCESS TYPE

FIG. HA-1120-3 HOUSING, AIR CONDITIONING UNIT: WALK-IN TYPE



ARTICLE HA-2000
REFERENCED DOCUMENTS

The effective date of edition for references listed below shall be as specified in Article AA-2000, the date of edition invoked by the design specification, or as given below.

American Institute of Steel Construction (AISC) Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings, Ninth Edition

Publisher: American Institute of Steel Construction (AISC), One East Wacker Drive, Chicago, IL 60601-2001

ASME N509-1989, reaffirmed December 9, 1996, Nuclear Power Plant Air-Cleaning Units and Components

ASME Boiler & Pressure Vessel Code, 1995 Edition with the 1997 Addenda, Section IX, Welding and Brazing Qualification

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

ASHRAE Handbook of Fundamentals, 1997 Edition

Publisher: American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329

ASTM D5144–1997, Standard Guide for Protective Coating Standards in Nuclear Power Plants

ASTM D1056-91, Standard Specification for Flexible Cellular Materials–Sponge or Expanded Rubber

ASTM A-370–1997, Test Methods and Definitions for Testing Steel Products

ASTM D2240–1997, Test Method for Rubber Properties

Publisher: American Society for Testing and Materials (ASME International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

AWS D1.1, 1998 Structural Welding Code for Steel

AWS D1.3, 1989 Structural Welding Code for Sheet Steel

AWS D9.1, 1990 Specification for Welding of Sheet Metal

Publisher: American Welding Society (AWS), 550 NW LeJeune Road, Miami, FL 33126

HVAC Duct Construction Standards — Metal and Flexible, 1996

Rectangular Industrial Duct Construction Standards, 1980

Round Industrial Duct Construction, 1977

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

IES Lighting Handbook, Eighth Edition, 1993

Publisher: Illuminating Engineering Society of North America (IESNA), 120 Wall Street, New York, NY 10005

Industrial Ventilation 23rd Edition

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

Manual of Steel Construction, Allowable Stress Design, Ninth Edition

Nuclear Air Cleaning Handbook — Design, Construction, and Testing of High Efficiency Air Cleaning Systems for Nuclear Applications, C. Burchsted, Kahn, and Fuller, ERDA-76-21

Publisher: American Institute of Steel Construction (AISC), One East Wacker Drive, Chicago, IL 60601-2001

NFPA 90 A, 1996, "Installation of Air Conditioning & Ventilation Systems"

Publisher: National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101

Specification for the Design of Cold-Formed Steel Structural Members, 1996 Edition

Publisher: American Iron and Steel Institute (AISI), 200 Town Center, Southfield, MI 48075

201-90, "Fans and Systems"

Publisher: Air Movement and Control Association, Inc. (AMCA), 30 West University Drive, Arlington Heights, IL 60004-1893

ARTICLE HA-3000
MATERIALS

HA-3100 ALLOWABLE MATERIALS

HA-3110 GENERAL REQUIREMENTS

(a) Material used shall have properties and composition suitable for the application as defined by the design specification and the service conditions, as defined in AA-4213. Materials shall be in conformance with the ASME and the ASTM materials listed in Table HA-3110. Substitute materials shall be equivalent to or exceed the requirements in Table HA-3110. Substitute materials shall be approved by the Owner or designee.

(b) Materials that are part of the pressure boundary or equipment support shall meet the structural requirement of Article HA-4000.

(c) Materials expressly prohibited or limited shall be explicitly described in the design specification.

(09) HA-3111 Protective Coatings

All carbon steel surfaces shall be painted to protect against corrosion and to facilitate cleaning and decontamination. Coatings shall comply with the requirements of AA-6500 and ASTM D 5144. Coatings shall meet radiation resistance, chemical resistance, and decontamination requirements in accordance with the design specification. Stainless steel, galvanized, bronze, copper, aluminum, and glass surfaces are not required to be coated.

HA-3200 SPECIAL LIMITATIONS ON MATERIALS

HA-3210 METALS

HA-3211 Physical Properties

Changes in the physical properties of metals at minimum and maximum design temperatures must be recognized and factored into the design of housings.

HA-3212 Galvanic Corrosion

The possibility of galvanic corrosion due to the relative potentials of aluminum, copper, and their alloys should be considered when used in conjunction with each other, or with steel or other metals and their alloys.

HA-3213 Corrosive Vapors

Aluminum and zinc shall not be used in the presence of corrosive vapors unless protected by coatings designed to prevent deterioration of the metal. Protective measures other than coating shall be approved by the Owner or designee.

HA-3214 Nonmetallic Materials

The use of nonmetallic materials such as plastics, elastomers, and similar substances is permitted in the construction of housings provided that in the selection of these materials, consideration is given to

(a) emission of toxic vapors

(b) degradation of properties caused by temperature extremes, radiation exposure, chemical exposure, and aging

(c) maintainability

HA-3215 Deterioration of Materials in Service

It is the responsibility of the Owner or designee to identify the environment in which housings must operate so that the Manufacturer can select the grade of materials to meet the conditions stated in the design specification.

HA-3300 CERTIFICATION OF MATERIAL

For structural and pressure boundary materials, the supplier shall make available certified test reports of chemical and physical properties. For those ASTM materials that do not have physical testing required by the ASTM specification, tensile testing shall be performed per ASTM A370.

All other materials used in the construction of housings shall be provided with a manufacturer's Certificate of Compliance covering the ASME, ASTM, or other material specification, grade, and class, if applicable.

(09)

TABLE HA-3110
ALLOWABLE MATERIALS

ASME Designator	ASTM Designator	Publication Title
Plate, Sheet, and Strip		
SA-240	A 240	Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels
SA-36	A 36	Structural Steel
. . .	A 283	Low- and Intermediate-Tensile Strength Carbon Steel Plates
. . .	A 284	Pressure Vessel Plates, Carbon Steel, Low and Intermediate Strength
. . .	A 366	Steel, Carbon, Cold-Rolled Sheet, Commercial Quality
SA-414	A 414	Carbon Steel Sheet for Pressure Vessels
. . .	A 446	Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Structural (Physical Quality)
. . .	A 525	Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, General Requirements
. . .	A 526	Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Commercial Quality
. . .	A 527	Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Lock-Form Quality
. . .	A 568	General Requirements for Steel, Carbon, and High-Strength, Low-Alloy, Hot-Rolled Sheet and Cold-Rolled Sheet
. . .	A 569	Steel, Carbon (0.15 max, %), Hot-Rolled Sheet and Strip, Commercial Quality
. . .	A 570	Hot-Rolled Carbon Steel Sheet and Strip, Structural Quality
. . .	A 611	Steel, Cold-Rolled Sheet, Carbon, Structural
. . .	A 620	Steel, Sheet, Carbon Drawing Quality, Special Killed, Cold-Rolled
. . .	A 621	Steel Sheet and Strips, Carbon, Hot-Rolled, Drawing Quality
. . .	A 635	Steel Sheet and Strips, Heavy Thickness Coils, Carbon, Hot-Rolled
. . .	A 642	Steel Sheet, Zinc Coated (Galvanized) by the Hot-Dip Process, Drawing Quality, Special Killed
. . .	A 666	Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar for Structural Applications
SB-209	B 209	Aluminum and Aluminum-Alloy Sheet and Plate
	B 16	Standard Specification for Free-Cutting Brass Rod, Bar, and Shapes for Screw Machines
	B 140	Standard Specification for Copper-Zinc-Lead (Leaded Red Brass or Hardware Bronze) Rod, Bar, and Shapes
Structural Bar and Shapes		
SA-36	A 36	Structural Steel
. . .	A 108	Steel, Bar, Carbon, Cold-Finished, Standard Quality
. . .	A 276	Stainless and Heat-Resisting Steel Bars and Shapes
. . .	A 493	Stainless and Heat-Resisting Steel for Cold-Heading and Cold-Forging Bar and Wire
. . .	A 500	Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Round and Shapes
. . .	A 501	Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
. . .	A 576	Steel Bars, Carbon, Hot-Wrought, Special Quality

TABLE HA-3110
ALLOWABLE MATERIALS (CONT'D)

ASME Designator	ASTM Designator	Publication Title
Hardware		
SA-182	A 182	Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, Valves, and Parts for High Temperature
SA-193	A 193	Alloy-Steel and Stainless Steel Bolting Material for High-Temperature Service
SA-194	A 194	Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service
SA-307	A 307	Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength
SA-325	A 325	High-Strength Bolts for Structural Steel Joints
SA-403	A 403	Wrought Austenitic Stainless Steel Piping Fittings
SA-449	A 449	Quenched and Tempered Steel Bolts and Studs
. . .	A 548	Steel Wire, Carbon, Cold-Heading Quality, for Tapping or Sheet Metal Screws
. . .	A 563	Carbon Steel Nuts ANSI B18.21.1 Lock Washers ANSI B18.22.1 Flat Washers
. . .	F 467	Nonferrous Nuts for General Use
ANSI B18.21.1		Lock Washers
ANSI B18.22.1		Flat Washers
Pipe and Tube		
. . .	A 53	Pipe, Steel, Black and Hot-Dipped, Zinc Coated, Welded and Seamless
. . .	A 450	General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes
	A 511	Seamless Stainless Steel Mechanical Tubing
	A 554	Welded Stainless Steel Mechanical Tubing
	A 312	Standard Specification for Seamless and Welded Austenitic Stainless Steel Pipes
	A 376	Standard Specification for Seamless Austenitic Stainless Steel Pipe for High-Temperature Central-Station Service
	A 632	Seamless and Welded Austenitic Stainless Steel Tubing (Small Diameter) for General Service
ANSI C80.3		Electrical Metallic Tubing Zinc-Coated
Coatings		
	D 5144	Standard Guide for Protective Coating Standards in Nuclear Power Plants
Gaskets		
	ASTM D2000	Neoprene Class BC
	ASTM D1056	Silicone Rubber

ARTICLE HA-4000
DESIGN

HA-4100 GENERAL DESIGN

Housings shall be designed in accordance with the requirements of Article AA-4000 and this section. The design shall incorporate requirements for structural strength, rigidity, and sealing surfaces to provide leak-tightness of internal mounting frames to the housing. Decontamination requirements shall be specified by the Owner or designee in the design specification.

HA-4200 DESIGN CRITERIA

HA-4210 LOAD CRITERIA

HA-4211 Loads

Loads to be considered in the structural design of housings are listed in AA-4211 with the following additions and clarifications.

component load (CL): the force of the internally mounted components imposed on the housing. CL is separated into four portions: deadweight, normal operating pressure differential (NOPD) for the particular component, OBE, and SSE. Additional dynamic loads (ADL) will be provided by the design specification as applicable.

deadweight (DW): the weight of the housing members excluding the deadweight of internal equipment such as HEPA filters and their respective mounting frames. DW includes sheet metal panels, door panels, frame members, and stiffeners.

design pressure differential (DPD): the dynamic external pressure load resulting from a design basis accident (DBA), intermediate break accident (IBA), or small break accident (SBA). Housings should be located outside the local pipe break affected area. If housings are subjected to these loads, the design specification (HA-4600) shall address the specific design requirements considering a Level D load combination.

external load (EL): as defined in AA-4211.

fluid momentum load (FML): as defined in AA-4211. Housing internal components shall be designed to withstand FML resulting from air turbulence from fan discharges into the housing. The housing portion where this load is significant is determined by the length required to regain uniform airflow as given by AMCA 201, Fig. 3-3.

hydrostatic load (HL): shall be added to the deadweight (DW) case as applicable. These loads are from accumulated condensate, water deluge systems, moisture separators, and associated housing flooding. The hydrostatic load shall be established by documented analysis based on housing internal configuration and component function.

live load (L): includes a construction mainload of 250 lb on the roof of the housing. Housing sheet metal floors shall be designed for at least a 50 psf live load when no other floor system is provided (e.g., grating, concrete slab).

normal operating pressure differential (component) ($NOPD_c$): the opening pressure differential across the component from upstream to downstream of the component included in the housing. See applicable Division II component sections for all component NOPD's.

normal operating pressure differential (housing) ($NOPD_h$): the maximum pressure differential between inside the housing and external to the housings. For ease of design, a housing may be designed using one pressure value that envelopes SOPT and NOPD.

seismic loads (SL): loads that are the result of the envelope of the operating basis earthquake (OBE) and the safe shutdown earthquake (SSE). As an option, the OBE and SSE may be considered separately with the OBE loads used for the level B load combination. Both orthogonal components of horizontal and vertical components of the seismic excitation shall be applied simultaneously in the direction that will produce worst-case stresses and deflections. These components may

TABLE HA-4212
LOAD COMBINATIONS

Service Level	Load Combination
A	N + T + L + CL + W
B	Not required, see Level C
C	N + T + L + CL + SL + ADL
D	If DPD Applicable, N + DPD + SSE + ADL

be combined by the square root of the sum of the squares (SRSS) method.

system operational pressure transient (SOPT): as defined in AA-4211 or may be enveloped with $NOPD_h$ and $NOPD_c$.
T and *N*: defined in AA-4211.

For other component load criteria, see the following sections and/or other applicable Division II Code sections:

(a) HEPA filters: FC-4300
(b) Type II adsorbers: FD-4400
(c) Type III adsorbers: FE-4400
(d) Mounting frames: FG-4200
(e) Dampers: Article DA-4000
(f) Moisture separators: Article FA-4000
(g) Prefilters: Article FB-4000
(h) Coils: Article CA-4000
(i) Fans: Article BA-4000
(j) Ductwork: SA-4200
(k) Type IV adsorbers: FH-4300

HA-4212 Load Combinations

The applicable loads are given in Table HA-4212.

HA-4213 Service Conditions

The requirements of AA-4213 apply.

HA-4214 Design and Service Limits

The requirements of AA-4214 apply.

HA-4215 Housing Supports

Housing supports shall be designed per the loads and load combinations in HA-4211 and HA-4212. The stress criteria for each load combination shall be per HA-4220.

Floor-mounted housing supports shall be designed to act as an integral base of the housing. Anchorage to the floor shall be designed to transfer the lateral forces without overturning or deforming the housing unit. Units with internal mounting frames where leakage is a design consideration, shall have floor anchorages near the junction of the mounting frame and base. Smaller units, which are typically provided with the base from the vendor's facility, shall be designed for the installation/erection loads associated with a package unit. Larger units that are installed using modular construction need only consider the installation loads associated with each piece.

HA-4220 STRESS CRITERIA

The allowable stresses for housing sheet metal material and cold-formed members shall be as defined in the AISI *Specification for the Design of Cold-Formed Steel Structural Members*. The allowable stresses for hot-rolled shapes and plates shall be as defined in the AISC *Specification for the Design, Fabrication and Erection of Structural Steel for Buildings.*

The basic general membrane design stress for the Service Level A condition shall not exceed $0.6F_y$ and shall be reduced as appropriate to consider lateral-torsional buckling of bending members and effective lengths of compression members. The basic general membrane design stress for the Level C condition shall not exceed $1.2 \times 0.6F_y$ per AA-4321.

The combined membrane and bending design stress for Service Level A shall not exceed $1.5 \times 0.6F_y$ and shall be reduced as appropriate to consider lateral-torsional buckling of bending members and effective lengths of compression members. The combined membrane and bending design stress for the Level C condition shall not exceed $1.8 \times 0.6F_y$ per AA-4321.

HA-4230 DEFLECTION CRITERIA

HA-4231 Deflection Limits

The deflection limits shall be specified in the design specification and shall be in accordance with AA-4231.

HA-4232 Deflection Limits for Mounting Frames and Equipment Interfaces

For walk-in housings, the deflection limits for the mounting frames shall also be considered at the interface between the frame and the housing.

For deflection limitations of other equipment (e.g., fans, dampers, ductwork) see the applicable Division II Code sections.

HA-4240 OTHER CRITERIA

HA-4241 Vibration Isolation

Vibration isolation requirements shall be specified by the Owner or designee in the design specification.

HA-4242 Provisions for Relative Movement

Clearance shall be provided to allow for relative movement of the internal equipment during operation and maintenance of the equipment.

HA-4243 Tolerances

Tolerances shall be specified for all external and internal interface boundaries. Tolerances shall be specified in the design documents. Tolerances shall be accounted for in applicable design analysis (e.g., location of applied load).

HA-4244 Housing Attachments

The attachment design shall include all service limits and load combinations set forth in HA-4212 and HA-4213, or as required by the design specification.

Attachments shall be either the welded or bolted type.

HA-4245 Welded Attachments

Consideration shall be given to local stresses induced in the housing wall by integral attachments as defined in AA-4243.

Attachment and housing material shall be compatible for welding. See Article AA-6000.

The permissible types of welded joints shall be in accordance with AWS D1.1, AWS D9.1, AWS D1.3, or ASME Section IX, as applicable.

HA-4246 Bolted Attachments

Consideration shall be given to bolting and local stresses induced in the housing wall by nonintegral attachments as defined in AA-4243.

The design of bolts for structural supports shall meet the requirements of AISC Specification for the Design, Fabrication, and Erection of Structural Steel, Ninth Edition, Part 4.

HA-4247 Fatigue Considerations

Internal housing components subjected to FML should be designed for fatigue based on cyclic loading of the element. See HA-4211 to determine the portion of the affected internal housing components. The appropriate reductions in allowable stresses are given in Section 5, Appendix B of the AISC Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings, Ninth Edition.

HA-4248 Fire Protection

Fire protection requirements shall be specified by the Owner or designee commensurate with individual component requirements.

Fire protection for Type III adsorbers shall be provided per FE-4620.

HA-4300 HOUSING JOINTS AND SEAMS

HA-4310 GENERAL

Selection of joints and seams used in the assembly of housing sections shall be based on the required structural integrity, leak-tightness, and the fluid flow within the system. Duct-housing interconnections shall be designed with consideration of the air distribution uniformity.

HA-4320 HOUSING JOINTS AND SEAMS

HA-4321 Acceptable Longitudinal Seams and Joints

The following longitudinal seams and joints are acceptable for use in housing sections subject to the limitations of HA-4330, HA-4340, and HA-4500:

(a) welded lap joint
(b) welded butt joint
(c) welded flange
(d) fillet corner welds

HA-4322 Acceptable Transverse Joints

The following types of transverse joints are acceptable for use in housing sections subject to the limitations of HA-4330, HA-4340, and HA-4500:

(a) welded lap joint
(b) welded butt joint
(c) welded flange
(d) companion angle: gasketed and bolted

HA-4323 Other Types of Connections

Other types of rigid longitudinal and transverse connections may be acceptable provided that the design structural characteristics are qualified. Qualification shall be documented by engineering evaluation or test as specified by the Owner or designee. Qualification test shall demonstrate the joint's ability to withstand load combinations in HA-4212. Joint design qualification shall be completed prior to the start of fabrication.

HA-4324 Bolts and Fasteners

Connections shall be designed to sustain all loading combinations. Bolted connection and joint design shall be designed to meet allowable leakage of HA-4500.

HA-4330 AIR CLEANING UNIT JOINTS AND SEAMS

HA-4331 Welds

The pressure boundary joints and seams for all air cleaning unit housings shall be continuously welded.

HA-4332 Seals

Penetrations on housings shall be sealed by welding, with a sealant qualified for the housing's environment, or with adjustable compression or gland-type seals. Gland-type seals include but are not limited to O-rings, gaskets, and other nonmetallic materials.

HA-4333 Electrical Conduits and Drains

All penetrations by electrical conduits and drains shall be arranged and individually sealed or valved so that bypassing of HEPA filter banks or adsorber banks cannot take place. Electrical conduit open to the inside shall be internally sealed to meet allowable leakage determined in HA-4500.

HA-4334 Separate Mounting Frames

Where separate mounting frames for HEPA filters and adsorbers are required, they shall be continuously seal welded to the housing.

HA-4340 Air Conditioning and Air Handling Units Housing, Joints and Seams

These unit joints and seams shall be of either welded or bolted construction or other types meeting the requirements of HA-4323 and the allowable leakage criteria specified in the design specification.

HA-4341 Penetrations

Penetrations on housings shall be sealed by welding, adjustable compression, gland-type seals, or other method capable of meeting allowable leakage criteria for the housing as determined in HA-4500.

HA-4400 ACCESSORIES

HA-4410 GASKETS

Gaskets shall be made of materials that are compatible with the conditions of HA-4600. Gasket dimensions shall be based on joint design. An acceptable criterion for compression of gasket material shall be established on the basis of the gasket chosen. This acceptance criterion and the service life of the gasket anoint shall be documented by evaluation or testing as determined by the Owner or designee.

HA-4420 ACCESS DOORS AND PANELS

Construction of doors/panels and door frames shall be selected to meet the allowable leakage determined in HA-4500. Sealing surfaces between the door/panel and frame shall be designed for compression sealing. The design shall incorporate means for adjusting compression forces, gasket compression, and alignment.

Spacing of hinges, latches, and bolts shall be determined by calculation or test to ensure a uniform compression of the gasket. Spacing shall enable a compression tight enough to ensure leakage requirements are met (HA-4500) and provide a gasket compression uniformity of ±20 deg.

Hinged doors, if specified, shall be designed to minimize damage to compression seals due to friction and shear forces during opening and closing of the doors.

Doors shall be designed for ease of operation by one person. Man-entry housing doors shall be operable from both inside and outside the housing and be clearly labeled for open and closed latch position.

Hinges and latches shall be designed such that lubrication materials shall not enter the interior of the housing.

See Nonmandatory Appendix HA-B (HA-B-1110) for additional guidance on the design of access doors.

HA-4430 PROVISIONS FOR TESTING AND MAINTENANCE

HA-4431 Test Ports

The Owner or designee shall evaluate the design function of the equipment to determine where test ports (including injection and sampling ports) are required.

The penetration shall comply with HA-4332, and have a cap or plug that is suitable to meet the pressure requirements of the housing.

HA-4432 Manifolds

The Owner or designee shall determine where injection and sampling manifolds are required. Injection and sampling manifolds shall be constructed of metal to minimize damage potential and to maintain manifold qualification. Sampling and injection manifolds that are required to be installed within the filter housing should be designed for permanent installation within the housing. If permanently installed manifolds cannot be provided, then manifolds shall be designed to be removable, with each manifold piece numbered, tagged, and marked for reinstalling prior to each test. Permanent manifold installation is recommended to obtain better repeatability of test results. When an air cleaning unit contains two or more HEPA filter banks or adsorber banks in series, or both, injection and sampling manifolds for the respective test agents are required for each of the filter and/or adsorber banks. General guidance for manifolds is given in Nonmandatory Appendix HA-C.

Injection manifolds shall be qualified in accordance with HA-5700. Sampling manifolds shall be qualified in accordance with HA-5800.

HA-4433 Housing Access

Walk-in housings shall be protected and braced to prevent damage by personnel entering for inspection and maintenance. Walk-in access doors (20 in. wide by 50 in. high, minimum) (51 cm wide by 127 cm high) shall be provided on each side of each component section when housing size permits. A permanent platform shall be installed internal to the housing to provide access to filters for filter banks greater than or equal to 6 ft (approx. 1.8 m) in height. Platform shall not interfere with filter access or airflow distribution.

Space shall be provided both internal and external to the housing for equipment removal and maintenance. See Nonmandatory Appendix HA-B for additional guidance.

HA-4434 Lighting

Walk-in housings shall be fitted with vapor-tight lights between each bank of components. For walk-in air cleaning unit housings, fixtures shall be flush mounted and serviceable from outside of the housing. Lighting levels shall be determined based on personnel safety visual requirements as given in the design specfication and guidance provided by IES Lighting Handbook as published by the Illuminating Engineering Society of North America.

HA-4440 MISCELLANEOUS

HA-4441 Drains

Consideration shall be given to drains depending on requirements, services, or components within each compartment. For example, drains shall be required for

(a) fire protection systems
(b) removal of decontamination liquids
(c) moisture separators
(d) condensing cooling coils

Drains form an integral part of the housing pressure boundary and are subject to air leakage requirements established in HA-4500.

The size selected for each drain furnished in the housing as well as the collection point for each drain shall be documented by calculation or test as determined by the Owner or designee.

For additional guidance on the design of drains, see Nonmandatory Appendix HA-B (HA-B-1120).

HA-4442 Insulation

(a) Insulation shall be provided as specified by the Owner or designee to ensure air conditioning function, limit condensation, or provide acoustic noise reduction as required.

(b) Acoustic linings and thermal insulation shall not be applied to the inside of housings that may become contaminated.

(c) Insulation applied to the outside of housings shall not prevent access to doors, access panels, or other components requiring adjustment or maintenance.

(d) The fire hazard classification of applied insulation, adhesive, and sealer shall not exceed a flame spread of 25 and smoke developed of 50 in accordance with NFPA-90A.

HA-4443 Clamping Mechanism

Side-access housings shall have a clamping mechanism, filter retrieval features, and filter indexing mechanisms. The clamping mechanism shall be individually adjustable for each HEPA filter or adsorber.

For side-access housings with fluid seals, the filter clamping mechanism shall be capable of moving the filter on and off through adequate travel to ensure the knife edge is embedded into the pliable sealant and provides seal for the complete perimeter of each filter or adsorber.

The clamping mechanism shall provide for uniform gasket compression. The clamping mechanism for walk-in housings shall be designed per Section FG.

HA-4500 PRESSURE BOUNDARY LEAKAGE

HA-4510 GENERAL

Pressure boundary leakage shall be controlled to ensure satisfactory environmental conditions, either within or outside of the nuclear facility.

Allowable leakage for a housing, or portion of a housing, shall be determined considering the following factors:

(a) control of airborne contamination
(b) control of space pressure
(c) control of space temperature
(d) control of space humidity

HA-4520 APPLICABILITY

Housing pressure boundary leakage shall apply to air cleaning, air conditioning, and air handling systems. Each housing's pressure boundary shall include the following items:

(a) housing enclosure
(b) access panels and doors
(c) penetrations for instrumentation piping, electrical, and other utilities

HA-4530 EVALUATION

HA-4531 Responsibility

The Owner or designee shall establish the allowable leakage to ensure ventilation, temperature, and contamination control functions are achieved.

HA-4532 Allowable Leakage Determination

The following criteria shall be utilized in the determination of allowable leakage:

(a) application of governing codes, regulations, and plant-specific requirements
(b) consideration of each housing's operating mode, including anticipated system upset condition, such as rapid closure of dampers
(c) normal and maximum operating pressures throughout the pressure boundary
(d) system internal and external environmental conditions

Guidance for determination of allowable leakage is given in Section SA, Nonmandatory Appendix SA-B.

HA-4533 Exceptions to Leakage Requirements

Air cleaning, air conditioning, and air handling housings exhibiting one of the following conditions need not be subjected to quantitative measurement of leakage unless otherwise required by the design specification.

(a) Housings in systems serving only the protected space and located only within the same protected space.
(b) Housings under negative pressure that are located entirely in a clean interspace, and only provide air cooling or heating function.

However, the housing shall be pressurized to locate and seal all audible leaks. Reference Section SA, Nonmandatory Appendix SA-B, Figs. SA-B-1410-1 through SA-B-1410-3 for typical system configurations.

HA-4534 Documentation

Derivation of allowable leakage for each housing, or portion thereof, shall be documented by the Owner or designee. This documentation shall include the following:

(a) identification of housing or portion of housing
(b) governing codes, regulations, and plant-specific requirements
(c) purpose of leakage control; see HA-4510
(d) system mode of operation
(e) normal and maximum operating pressure
(f) method of derivation of allowable leakage
(g) test pressures and associated allowable leakage

HA-4600 DESIGN SPECIFICATION

The Owner design specification shall contain the following information that is relevant to the housing and housing supports covered by this section.

(a) Loads as defined by HA-4211.
(b) Environmental conditions.

(1) Housing external-design environmental conditions including, but not limited to pressure, temperature, relative humidity, radiation exposure, and hostile environmental factors for all plant conditions.

(2) Housing internal-design environmental conditions for all system operating conditions.

(c) Service conditions as defined by AA-4213.
(d) Design and service limits as defined by AA-4214.
(e) Allowable housing leakage as defined by HA-4500.
(f) System safety-related function: Identify the function of the housing for each plant condition. The function shall consist of purpose and operational parameters (i.e., flow, leakage, pressure, temperature). Plant conditions and service limits are defined by AA-4213 and AA-4214.
(g) Fire protection requirements.
(h) Material certification requirements.
(i) Tolerance requirements.

(j) Inlet and outlet configurations.
(k) Housing components:
(1) adsorbers
(2) fans
(3) filters
(4) moisture separators
(5) dampers
(6) heaters
(7) coils
(8) insulation
(9) access requirements (i.e., doors, access panels)
(10) instrumentation and controls
(11) spray-type conditioners

ARTICLE HA-5000
INSPECTION AND TESTING

HA-5100 GENERAL

HA-5110 SCOPE AND APPLICABILITY

This section contains general requirements for the inspection and testing of housings and housing supports.

HA-5120 RESPONSIBILITY FOR PROCEDURES

When an inspection or test is required herein, written inspection or testing procedures shall be developed, by the parties performing the test or inspection, to the specific requirements of this section. The inspection or testing shall be performed by personnel qualified in accordance with ASNT SNT-TC-1A as amended by ASME NQA-1 and AA-6433.

HA-5200 INSPECTION

HA-5210 GENERAL REQUIREMENTS

Visual inspections shall be performed in accordance with AA-5200 and TA-3510.

Inspection and testing of welds shall be performed in accordance with AA-5300 and Article AA-6000.

HA-5220 HOUSINGS

Housings shall be inspected for proper dimensions including tolerances, as specified by HA-6400 and governing construction documents.

HA-5221 Joints and Seams

Joints and seams shall be visually inspected. Acceptance criteria shall be as follows:

(a) Joints and seams shall comply with the requirements of HA-6400 and HA-6500.

(b) Gasketed joints shall provide uniform gasket compression. Gaskets shall be installed per construction documents.

(c) Longitudinal or transverse welded joints shall comply with Article AA-6000 requirements.

(d) Threaded fasteners shall be provided with locking devices in accordance with AA-6258.

HA-5222 Stiffeners

Stiffeners shall be visually inspected to ensure compliance with the following acceptance criteria:

(a) Stiffeners shall comply with the fabrication and installation requirements of Article HA-6000.

(b) Welds shall comply with Article AA-6000 requirements.

(c) Threaded fasteners shall be provided with locking devices in accordance with AA-6258.

(d) Removal of temporary attachments shall be verified.

HA-5230 HOUSING SUPPORTS

Supports shall be visually inspected during installation, after installation, or both in accordance with the following acceptance criteria:

(a) Supports shall comply with the fabrication and installation requirements of HA-6400.

(b) Welded joints shall comply with Article AA-6000 requirements.

(c) Threaded fasteners shall be provided with locking devices in accordance with AA-6258.

(d) Removal of temporary attachments shall be verified.

HA-5240 FILTER MOUNTING FRAME TO HOUSING WELD INSPECTION

The housing filter mounting frame for HEPA filter and adsorbers shall be inspected using visual and nondestructive test methods per AA-6330.

HA-5300 PRESSURE BOUNDARY LEAKAGE TESTING

HA-5310 GENERAL

Temporary isolation at a transverse joint shall be allowed subject to the following requirements.

(a) Transverse joints not subjected to a quantitative leak test shall be companion angle type or other types that enable visual inspection of the sealing mechanism between mating housing sections.

(b) Assembled joints utilizing gasketing shall be visually inspected to ensure uniformity of gasket compression.

(c) The reduced allowable leakage (L_r) of housing sections shall be as follows:

$$L_r = L_s - R$$

$$R = (C_j / C_T)L_s$$

where

C_j = total perimeter of all joints in tested section, including capped end joints

C_T = total perimeter of all joints in tested section, including capped end joints

L_s = section allowable leakage

R = reduction in allowable leakage in cfm/ft^2

HA-5320 ALLOWANCES FOR HOUSING LEAKAGE RATES BY SECTIONS

Temporary isolation at a transverse joint shall be allowed subject to the following requirements.

HA-5330 TESTING PROCEDURES

Prior to pressure boundary leakage testing, test procedures shall be developed in accordance with TA-3430. All test equipment shall be specified with the proper range and required accuracy. Test procedures shall include acceptance criteria determined by HA-4500, HA-5320, and HA-5350.

HA-5340 DOCUMENTATION

A test report shall be prepared to document the pressure boundary leakage test. This report shall include the following information:

(a) housing or portion of housing tested

(b) specified allowable leakage and test pressure

(c) calculations for housing section square footage for housings tested by sections

(d) adjustments to allowable leakage per HA-5320(c)

(e) measured leakage test

(f) list of pressure boundary components which were not installed during the pressure boundary leakage test

(g) test equipment used; including model number, serial number, and evidence of calibration

(h) names of test personnel

(i) date of test

HA-5350 ACCEPTANCE CRITERIA

HA-5351 Quantitative Leakage Tests

Acceptance criteria for quantitative leakage tests shall comply with HA-4500 and HA-5320(c).

HA-5352 Nonquantitative Leakage Tests

For nonquantitative leakage tests allowed by HA-4533, the acceptance criteria shall be that audible leaks have been sealed.

HA-5400 MOUNTING FRAME TO HOUSING LEAKAGE TEST

A mounting-frame pressure leak test may be used to detect leaks in the HEPA filter and adsorber mounting frames that could affect the results of the in-place leak tests in TA-4300. The test, if used, shall be conducted in accordance with Nonmandatory Appendix TA-A.

HA-5500 STRUCTURAL CAPABILITY TESTS

HA-5510 HOUSING PRESSURE TEST

A pressure test shall be performed at the structural capability pressure per TA-3522. This test shall be maintained for the duration of the inspection. Upon completion of this pressure test, housings exhibiting permanent distortion or breach of integrity shall be repaired or replaced. The pressure test shall be repeated after repair or replacement until no permanent distortion or breach of integrity is observed.

HA-5600 AIRFLOW DISTRIBUTION TESTS

When required by the Owner, airflow distribution qualification tests for housings containing more than one HEPA filter or adsorber bank shall be made in the shop in accordance with TA-4600. This requirement shall be specified in the Owner's specification. Acceptance criteria shall be in accordance with TA-4600.

Housings containing HEPA filter(s), adsorbers, or both shall be field tested to demonstrate adequate airflow distribution in accordance with TA-4600. Tests shall be performed with components in the housing and the housing complete (i.e., assembled). Minor items such as temperature elements, pressure taps, etc., do not need to be installed as these components do not significantly influence airflow distribution.

The Owner or designee shall specify a shop test in the design specification when housing inlet or outlet conditions could result in nonuniform flow distribution.

HA-5700 AIR-AEROSOL MIXING UNIFORMITY TESTS

When required by the Owner or designee, air-aerosol qualification tests for housings containing more than one HEPA/adsorber shall be made in the shop in accordance with TA-4600 for each manifold design. This requirement shall be specified in the Owner's specification. Acceptance criteria shall be in accordance with TA-4600. Tests shall be performed with components in the housing and the housing complete (i.e., assembled). Minor items such as temperature elements, pressure taps, etc., do not need to be installed as these components do not significantly influence mixing. This design qualification test may be performed once and submitted to the Owner or designee for approval. The design of the manifold and its location in the housing must be the same as qualified or a new aerosol mixing test is required.

HA-5800 SAMPLING MANIFOLD TESTING

Sampling manifolds shall be qualified to demonstrate that they collect a representable sample equivalent to a single-point sample taken at a point at least 10 duct diameters downstream of the filters. Refer to Nonmandatory Appendix D for performance test guidance. To ensure required leakage detection, acceptance criteria for sampling manifolds shall be equal to or greater than the concentration detected with the single-point sample.

HA-5900 AIR CONDITIONING AND AIR HANDLING UNIT TESTING

When required by the Owner or designee, integrated component functional acceptance testing shall be performed in the shop per Article TA-4000. This requirement shall be included in the Owner's specification.

ARTICLE HA-6000
FABRICATION

HA-6100 GENERAL

Air cleaning, air conditioning, and air handling unit housings and supports shall be fabricated in accordance with this section and Article AA-6000.

HA-6110 SCOPE AND APPLICABILITY

This article contains specific requirements for the fabrication of air cleaning, air conditioning, and air handling unit housings and their supports.

HA-6120 MATERIALS

HA-6121 Material Selection

Materials used in fabrication performed under this section shall conform to Article HA-3000 requirements.

HA-6122 Material Identification

Materials to be utilized in the fabrication and installation of components, parts, and appurtenances shall be identified on fabrication drawings and in the specification, as required in Article AA-6000.

HA-6123 Repair of Material With Defects

Material with defects that are discovered or produced during the fabrication process may be used, provided the defects are repaired in accordance with the requirements of Article AA-8000, and for weld repairs, in accordance with AA-6300.

HA-6130 CONTROL OF INSTALLATION AND FABRICATION PROCESS

Quality control procedures shall be prepared and maintained current for all fabrication processes in accordance with Article AA-8000 requirements.

HA-6140 WELDING

The welding of filter housings and supports shall comply with the requirements of AWS D1.1, AWS D1.3, AWS D9.1, or ASME Boiler and Pressure Vessel Code, Section IX.

Welding and brazing performed in accordance with this section shall meet the requirements of AA-6300 and AA-6400.

HA-6200 FABRICATION PROCESS

HA-6210 CUTTING, FORMING, BENDING, ALIGNING, AND FITTING

HA-6211 Uncoated Metal

Uncoated metal may be cut, formed, or bent by any means that does not degrade the mechanical or chemical properties of the material.

HA-6212 Coated Metal

Coated metal may be cut, formed, or bent as described in HA-6211. Coating damaged by scratches, gouge marks, or the removal of coating shall be repaired in accordance with AA-6540.

HA-6213 Inside Bend Radii

Inside bend radii shall not be less than the values of the material grade given in the AISC Manual of Steel Construction, Allowable Stress Design.

HA-6214 Joining Parts

Parts that are to be joined may be fitted, aligned, and retained in position during the joining operation by the use of bars, jacks, clamps, drift pins, tack welds, or other temporary attachment. The fitting and aligning process shall not damage the joined parts, or their surfaces, or enlarge bolted holes greater than the values shown in AISI, Specification for Design, Fabrication, Erection of Structural Steel for Buildings, Table 1.23.4.

HA-6215 Temporary Attachments

Temporary welded attachments may be used in the fabrication process but shall be completely removed after use. Where such temporary attachments are used, they shall be subject to the following requirements.

(a) Material shall be suitable for welding with no reduction in the structural integrity of the member to which the attachment is secured.

(b) Attachment material shall be identified as required by Article HA-3000.

(c) The welder and welding procedures shall be qualified in accordance with HA-6140.

HA-6300 MECHANICAL FASTENING

HA-6310 GENERAL

HA-6311 Nuts

Nuts for all bolts and studs shall be engaged for the full length of the nut thread. Margin shall be allotted to prevent the nut from engaging the unthreaded portion of the bolt or stud.

HA-6312 High-Strength Bolts

High-strength bolts, used in making bolted structural joints, shall be installed in accordance with the requirements of the *Specification for Structural Joints Using A325 or A490 Bolts* AISC Code.

HA-6313 Pins

Pins for securing insulation should be secured to the metal surface by welding. Other attachment methods are acceptable, if allowed by the design specification. Justification of the attachment method used shall be supported by evaluation or calculation as determined by the Owner or designee, considering the requirements of the design specification.

HA-6314 Connecting

Connecting flange faces shall be free of joint crevices at corners. These defects shall be eliminated by welding or grinding.

HA-6400 FABRICATION TOLERANCES

HA-6410 GENERAL

Housing fabrication shall be accomplished within the tolerances detailed in the manufacturer's design drawings. These fabrication tolerances provide a method of quality control. For separately installed frames in walk-in housings, see Section FG.

HA-6420 SIDE-ACCESS HOUSING AND GASKET SEAL SURFACES

HA-6421 Flatness

Each HEPA filter/adsorber housing seating surface shall be plane within $\frac{1}{16}$ in. (1.6 mm).

HA-6422 Surface Finish

Pits, roll scratches, weld spatter, and other surface defects within the sealing areas shall be ground smooth. After welding, ground areas shall merge smoothly with the surrounding base metal.

HA-6430 SIDE-ACCESS HOUSING FILTER FLUID SEAL SURFACES

HA-6431 Flatness

The tolerance on each knife edge shall be plane within $\frac{1}{8}$ in. (3.2 mm).

HA-6500 CLEANING

All surfaces shall be cleaned per AA-6500 prior to acceptance. No halogen-bearing materials or carbon steel tools shall be used to clean housings or components constructed of stainless steel. Cleaning shall be performed in accordance with the manufacturer's written procedures.

ARTICLE HA-7000
PACKAGING, SHIPPING, RECEIVING, STORAGE, AND HANDLING

HA-7100 GENERAL

Packaging, shipping, receiving, storage, and handling requirements shall be in accordance with Article AA-7000 and this section.

HA-7200 PACKAGING

HA-7210 GENERAL

Air cleaning, air conditioning, and air handling unit housing packaging requirements are dependent upon the protection level as described in AA-7230. Additional clarification or exceptions are provided below.

HA-7211 Protection

Air cleaning, air conditioning, and air handling unit housings shall be protected to prevent physical damage. All openings shall be covered with wood, metal, or plastic. Waterproofing is required to exclude moisture from interior spaces and external devices. Mating surfaces shall be identified and specifically protected from damage. Protection equal to Level D is required for the basic unit. Protection for housing components must be equal to that required by the level of protection specified in the applicable Code section.

HA-7300 SHIPPING

This subarticle relates to transportation methods from the manufacturer or supplier to the job site. Shipping shall comply with the provisions of AA-7100, AA-7200, and AA-7300.

HA-7400 RECEIVING

Receiving at the job site or intermediate location, where additional work is to be performed or for long-term storage, shall be accomplished in accordance with the provisions of Article AA-7000. It shall be the requirement, at any receiving point, to have adequate descriptions of items to permit suitable inspection for conformance, damage acknowledgment, and proper documentation.

HA-7500 STORAGE

HA-7510 GENERAL

Housing storage requirements are dependent upon the protection level described by AA-7230. Protection equal to Level D is required for the basic unit. Protection for housing components must be equal to that required by the level of protection specified in the applicable Code section. These levels shall be the required storage requirements along with the requirements of HA-7511 and HA-7512.

HA-7511 Drains and Vents

All housing drains or vents shall be sealed or closed as specified by the Owner or designee. Provisions may be made to use certain drains or vents for assurance that water or other objectionable material does not accumulate within the housing.

HA-7512 Other Components

Components covered by other sections of this Code that are installed into an integral assembly that is covered by this section shall be stored in accordance with AA-7230.

ARTICLE HA-8000
QUALITY ASSURANCE

HA-8100 GENERAL

Equipment and material covered under this section shall be manufactured, fabricated, installed, inspected, and tested in accordance with the provisions of a Quality Assurance Program meeting Article AA-8000 requirements.

HA-8200 MATERIAL IDENTIFICATION

Measures shall be established for controlling and identifying material throughout the manufacturing process and during shipment in accordance with Article AA-8000.

HA-8300 DRAWINGS AND DOCUMENTATION

The design specification shall list the documentation requirements for the housing and list when this documentation is to be provided by the manufacturer, supplied to the Owner or designee. Housing-related items shall include, but not be limited to the following:

(a) material certification and test reports

(b) housing drawings including

(1) outline drawings

(2) piping and instrumentation diagrams

(3) wiring diagrams

(c) material list

(d) welding procedures and procedure qualification records as required by applicable welding code listed in HA-6140

(e) reports for tests and inspections required by Article HA-5000

(f) seismic and environmental qualification reports

(g) operating, installation, and maintenance manuals

ARTICLE HA-9000
NAMEPLATES AND STAMPING

HA-9100 GENERAL

All items manufactured under the requirements of this section shall be identified to ensure compliance with Article AA-9000 requirements.

Records, as necessary to ensure compliance with AA-8200, shall be maintained by the responsible organization in accordance with the approved quality assurance program.

HA-9110 STAMPING/MARKING

Stamping/marking, as used herein, provides a means of maintaining identification of finished products for the purpose of retaining traceability of material.

HA-9111 Housings

Housings shall be provided with nameplates, in accordance with AA-9120, which relate the housings to the applicable design and fabrication documents. Housings fabricated in multiple sections need only one nameplate. Each section shall have identification markings, observable after completed installation, which relate all sections. Nameplates shall be visible after completed installation.

HA-9112 Housing Accessories

Housing accessories shall be marked, stamped, or provided with a nameplate that shall relate to the design and fabrication drawings. Identification shall be observable after completed installation.

NONMANDATORY APPENDIX HA-A
DIVISION OF RESPONSIBILITY

This Nonmandatory Appendix is intended to identify the roles normally assumed by the organizations responsible for fulfilling Code requirements when not specifically addressed in an article or subarticle. These are guidelines to assist with Code compliance and are not to be construed as legal or contractual responsibilities unless so invoked by the Owner or designee.

TABLE HA-A-1000
DIVISION OF RESPONSIBILITY

HA-	Item	Responsible Party
3100	Allowable materials	Owner or designee
3200	Special limitations on materials	Owner or designee
3300	Certification of material	Manufacturer/Supplier
4200	Design criteria	Owner or designee
4300	Housing joints and seams	Manufacturer/Owner or designee
4400	Accessories	Manufacturer/Owner or designee
4500	Pressure boundary leakage	Owner or designee
4600	Design specification	Owner or designee
5120	Responsibility for procedures	Manufacturer/Contractor/Owner or designee
5200	Inspection	Contractor/Manufacturer/Owner
5320	Allowances for housing leakage rates by sections	Owner or designee/Contractor
5330	Testing procedures	Owner or designee/Manufacturer/Contractor
5340	Documentation	Contractor
5350	Acceptance criteria	Contractor/Owner or designee
5500	Structural capability tests	Manufacturer/Contractor
5600	Airflow distribution tests	Manufacturer
5700	Air-Aerosol mixing uniformity tests	Manufacturer
6000	Fabrication	Manufacturer
7000	Packaging, shipping, receiving, storage, and handling	Manufacturer/Supplier Contractor/Owner or designee
8000	Quality assurance	All Parties
9000	Nameplates and stamping	Manufacturer/Supplier

NONMANDATORY APPENDIX HA-B
ADDITIONAL GUIDELINES FOR HOUSING DESIGN AND CONSTRUCTION

ARTICLE HA-B-1000 FUNCTIONAL DESIGN

Procedures and data for sizing of housings to provide the desired air quantities and distribution are presented in the ASHRAE Handbook, *Fundamentals* and in the SMACNA manual, *HVAC Duct System Design.* Principles of room-air distribution and duct system layout are also described in those publications. Exhaust system concepts are described in *Industrial Ventilation,* published by the American Conference of Governmental Industrial Hygienists.

Guidance for design, construction, and testing of housings is provided by the "Nuclear Air Cleaning Handbook — Design, Construction, and Testing of High Efficiency Air Cleaning Systems for Nuclear Application," C. Burchsted, Kahn, and Fuller, ERDA 76-21, and additional guidance provided herein.

HA-B-1100 GENERAL

HA-B-1110 ACCESS DOORS

HA-B-1111 General

(a) Seals. Gaskets should be installed on doors and a "knife-edge" sealing surface for the gasket should be provided. Gaskets should be neoprene or silicone rubber with a recommended 30-40 "Shore A Durometer" (Reference ASTM D 2240, *Test Method for Rubber Properties — Durometer Hardness*). Access door design should enable a compression of at least 50% of nominal gasket thickness and provide a gasket compression uniformity of ±20%.

The gasket should be installed in as few pieces as possible to minimize the number of joints. Gasket joints should be designed to prevent leakage due to misfitting butt joints.

The gasket for walk-in type housings should be protected from possible damage when the door is opened by installing the gasket within a channel or with a metal bar between the door edge and the gasket to protect it in an equivalent manner.

Side access, bag-out access doors often use gaskets that accommodate the door to the housing seal. The gasket ensures the ability to seal the door within the allowable leakage criteria.

(b) Hinges and Latches. Latches should seal in less than 270 deg of motion. Latches should not have more than one handle per location.

Latches should be configured so that, when open, gravity will hold them in the open position.

Latch assemblies should have a minimum number of components and be designed so loose components cannot fall off.

Side access, bag-out access doors should have hinges, latches, or bolts of sufficient quantity and strength to compress the gasket and maintain the proper seal so that the housing leakage criteria is met.

(c) Additional Guidance. Sufficient clearance should be provided to enable doors to be opened allowing access for testing, component replacement, repair, or inspection.

Drawings for each type and size door should be submitted to the Owner for review prior to fabrication. Door drawings should show location and details of hinges, latching lugs, and gaskets.

HA-B-1120 DRAINS

The number of normally open drains should be kept to a minimum as specified by the Owner or designee (i.e., drains should be manually valved off when not needed during operation) to reduce the possibilities of degrading the pressure boundary or bypassing the air-cleaning unit or filter banks.

Drain lines shall be valved, sealed, trapped, or otherwise protected to prevent an adverse condition where one of the following could occur:

(a) air bypass can occur around filtration components

(b) cooling/heating coil capacity is negatively impacted

(c) contaminated (radioactive or otherwise) air is transferred through the piping to a protected environment (either into or out of housing)

Traps or loop seals, when used, should be designed for the maximum operating (static) pressure the housing may experience during system start-up, normal operation, system transients, or system shutdown. Provision should be made for manual or automatic fill systems to ensure water loop seals do not evaporate. If manual filling is utilized, a periodic inspection or filling procedure should be implemented. A sight glass should be considered to aid in inspection. The same applies if a local sump is included in the design.

The drain system should be designed so that liquids do not backup into the housing. Hydraulic calculations should be prepared by the Manufacturer to document this feature of drain system design. Provision should be made in plant radwaste systems to treat maximum coincident flow rate.

Initial testing of the drain system should be performed by the Owner on site, after installation, to demonstrate operability.

When shutoff valves or check valves are utilized, they should be initially tested on site, after installation, and periodically thereafter for operability and leakage.

Valve leakage should be considered as part of the allowable housing leakage criteria derived in HA-4500.

NONMANDATORY APPENDIX HA-C
MANIFOLD DESIGN GUIDELINES

ARTICLE HA-C-1000
GENERAL

Test manifolds discussed in this Appendix are those required for test agent injection, or sampling, to perform in-place aerosol tests per TA-4600 and TA-4700.

HA-C-1100 MANIFOLD REQUIREMENTS FOR IN-PLACE TESTS

HA-C-1110 AIRFLOW

Airflow capacity and distribution may require access ports for traverse measurements of airflow velocity on housings too small for a person to enter and take the necessary data. Specifically, there must be provision to measure the airflow capacity, which is best measured in a straight run by standard pitot tube traverse. If there is no straight run, then the measurements should be taken downstream of a HEPA filter bank. This is the same location at which the airflow distribution test data are usually taken.

The ports shall provide sufficient access to allow at least 10 measurements to be taken evenly over the face of the HEPA filter bank. Walk-in housings with more than 10 filters will be large enough to allow entry, unless unusual contamination restricts entry.

HA-C-1120 CHALLENGE/AIR MIXING UNIFORMITY

Manifold requirements for challenge/air mixing uniformity testing is similar to the access requirements for airflow distribution. The difference is that the measurements must be taken upstream of the HEPA filter bank or adsorbent bank. Large housings usually allow entry for personnel to locate sample lines by hand. Only small or highly contaminated systems need to be tested with a remote traverse.

HA-C-1130 MULTIPLE-COMPONENT BANKS IN SERIES

The most common problem area is leak testing multiple-component banks in series. There are many possible configurations that create this situation. A HEPA-Adsorber-HEPA bank is the most common case; however, HEPA-HEPA, Adsorber-Adsorber, HEPA-Adsorber, or Adsorber-HEPA banks alone, or in combination, also may require the use of manifolds. Refer to Figs. HA-C-1130-1 through HA-C-1130-5.

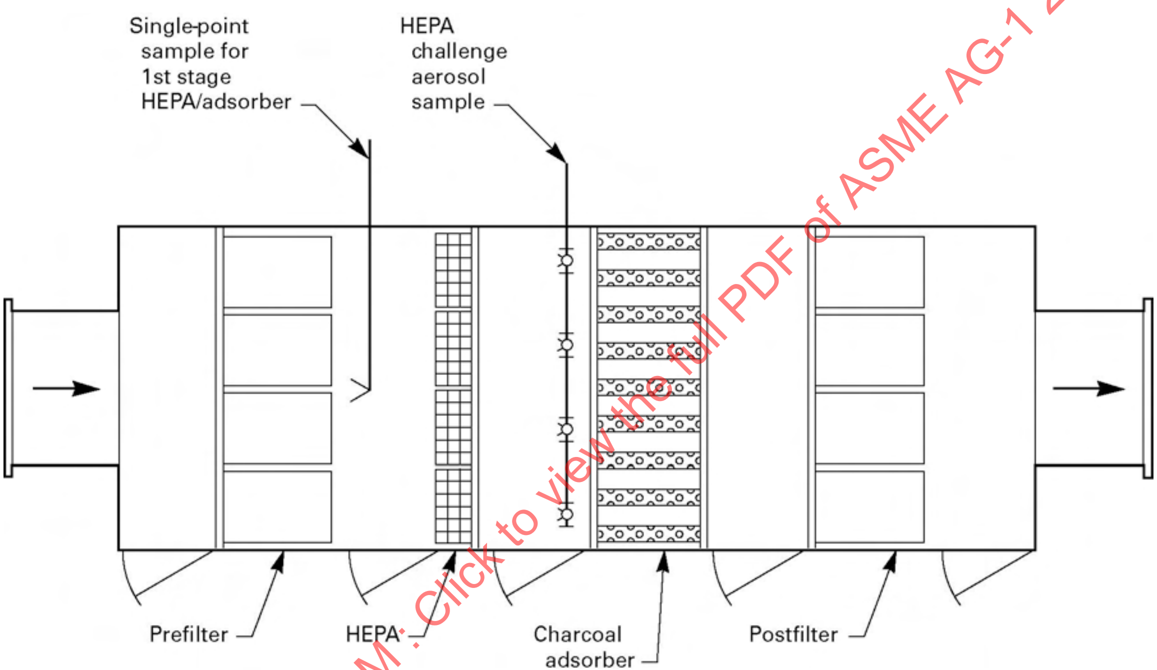
HA-C-1140 ABSENCE OF COMPONENTS IN SERIES

Even in a housing without components in series, manifolds may be necessary. An example is a recirculation system with no inlet duct before the filter bank. An injection manifold is required to obtain uniform test agent distribution.

HA-C-1150 UNIFORMITY

Manifolds are required whenever injection of a test agent at a single point does not result in the required distribution of the agent over the inlet face of the filter bank to permit the performance of the leak test or where sampling is required from an unmixed stream. An injection manifold is required to obtain uniform test agent distribution.

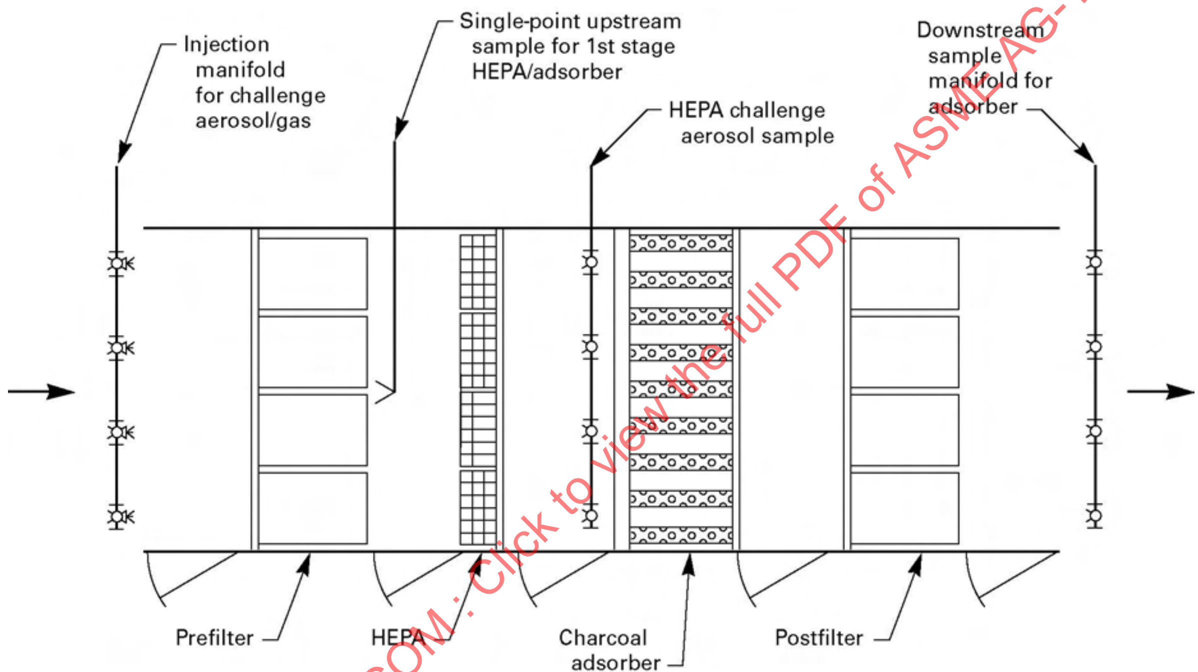
FIG. HA-C-1130-1 COMMON CONFIGURATIONS REQUIRING TEST MANIFOLDS (PLAN A)



GENERAL NOTES:
(a) Injection of challenge aerosol/gas is in inlet duct.
(b) Downstream challenge aerosol/gas sample port may be located in outlet duct.

Plan A: ducted inlet/outlet HEPA/adsorber configuration

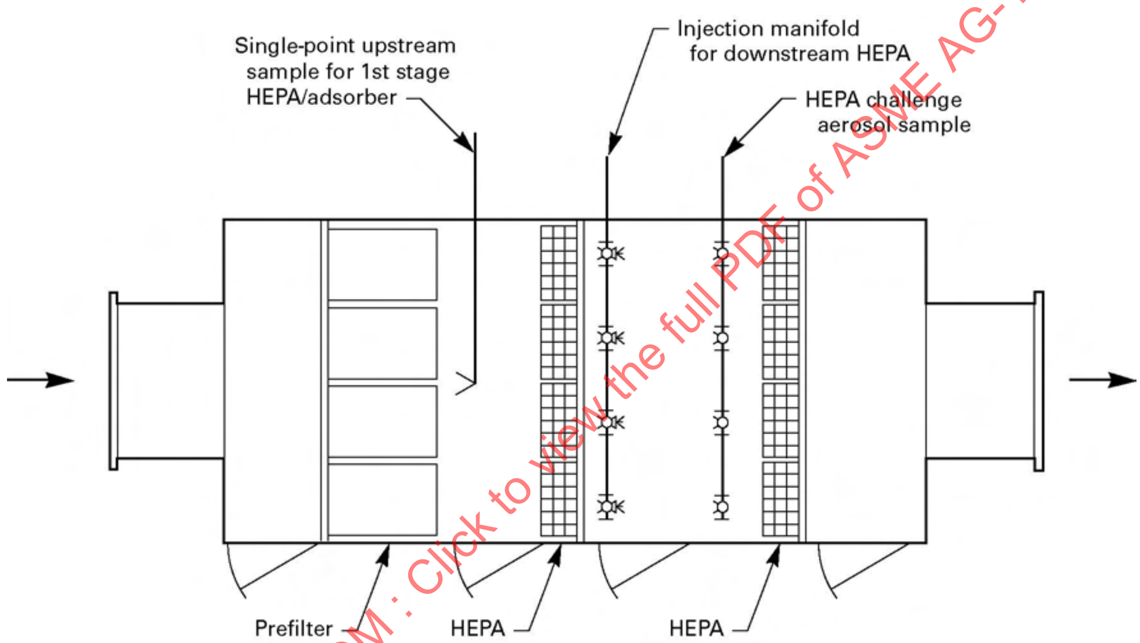
FIG. HA-C-1130-2 COMMON CONFIGURATIONS REQUIRING TEST MANIFOLDS (PLAN B)



GENERAL NOTES:
(a) If an inlet duct is provided, the challenge aerosol/gas injection can be located in the inlet duct.
(b) If an outlet duct is provided, the downstream sample can be located in the outlet duct.

Plan B: unducted inlet/outlet HEPA/adsorber configuration

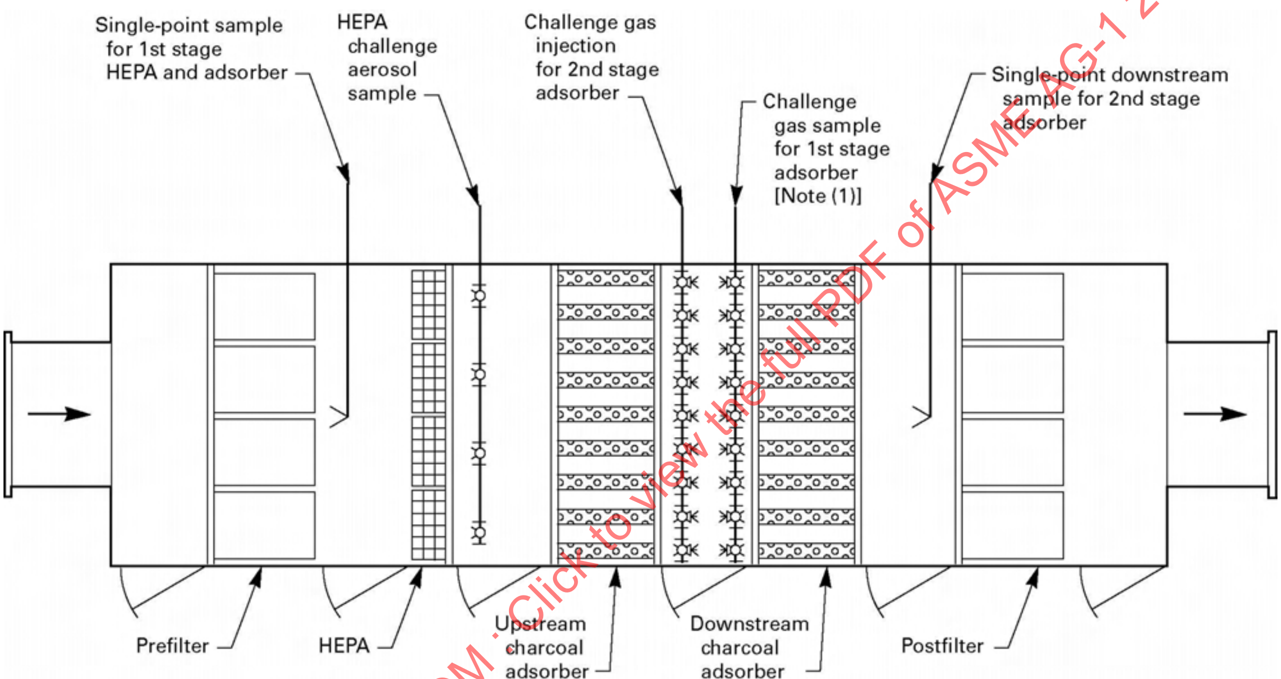
FIG. HA-C-1130-3 COMMON CONFIGURATIONS REQUIRING TEST MANIFOLDS (PLAN C)



GENERAL NOTES:
(a) Injection of challenge aerosol/gas is in inlet duct.
(b) Downstream challenge aerosol/gas sample point may be in outlet duct.

Plan C: ducted inlet/outlet
HEPA/HEPA configuration

FIG. HA-C-1130-4 COMMON CONFIGURATIONS REQUIRING TEST MANIFOLDS (PLAN D)

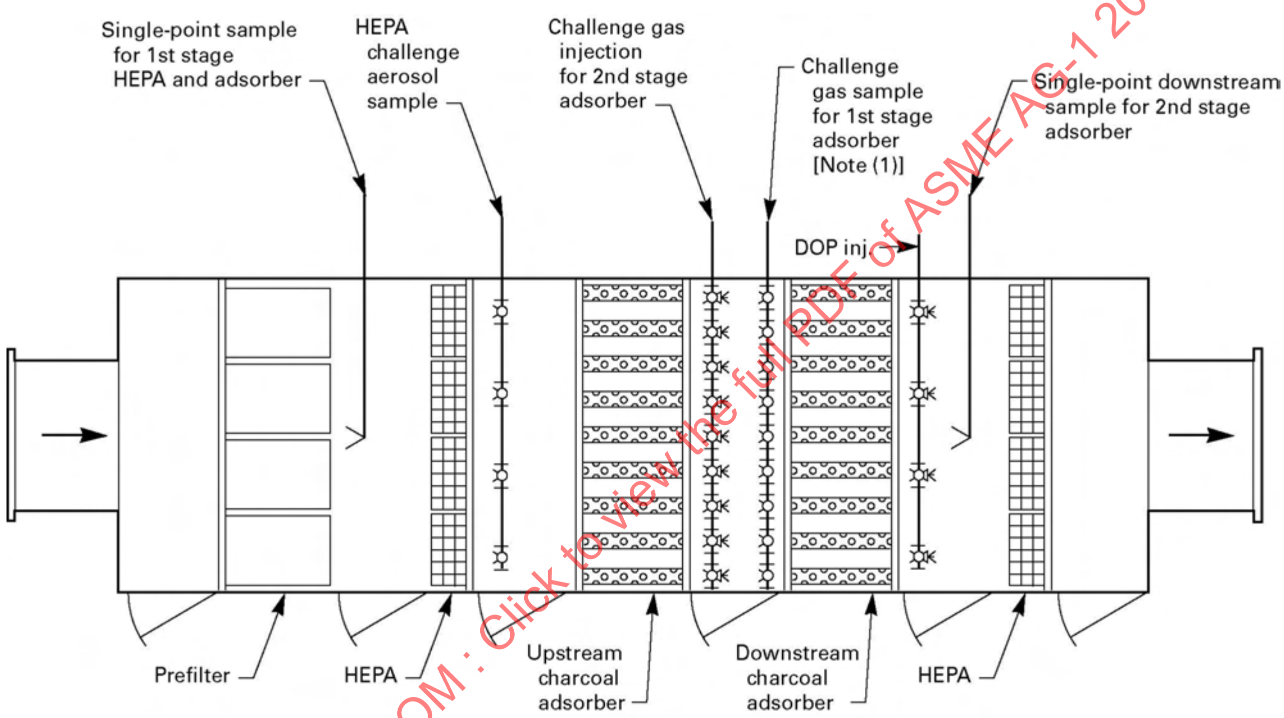


GENERAL NOTES:
(a) Injection of challenge aerosol/gas is in inlet duct.
(b) Downstream challenge aerosol/gas sample point may be in outlet duct.

NOTE:
(1) First stage challenge gas sample point can be used for second stage upstream sample in lieu of single-point sample.

Plan D: ducted inlet/outlet HEPA/adsorber/adsorber configuration

FIG. HA-C-1130-5 COMMON CONFIGURATIONS REQUIRING TEST MANIFOLDS (PLAN E)



GENERAL NOTES:
(a) Injection of challenge aerosol/gas is in inlet duct.
(b) Downstream challenge aerosol/gas sample point may be in outlet duct.

NOTE:
(1) First stage challenge gas sample point can be used for second stage upstream sample in lieu of single-point sample.

Plan E: ducted inlet/outlet HEPA/adsorber/adsorber HEPA configuration

HA-C-1200 CONSIDERATIONS FOR USE OF PERMANENTLY INSTALLED MANIFOLDS

HA-C-1210

Permanently installed manifolds, which have passed Appendix D acceptance testing, provide a quick and simple means to repeat leak tests.

HA-C-1220

Alternate methods of testing when a single-point sample cannot be used, including temporary manifolds, are more time consuming than using a permanently installed manifold system.

HA-C-1230

Other methods require entering the air cleaning unit to install a temporary manifold, take multiple samples, place a shroud, remove a component, etc. This not only takes time, but can be a personnel exposure and contamination control problem with a contaminated system.

HA-C-1240

A permanently installed manifold system allows a bank test of the air cleaning unit without turning the air cleaning unit off or breaching the pressure boundary that could affect system operation.

HA-C-1250

For permanently installed manifolds, consideration should be given to installation and removal of filters. If the manifolds interfere with installation and removal, then they should be designed for removal to allow access to the filters.

HA-C-1300 INJECTION MANIFOLDS

HA-C-1310 GENERAL

An injection manifold is a device to allow uniform distribution of the injected challenge agent into a housing to permit proper leak testing of a filter or adsorber bank. The challenge agent shall be uniform across the face of the bank, including frame-to-housing interface, within ±20% of the average, to be confirmed by the Air-Aerosol Mixing Uniformity Test per TA-4600.

HA-C-1320

The complexity in design and installation of an injection manifold varies greatly depending on the unit/housing configuration. An injection manifold downstream of a Type III adsorber (reference Section FE) is relatively simple given that the small manifold will follow the slots and take advantage of the high velocity flow from them. Refer to Figs. HA-C-1130-2 and HA-C-1130-3.

The HEPA-HEPA configuration requires a wider distribution of injection and sampling because of the low velocity and laminar flow.

The distance between the component banks should be considered when designing the manifold.

HA-C-1330

Aerosol injection manifolds require a much larger diameter and additional design consideration than for challenge agent manifolds used for adsorber testing. Challenge agent is a gas at normal ambient conditions, so condensation and plate out is usually not a problem. All aerosol is subject to plate out, condensation, and agglomeration; therefore, all of the following recommendations are critical.

HA-C-1340 GENERAL RULES APPLICABLE TO ALL INJECTION MANIFOLDS

HA-C-1341

The total area of the exit holes are typically $1\frac{1}{4}$ times the cross section of the pipe in which the holes are located.

HA-C-1342

Headers should have a cross section $1\frac{1}{4}$ times the sum of the cross sections of all branches. [Four branches, each 1 in. (25.4 mm)(0.8 in.^{2})(516 mm^2) results in a header of (1.25)(4)(0.8 in.^{2}) = 3.9 in.^{2} or $2\frac{1}{4}$ in. diameter header. [(1.25)(4)(516 mm^2) = 2 580 mm^2 or 57.3 mm.]

HA-C-1343

Paragraphs HA-C-1341 and HA-C-1342 are subject to allowances for standard drill and pipe dimensions. When compromise must be made, it is better to be on the high side of hole and branch area.

HA-C-1344

Valves should be used only to isolate branches. If possible, it is better to avoid them because the valve settings could change and require reverification of the manifold design.

HA-C-1345

The low point of each branch should have a screw cap to allow the leg to be drained if necessary.

HA-C-1346

A sharp radius change of direction should be avoided. Compound bends are preferable to multiple elbows. When elbows are used, they should be kept to the minimum; however, two 45 deg elbows in series are better than one 90 deg elbow.

HA-C-1347

The inside diameter of the manifold shall be smooth and free from sharp edges, burrs, crevices, and other configurations that would tend to trap aerosol.

HA-C-1348

The existing high velocity areas, or turbulence, within the air cleaning unit should be used to enhance mixing, and therefore, simplify the manifold design.

HA-C-1349

The inlet to the injection manifold should be at a location accessible for connecting the generator.

HA-C-1350

The location of permanent manifolds should be checked for possible interference with component change out and other maintenance access requirements.

HA-C-1360

Manifold outlet holes should be oriented to take advantage of the flow path to assist the mixing. Configurations that would subject the manifold holes to direct velocity pressure from the airflow should be avoided in all but the most exceptional circumstances. Holes should be on a staggered pattern, 90 deg to each other, 45 deg on the centerline. Reference Fig. HA-C-1130-3.

HA-C-1370

The design of an aerosol injection manifold is dependent on the bank and housing configuration.

HA-C-1380

Unique injection manifold designs shall be qualified by testing to ensure meeting the Air-Aerosol Mixing Uniformity Test of TA-4600.

HA-C-1390

If adjustments are required in a manifold to pass the uniformity test, they should be permanent. This will eliminate the need to repeat the uniformity test each time a leak test is performed. Examples of permanent adjustments are

(a) drilling out a hole to a larger diameter
(b) closing (full or partial) a hole with solder or weldment
(c) addition of holes
(d) addition of orifice plates
(e) addition of permanent baffles to manifold
(f) basic change of design

HA-C-1400

All design points mentioned for injecting manifolds apply to sample manifolds. The main difference is the low concentration of challenge, on the order of 1,000 to 100,000 times less. This greatly reduces the problem of aerosol agglomeration and plate out. Further, the challenge is usually in the thermal equilibrium with the airstream and manifold, so condensation should not be a problem.

HA-C-1410

A major point to stress is that for the aerosol size used for in-place testing, isokinetic flow is **NOT REQUIRED.** For particle size less than 5 microns, isokinetic sampling is not required. For a gas, such as halide, isokinetic sampling is not required.

HA-C-1420

Given the low concentrations, the tube diameter of the sampling manifolds can be of much smaller diameter than for injection manifolds, but a larger number of branches is required to ensure detecting a leak point.

The diameters are based largely on airflow considerations. These are a compromise of small ID for higher velocity (less delay) and pressure drop.

HA-C-1430

For adsorbers, even with the smaller diameter for sampling manifolds, the volume is usually significant as far as sample delay. The sample pumps in most detectors are sized for standard $^1/_4$ in. (6.35 mm) nylon lines. An auxiliary pump/blower is usually required to avoid delays in the sample from the furthest point reaching the detector. This delay is calculated from the volume and layout of the manifold and the capacity of the pump. It must be used as a factor or correction in the penetration calculations for adsorbers.

HA-C-1440

Since most detectors are designed to operate with the sample being drawn from ambient or near-ambient pressures, care is required in connecting the detector to an auxiliary blower system. It must not be “hard piped” to a closed system or subject to the positive output pressure of the blower. An open hole in the main sample line or a tee before the blower is preferred. The setup must not allow dilution air to enter the detector sample line (dilution of the sample past the takeoff point is not relevant). It must not allow velocity pressure from the auxiliary blower to change the pressure in the detector sample. The connection must be firm enough that no change will occur during the test.

NONMANDATORY APPENDIX HA-D
PERFORMANCE TEST FOR QUALIFICATION OF SAMPLING MANIFOLDS

ARTICLE HA-D-1000

HA-D-1100 PURPOSE

The purpose of this test is to provide objective verification that installed sampling manifolds provide a representative sample of subsequent component bank leak tests performed in the field per Section TA.

HA-D-1200 LIMITS

This is a factory test for sampling manifolds. It cannot be performed satisfactorily in the field.

HA-D-1300 TEST REQUIREMENTS

HA-D-1310

The housing, component banks, and sampling manifolds shall be complete and in their final ready-for-use configuration. Any later modification shall invalidate prior tests and require a retest.

HA-D-1320

Aerosol shall be used to qualify all sampling manifolds and challenge agent sampling manifolds.

HA-D-1330

Aerosol shall be used to qualify all sampling manifolds and challenge agent sampling manifolds.

HA-D-1340

The test shall be conducted at the housing design airflow rate ±10%. If more than one flow rate is required for operation, a manifold performance test shall be performed at each flow rate. If the design has a variable flow rate, then the minimum and maximum (10% for each) shall be used to perform the tests. Airflow distribution testing per HA-5600 shall be performed as a prerequisite to a manifold qualification test.

HA-D-1350

To ensure complete mixing, a temporary duct and fan shall be provided downstream of the housing. The duct shall be long enough and have provisions sufficient to guarantee mixing so that a representative single point sample may be taken. Baffles, vanes, or other means of providing good mixing are acceptable in the duct assembly. They shall be clearly shown on the sketch and documented sufficiently for independent review.

In other configurations, the number of sample points shall be in accordance with Chapter 9 of Testing of Ventilation Systems of Industrial Ventilation, 23rd Edition. If necessary the number of sampling points, mixing, or duct length shall be increased so each sampled concentration is within ±5% of the calculated average.

HA-D-1360

The temporary duct and fan assembly shall be leak tight so that no dilution air can enter or leave the test boundary. This shall be confirmed by a documented leak test in accordance with Section TA.

HA-D-1370

A visual inspection using applicable articles of Section TA is required. The visual inspection checklist shall be used after the test setup is completed, but before the test is performed. Nonconformances shall be resolved before the test is performed.

HA-D-1380

Test engineers and technicians shall be qualified in accordance with ASME NQA-1. A Level II Test Engineer shall prepare the test procedure and review the test results for acceptance.

HA-D-1400 TEST METHOD

HA-D-1410

The basis of the test is to compare the single-point aerosol concentration taken in the temporary test duct with that obtained from the sampling manifold under test.

HA-D-1420

Test data shall be taken with all filter elements and adsorbent installed without any artificial leak paths, as follows:

(a) the artificial leak paths shall be located, one at a time, to simulate leaks in the filter/adsorbent face, the frame-to-wall welds (including floor and ceiling), and gasket-to-frame seals (where applicable), and at structural welds on Type III adsorbers.

(b) the number and exact placement of the artificial leak paths depends on the size and configuration of the bank and housing, but shall be not less than ten with at least four at frame-to-wall floor and ceiling locations. Tests with multiple leak paths are permissible after the required 10 tests with single leak paths are performed.

HA-D-1430

Aerosol concentration shall be by traverse at a single point measured in the temporary duct and while using the sampling manifold. For each test condition the single-point sample concentration shall be the average of the traverse readings in the temporary duct.

HA-D-1440

If the sampling manifold concentration does not agree with the single-point sample result within 5%, the sample manifold shall be modified to produce a result within ±5% for all test conditions.

HA-D-1441

A useful method to locate nonuniform concentration is to scan in front of the manifold while the challenge aerosol is flowing. This will provide data to assist the redesign/modification of the manifold.

HA-D-1500 ACCEPTANCE CRITERIA

HA-D-1510 SINGLE-POINT SAMPLE

All traverse concentration measurements taken at the single-point sample location cross section shall be within ±5% of the calculated average concentration.

HA-D-1520 SAMPLE MANIFOLD

The sample manifold concentration shall be within ±5% of the single-point sample concentration for all artificial leak paths.

HA-D-1600 DOCUMENTATION

HA-D-1610

A sketch of the factory test setup shall be provided. It shall provide sufficient dimensions and detail to allow analysis by the Owner or designee prior to the start of testing.

HA-D-1620

The details of the test instruments for airflow and aerosol generation and detection shall be provided. They shall include, as a minimum, the manufacturer, model, serial number, and calibration date.

HA-D-1630

The test procedures shall be submitted to the Owner or designee for review prior to the start of testing. All data shall be presented in a manner that will allow independent analysis of the test results.

HA-D-1640

The location, date, and the names of test engineers/technicians shall be listed with signatures.

HA-D-1650

An ASME NQA-1, Level II Engineer shall sign the test report to be submitted to the Owner for review prior to shipping the unit.

HA-D-1700 ACCEPTANCE OF RESULTS

HA-D-1710

The Owner or designee shall review and approve the detailed test procedure, including drawings of the temporary duct and hardware, before the test is performed and may provide comments to the testing organizations.

HA-D-1720

The Owner or designee shall review the results of the test before the housings are shipped. It is recommended that such approval be revised before the test assembly is dismantled. The Owner or designee shall advise the manufacturer, in writing, of acceptance of sampling manifold qualification test results prior to the unit's being shipped.

SECTION RA
REFRIGERATION EQUIPMENT

ARTICLE RA-1000 INTRODUCTION

RA-1100 SCOPE

This section covers requirements for the performance, design, materials, construction, acceptance testing, and quality assurance for nuclear safety-related refrigeration equipment used in nuclear power plants. Refrigeration equipment covered by this section constitutes equipment used to refrigerate fluids that ultimately maintain operating personnel habitability and process cooling for nuclear power plant systems. A nuclear power plant process system, as used herein, is defined in AA-1130. Criteria are established for the equipment operability, reliability, and testability in order for the equipment to perform in accordance with the design specification. Nonmandatory Appendix RA-A is a guide for the determination of responsibilities under this section.

RA-1200 PURPOSE

The purpose of this section is to ensure that refrigeration equipment used in nuclear power plants is adequate in all aspects of performance, design, and construction.

RA-1300 APPLICABILITY

(a) This section provides requirements for new refrigeration equipment. It is not intended to provide the criteria for inservice deterioration, which may occur due to unspecified corrosion, erosion, or instability of material. These effects shall be taken into account in the design specification with a view toward the equipment design life — the end purpose for which the equipment shall be used — and the system in which it is to be installed.

(b) This section provides requirements only for refrigeration equipment used for nuclear safety-related air and gas treatment.

(c) This section addresses only general system requirements for instrumentation and control associated with refrigeration equipment. It does not address requirements for materials or component design for instrumentation and controls. For instrumentation and control requirements, see Section IA (in the course of preparation).

(d) This section does not provide requirements for the sizing of refrigeration equipment, nor does it provide requirements for the design of the system in which the equipment is to be installed.

(e) This section does not address system single failure criteria or redundancy.

(f) This section does not provide requirements for drivers or drives for open refrigeration equipment.

(g) This section does not provide requirements for refrigerant transfer system pumps and compressors.

(h) This section does not provide requirements for refrigerant direct expansion air cooling coils used in refrigeration systems. The boundary of this exclusion is from the inlet of the refrigerant distributor through the coil outlet nozzle.

RA-1400 DEFINITIONS AND TERMS

See Glossary, Section AA. For additional refrigeration terms and definitions, see ASHRAE Terminology of Heating, Ventilation Air Conditioning and Refrigeration.

ARTICLE RA-2000
REFERENCED DOCUMENTS

The codes, standards and specifications referenced below shall supplement those documents listed in Section AA. The latest edition shall be used if no publication date is specified.

ANSI/ARI 450-99, Water Cooled Refrigerant Condensers, Remote Type

ARI 480-01, Refrigerant-Cooled Liquid Coolers, Remote Type

ARI 550/590-03, Water Chilling Packages Using the Vapor Compression Cycle

Publisher: Air Conditioning and Refrigeration Institute (ARI), 4100 North Fairfax Drive, Arlington, VA 22203

ANSI/ASHRAE 15-04, Safety Standard for Refrigeration Systems

ASHRAE Terminology of Heating, Ventilation, Air-Conditioning, & Refrigeration, Second Edition, 1991

Publisher: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329

ASME B31.5-01, Refrigeration Piping and Heat Transfer Components

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

ANSI/IEEE 43-00 Recommended Practice for Testing Insulation Resistance of Rotating Machinery

IEEE 118-1978 (R92), Standard Test Code for Resistance Measurement

IEEE 382-1996, Standard for Qualification of Actuators for Power Operated Valve Assemblies With Safety-Related Functions for Nuclear Power Plants

Publisher: Institute of Electrical and Electronics Engineers (IEEE), 445 Hoes Lane, Piscataway, NJ 08854

ARTICLE RA-3000
MATERIALS

RA-3100 GENERAL MATERIAL REQUIREMENTS

(a) All materials used shall have properties and composition suitable for the application as defined by the design specification and the operating environmental conditions, as defined in RA-4200(b). When the equipment application requires the use of specific materials, these materials shall be explicitly defined in the design specification. All materials expressly prohibited or limited shall be explicitly described in the design specification.

(b) Deterioration of water-side materials caused by unspecified service, such as corrosion or erosion, is outside the scope of this Code. Water-side materials suitable for the conditions must be stated in the design specification, with special attention being given to the effects of service conditions upon the properties of the materials. Materials for the refrigerant side shall be selected to conform with para. 9.1 of ANSI/ASHRAE 15.

(c) The rules of this section do not apply to any instruments or the permanently sealed, fluid-filled tubing systems furnished with any instruments that function as temperature or pressure responsive devices.

(d) Allowable stress data shall be

(1) for ASME Code Section III and Section VIII, use ASME Code Section II, Part D. For materials not listed in Section II, Part D, use ASME B31.5, para. 502.3.1(e).

(2) for steel of unknown specification, use ASME B31.5, para. 502.3.1(e).

RA-3110 PRESSURE RETAINING MATERIALS

(a) All materials that form the pressure boundary of systems subject to ASME Code, Section III, requirements shall meet the material requirements for Class 3 components of that Code (Article ND-2000).

(b) All material that represents a pressure boundary of systems not subject to ASME Code, Section III, requirements shall meet the applicable requirements for materials as specified in the ASME Code, Section VIII, Division 1.

(c) All pressure boundary materials that are exempted by the codes listed in RA-3110(a) and (b) shall meet the material requirements ASME B31.5, Chapter III, or shall meet the material requirements of para. 9.1 of ANSI/ASHRAE 15.

Components constructed from manufacturer's qualified material (AA-1130) shall have their suitability demonstrated by test per RA-5213 in lieu of the requirements stated in Article AA-3000.

RA-3120 COMPONENT SUPPORT MATERIALS

(a) All materials that form the support structure for ASME Code, Section III, components within the definitions provided in RA-4510, shall meet the material requirements specified in Article NF-2000 of Section III of the ASME Code.

(b) All materials that form the support structure of non-ASME Code, Section III, components shall be selected from ASME B31.1, Chapter IV; ASME 31.5, Chapter III; or Section II of the ASME Code.

RA-3130 ELECTRICAL MATERIALS

Electrical component materials are not within the scope of this section, except as covered by the referenced IEEE documents.

RA-3140 PUMP AND COMPRESSOR MATERIALS

It is recognized that there are materials used in the design and fabrication of lubrication pumps and compressors that are unique to particular manufacturers (see AA-1130). Proof of suitability of these materials, as related to the pressure boundary, will be demonstrated by test and documented by using Data Report Forms RA-2, RA-2a, RA-2b, RA-3, and RA-3a.

RA-3150 VALVE, PIPING, AND FITTING MATERIALS

RA-3151 Refrigerant

Valves, piping, and fitting materials for refrigeration systems shall meet the material requirements of Chapter III of ASME B31.5, and para. 9.1 of ANSI/ASHRAE 15.

RA-3152 Water

(a) Water valves, fittings, and piping that form the pressure boundary of systems subject to the ASME Code, Section III, requirements shall meet the material requirements for Class 3 of that Code (Article ND-2000).

(b) Valves, piping, and fittings for water systems (refrigerant transfer systems) that are not subject to the ASME Code, Section III, requirements shall meet the material requirements of Chapter III of ASME B31.1.

RA-3153 Lubrication

Valves, piping, and fittings for oil circuits of lubrication subsystems shall meet the material requirements of Chapter III of ASME B31.5, or be as specified in RA-3110(c).

RA-3154 Control

Valve and piping materials for control systems shall be compatible with the interfacing system materials and shall meet the requirements of Chapter III of ASME B31.1 or ASME B31.5.

RA-3160 WELDING AND BRAZING MATERIALS

(a) Materials for welding and brazing of components that form the pressure boundary of a system subject to the requirements of the ASME Code, Section III, shall meet the requirements specified in ND-2400 of that Code.

(b) Welding materials for structures and supports of the ASME Code, Section III, Subsection ND, pressure vessels shall meet the requirements of Subsection NF of that Code.

(c) Welding and brazing materials for components that form the pressure boundary of a system subject to the requirements of ASME B31.5 shall be as specified in Chapter V of ASME B31.5.

(d) Materials for welding and brazing of components not covered by the ASME Code, Section III, Subsections ND and NF, ASME B31.1, or ASME B31.5, shall be in accordance with AA-6310(e) and AA-6410(e).

ARTICLE RA-4000
DESIGN REQUIREMENTS

RA-4100 PURPOSE

The purpose of this Article is to establish the minimum design requirements for nuclear safety-related refrigeration equipment used in nuclear power plant applications.

RA-4200 DESIGN SPECIFICATION

The design specification shall clearly establish the purpose (design function) of the refrigeration equipment, its safety classifications, and any external interface safety classification. Typical external interface diagrams are shown in Nonmandatory Appendix RA-B.

(a) The design specification shall include performance requirements for all nuclear power plant operating modes wherein the equipment is expected to perform an intended function as defined in applicable ANSI documents. The event categories, design requirements, and safety functions for each safety class are defined in ANSI/ANS 51.1 for pressurized water reactors and in ANSI/ANS 52.1 for boiling water reactors.

(b) For each of the applicable operating conditions described in RA-4200(a), the following environmental and associated service conditions shall be specified in the design specification for the equipment.

(1) Temperature. The minimum and maximum external operating temperatures [°F (°C)] to which the machine will be subjected.

(2) Pressure. The minimum and maximum external operating pressures [psig (kPa gage)] to which the machine will be subjected.

(3) Humidity. The minimum and maximum external operating humidity levels [percent (%)] to which the machine will be subjected.

(4) Radiation Levels — Alpha, Beta, and Gamma. Both the maximum and cumulative dosage levels [rads (grays)] to which the machine will be exposed.

(5) Chemicals. Corrosion allowances shall be specified for equipment subject to thinning by corrosion. Concentration of each chemical.

(6) Structural Design Criteria. Structural loads to which the machine will be subjected. These loads shall include, but are not limited to, the loads listed in AA-4211. If a load is not applicable, it shall be so stated. The structural interface between open refrigeration equipment and its drive and drivers shall be included in these loads.

(7) Electrical Transients. Any electrical power transients to which the machine may be subjected. These abnormal conditions are stated in IEEE 323 and include variations in service parameters such as voltage and frequency. The minimum, maximum, and average values for all variables, as well as their duration, shall be specified.

(8) Cooling Load Requirements. The maximum cooling load for which the machine is to be designed, expressed in tons of refrigeration (kW) (see RA-1400).

(9) Cooling Load Profile and Time History. A cooling load profile that identifies the range of load that the machine must be designed to accommodate. The expected number of start–stop cycles during the life of the machine shall be specified.

(10) Restart Conditions. Conditions that are other than those identified in RA-4300 and that may affect the restart of the machine are defined as restart conditions. This shall include consideration for the requirements of RA-4200(c).

(11) Water-Side Design Pressures for Evaporator and Condenser. The maximum and normal water-side pressures to which pressure vessels will be subjected shall be given in psig (kPa gage) including below atmospheric pressures, if applicable. If the water sides are to be exposed to subatmospheric pressures, that information shall also be specified.

(12) Refrigeration Equipment Exposed to Harsh Environments. Temperature, pressure, relative humidity, and radiation time histories shall be provided for use in qualifying all refrigeration equipment Class 1E electrical equipment, cabling, controls, and accessories in accordance with IEEE 323.

(c) Structural Load Definition. Structural loads to be considered in the design of refrigeration equipment covered by this Code are defined in AA-4211. The magnitude and direction of all external loads shall be given in the design specification. Superimposed loads of a cyclical nature shall be clearly defined, including the occurrence of evaporator and condenser water flow variation or reversal, or both, where applicable. Loads selected shall be shown, and clearly identified, in the structural analysis report for the equipment.

RA-4300 EQUIPMENT PERFORMANCE REQUIREMENTS

The required performance of the refrigeration equipment, under the applicable conditions of RA-4200(a), shall be clearly specified in the design specification. The minimum performance requirements to be so specified shall be

(a) design load, tons of refrigeration, kW

(b) entering and leaving evaporator fluid temperature, °F (°C)

(c) minimum and maximum entering condenser fluid temperature, °F (°C)

(d) evaporator and condenser maximum and minimum flow rates, gal/min (m^3/min)

(e) evaporator and condenser fouling factors, hr-ft^2 – °F/Btu (m^2 – °C/W)

(f) evaporator and condenser tube material and nominal wall thickness, in. (mm) (corrosion and erosion effects should be considered)

(g) liquid to be cooled and condenser cooling medium, including type, properties, and level of impurities in coolant

(h) power supply voltage, phases, and frequency at the terminals of motors, starters, and controls for primary drives and auxiliaries

(i) maximum allowable pressure drop for liquid to be cooled and condenser cooling medium, ft (m)

(j) maximum evaporator and condenser tube fluid velocity, ft/sec (m/min)

RA-4400 MECHANICAL DESIGN REQUIREMENTS

RA-4410 WATER-SIDE SYSTEM

RA-4411 Code Class

Water-side pressure vessel components of the refrigeration equipment shall be, as a minimum requirement, the same ASME Code class as the fluid system in which they are to be installed. The design specification shall clearly identify this Code class.

RA-4412 Boundaries

The design specification shall define the boundaries of the water-side pressure vessels as required by Section III, NCA-3254, of the ASME Code.

RA-4420 REFRIGERANT SIDE SYSTEM

RA-4421 Heat Exchanger Design

The refrigerant side of all heat exchangers shall, as a minimum, meet the design requirements of Section VIII of the ASME Code.

RA-4422 Compressor

This paragraph identifies the design boundaries of refrigeration compressors. Refrigerant compressors include both the hermetic and open type used in either centrifugal, reciprocating, scroll, or screw refrigeration machines. Refrigerant transfer system compressors are excluded from this paragraph. Supporting structures, including integral casting, shall be analyzed per the requirements of RA-4510.

RA-4422.1 Centrifugal Compressor

(a) Hermetic

(1) The boundary of the hermetic compressor is defined as all refrigerant containing parts located between the first flange of the suction connection of the compressor and the first flange of the discharge connection of the compressor. It includes those components whose primary function is related to the compression of refrigerant (e.g., motor, impellers, volutes, shafts, bearings, and seals), but does not include secondary components whose function is to support compressor operation (e.g., lubrication system, compressor base, capacity control components and assemblies, and overtemperature protection devices). Supporting structures are covered in other sections of this Code.

(2) The design of the refrigerant containing portions of the compressor shall be in accordance with ANSI/ASHRAE 15.

(b) Open

(1) The boundary is the same as the hermetic compressor except the driver is not considered within the scope of this Code. This boundary ends at the shaft coupling and does not include the coupling itself. This Code does not address drives; therefore, the compatibility of the drives with the driven equipment shall be assured by the driver purchaser.

(2) The design of refrigerant containing portions of the compressor shall meet the requirements of ANSI/ASHRAE 15.

RA-4422.2 Reciprocating Compressor

(a) Hermetic

(1) The boundary is defined as all refrigerant containing components between the suction manifold and the discharge manifold. It includes those components whose primary function is related to the compression of refrigerant, e.g., motor, piston(s), cylinder head(s), and compressor casing.

(2) The design of refrigerant containing portions of the compressor shall meet the requirements of ANSI/ASHRAE 15.

(b) Open

(1) The boundary is the same as the hermetic compressor except the driver is not considered within the scope of this paragraph. The boundary ends at the shaft coupling and does not include the coupling.

(2) The design of refrigerant containing portions of the compressor shall meet the requirements of ANSI/ASHRAE 15.

RA-4422.3 Screw/Scroll Compressor

(a) Hermetic

(1) The boundary is defined as all refrigerant containing components between the suction and the discharge manifold. It includes those components whose primary function is related to the compression of refrigerant, e.g., motor, screw/scroll rotors, unloading mechanism, and compressor casing.

(2) The design of refrigerant containing portions of the compressor shall meet the requirements of ANSI/ASHRAE 15.

(b) Open

(1) The boundary is the same as the hermetic compressor except the driver is not considered within the scope of this paragraph. The boundary ends at the shaft coupling and does not include the coupling.

(2) The design of refrigerant containing portions of the compressor shall meet the requirements of ANSI/ASHRAE 15.

RA-4423 Refrigerant System Interconnecting Piping, Valves, and Fittings

The refrigerant system interconnecting piping, valves, and fittings shall meet the requirements of ASME B31.5 and ANSI/ASHRAE 15.

RA-4424 Transfer System

The refrigerant transfer system shall either meet the same requirements as the system to which it is connected, or shall be isolated mechanically and electrically from the system whenever the refrigeration equipment is performing a design function.

RA-4430 LUBRICATION SYSTEM

RA-4431 Piping Valves and Fittings

The lubrication system piping valves and fittings shall be in accordance with ASME B31.5.

RA-4432 Pump

The design of the lubrication pump (if required) shall be in accordance with the requirements of ANSI/ASHRAE 15. Pressure boundary portions of the pump shall be designed, constructed, and assembled to meet the requirements of para. 9.11.1 of ANSI/ASHRAE 15.

RA-4500 STRUCTURAL DESIGN REQUIREMENTS

RA-4510 GENERAL

All ASME Code, Section III, equipment and supporting structures shall be designed according to the rules established in the applicable subsections of that Code. Equipment classified as non-ASME Code, and the equipment as a whole, shall be designed, analyzed, or tested in accordance with the structural requirements of Article AA-4000. Any components, assemblies, piping, tubing, and supports not required for a design basis event (as defined in the design specification) shall be so noted and a justification shall be given for their exclusion. Applicable structural requirements and load definitions are given in RA-4200(c).

RA-4520 EQUIPMENT ATTACHMENT BOUNDARY

The attachment of the equipment to the foundation shall be designed according to AA-4360.

RA-4600 ELECTRICAL DESIGN REQUIREMENTS

All electrical and electromechanical equipment including, but not limited to, motors, wiring, and control components that is required for the refrigeration equipment to perform its design function during all nuclear power plant operating modes [see RA-4200(a)], and hereafter referred to as class 1E components as defined in ANSI/IEEE 323, shall be environmentally qualified in accordance with ANSI/IEEE 323. Qualification of these components to ANSI/IEEE 323 can be accomplished by qualification in accordance with the applicable subtier documents of ANSI/IEEE 323. If the power supply system for the refrigeration equipment includes fast bus transfer capability, the design specification shall provide pertinent voltage drop and transfer time data.

RA-4610 ELECTRIC MOTORS

All Class 1E motors shall be designed and tested in accordance with ANSI/IEEE 334, IEEE 112A, and NEMA MG-1. Non-Class 1E motors shall be designed and tested in accordance with IEEE 112A and NEMA MG-1 to ensure operability.

RA-4620 ELECTRIC VALVE AND VANE ACTUATORS

All Class 1E electric valve and vane actuators shall meet the requirements of IEEE 382.

All non-Class 1E valve operators shall be suitable for the design condition as specified in the design specification.

RA-4630 CONTROL SYSTEMS

All Class 1E control components and control panels shall meet the requirements of ANSI/IEEE 323. The design specification shall identify the required NEMA enclosure designation. The instrumentation and control functions shown in Mandatory Appendix RA-II are the minimum that shall be provided by the Manufacturer. Other functions, or provisions for functions, shall be specified in the design specification. All non-Class 1E control components shall be suitable for the design conditions specified in the design specification.

(a) Controls shall provide for the proper and safe operation of the equipment under all operating conditions, including the postulated design basis event and loss of coolant accident (LOCA) event.

(b) The design specification shall describe any equipment monitoring required and note whether provisions are to be made for remote annunciation. If the external electrical system is a Class 1E system, an interface between the machine electrical systems and external electrical systems must be identified in the design specification as being a Class 1E interface.

(c) Control system devices that could prevent or limit the machine from performing its design function during all of the nuclear power plant operating modes as defined in RA-4200(a) are not permitted. Equipment safety devices are excluded from this requirement.

RA-4640 ELECTRICAL WIRING, SPLICES, AND CONNECTIONS

All wiring connections for system internal wiring and for connecting points for field wiring shall be made at terminal blocks. Splices between terminal points shall not be used. Wiring from components located inside the control panel(s) shall be connected to terminal blocks within the panels before being routed outside the panels. All terminal connectors for control wiring shall be the ring type.

RA-4700 MAINTENANCE CRITERIA

(a) The equipment manufacturer's design shall ensure that all components that require maintenance are accessible for servicing. All components shall be designed and installed to facilitate servicing or replacement.

(b) The equipment manufacturer shall provide maintenance and access design information for use by the Owner or his designee.

ARTICLE RA-5000
INSPECTION, RATING, AND TESTING

The requirements of Article AA-5000 shall apply, except where expanded upon, modified, or otherwise exempted by the following.

RA-5100 RATING

Performance ratings shall be based upon the actual design conditions supplied by the design specification, rated in accordance with ARI 550/590, and tested in accordance with Mandatory Appendix RA-I.

RA-5200 TESTING

RA-5210 PRESSURE VESSEL TESTING

RA-5211 ASME Section III Vessels

ASME Boiler and Pressure Vessel Code, Section III, pressure vessels shall be hydrostatically or pneumatically tested in accordance with the requirements of Section III of the Boiler and Pressure Vessel Code, ND-6100 through ND-6400.

RA-5212 ASME Section VIII Vessels

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, pressure vessels shall be hydrostatically or pneumatically tested in accordance with the requirements of UG-99, UG-100, or UG-101 and UG-102. Section VIII, Division 2, pressure vessels shall be hydrostatically or pneumatically tested in accordance with the requirements of Part AT.

RA-5213 Non-ASME Pressure Vessels

RA-5213.1 Non-ASME pressure vessels shall be tested in accordance with the requirements of the code or standard specified in the design specification. Where not specified in the design specification, non-ASME pressure vessels shall

(a) be tested at a hydrostatic pressure of two times the design working pressure or pneumatically tested at a pressure of $1\frac{1}{2}$ times the design working pressure, provided that the design working pressure is less than or equal to 15 psig (103 kPa gage); or

(b) be tested in accordance with the requirements of Section VIII, provided that the design working pressure is greater than 15 psig (103 kPa gage).

RA-5213.2 If the requirements of RA-5213.1(a) and (b) are invoked by not specifying a code or standard, the equipment manufacturer shall document the tests using Data Report Form RA-1, RA-2, or RA-3, as applicable.

RA-5214 Other Non-ASME Components

RA-5214.1 Hermetic Centrifugal Compressor Testing. The following factory tests shall be performed on the compressors and hermetic motor housings.

(a) Pressure Test. The compressor and hermetic motor housings shall be strength tested at the higher of either (1) or (2) below:

(1) 45 psig (310 kPa gage)

(2) $1\frac{1}{2}$ times the design working pressure (hydrostatic) or $1\frac{1}{4}$ times the design working pressure (pneumatic).

The pressure tests may be performed individually, as a discrete assembly, or as an assembly with other refrigeration machine components. Tests shall be documented using Data Report Form RA-2b.

(b) Leak Test. A leak test shall be performed at the design working pressure of the compressor and hermetic motor housing assembly either as a discrete assembly, or as a subassembly or a complete assembly with other refrigeration machine components. No individual leak rates shall be greater than 0.1 oz (0.28 g) per year. Tests shall be documented using Data Report Form RA-2b.

(c) Mechanical Run Test. The compressor and motor assembly shall be run using the Manufacturer's approved test fluid to check for excessive vibration and proper operation of the lubrication system. This test shall be documented using Data Report Form RA-2.

RA-5214.2 Open Centrifugal Compressor Testing. The following factory tests shall be performed on the compressors.

(a) Pressure Test. The compressor shall be strength tested at the greater of either (1) or (2) below:

(1) 45 psig (310 kPa gage)

(2) $1\frac{1}{2}$ times the design working pressure (hydrostatic) or $1\frac{1}{4}$ times the design working pressure (pneumatic)

The pressure tests may be performed individually, as a discrete assembly, or as a subassembly or a complete assembly with the other refrigeration machine components. Tests shall be documented using Data Report Form RA-2b.

(b) Leak Test. A leak test shall be performed at the design working pressure of the compressor either as a discrete assembly, or as a subassembly or complete assembly with the other refrigeration machine components. No individual leak rates shall be greater than 0.1 oz (0.28 g) per year. Tests shall be documented using Data Report Form RA-2b.

(c) Mechanical Run Test. The compressor shall be run using the Manufacturer's approved test fluid to check for excessive vibration and proper operation of the lubrication system. This test shall be documented using Code Data Report Form RA-2.

RA-5214.3 Hermetic Reciprocating Scroll and Screw Compressor Testing

(a) Proof Test. The high and low side of the compressor and motor housing assembly shall be either hydrostatically tested at a minimum of $1\frac{1}{2}$ times or pneumatically tested at $1\frac{1}{4}$ times the design pressures as established by ANSI/ASHRAE 15, para. 9.2.

(b) Leak Test. The compressor and motor housing assembly shall be leak tested and proved tight at the design pressure(s) for which it is rated. No individual leak rates shall be greater than 0.1 oz (0.28 g) per year.

RA-5214.4 Open Reciprocating Scroll and Screw Compressor Testing

(a) Proof Test. The high and low side of the compressor shall be either hydrostatically tested at a minimum of $1\frac{1}{2}$ times or pneumatically tested at $1\frac{1}{4}$ times the design pressures as established by ANSI/ASHRAE 15, para. 9.2.

(b) Leak Test. The compressor shall be leak tested and proved tight at the design pressure(s) for which it is rated. No individual leak rates shall be greater than 0.1 oz (0.28 g) per year.

(c) Documentation. Proof and leak tests shall be documented using Data Report Forms RA-3 and RA-3a. The Manufacturer's test log shall be submitted for record purposes.

RA-5214.5 Lubricating Oil Pump Testing. Each pump and the associated lubrication system piping, valves, and fittings that form a pressure boundary shall be hydrostatically or pneumatically pressure tested. The system shall be leak tight at $1\frac{1}{2}$ times (hydrostatic) or $1\frac{1}{4}$ times (pneumatic) the maximum design pressure. The test shall be documented using Data Report Form RA-2a.

RA-5220 FUNCTIONAL TESTING

RA-5221 Electric Motors

RA-5221.1 Commercial Routine Test. This test shall include the following:

(a) no-load speed, current, and power test per IEEE 112A.

(b) locked rotor current test per IEEE 112A (all motors).

(c) routine tests per NEMA MG-1-12.51 (small motors) and NEMA MG-1-20.46 (large motors), temperature rise per Form A-1 of IEEE 112A with exclusion for hermetic motors.

NOTE: The starting torque in WK^2 requirements of NEMA MG-1-12.50 are excluded for hermetic motors.

(d) high potential test per NEMA MG-1-12.02 and MG-1-12.03 (small motors) and NEMA MG-1-20.47 (large motors).

(e) winding resistance test performed in accordance with IEEE 118.

(f) vibration test performed in accordance with NEMA MG-1-12.06 (small motors except for hermetic motors) and NEMA MG-1-20.53 (large motors). Hermetic motors may be tested at reduced voltage because of winding heating considerations. Test results for hermetic motors shall be in accordance with the requirements of NEMA MG-1-12.06.

(g) insulation resistance test performed in accordance with ANSI/IEEE 43.

(h) inspection of each motor for direction of rotation and, as applicable, the airflow of unidirectional cooling fans.

(i) inspection of each motor for measurement of air gap with motor stator and rotor at a measured ambient temperature.

RA-5221.2 Other Tests. The following tests shall be performed on the prototype motor or the first of a series of identical motors supplied under a single order:

(a) a complete test as necessary in accordance with IEEE 112A to determine efficiency, power factor, locked rotor torque and current, breakdown torque, rated load current and slip, rated load temperature rise (except

hermetic motors), and rated voltage (reduced voltage for hermetic motors) speed torque and speed current curves

(*b*) a noise test per NEMA MG-1-12.49B (small motors) and NEMA MG-1-20.49B (large motors), except that hermetic motors are exempt

(*c*) a shaft current test per IEEE 112A for motors covered by NEMA MG-1-20 only, except that hermetic motors are exempt

RA-5222 Equipment Functional Testing

The active refrigeration machine components shall be factory tested for proper and safe operation by the Manufacturer, using the Manufacturer's written procedures. Each complete refrigeration machine shall be given a factory performance test in accordance with Mandatory Appendix RA-I. Test results shall be documented using Data Report Form RA-5.

RA-5223 Control Functional Testing

All control components and assembled control panels shall be functionally tested by the Manufacturer. All wiring circuits shall have continuity and megger tests conducted by the Manufacturer. Test results shall be documented using Data Report Form RA-4.

RA-5224 Valve and Vane Electric Operator Functional Testing

All of the following tests shall be conducted by the original equipment manufacturer or the refrigeration equipment manufacturer. In either case, proof (Certificate of Conformance) that testing was done shall be made available to the Engineer.

RA-5224.1 All valve and vane operators shall be given a commercial routine test including

(*a*) no-load speed and current per IEEE 112A

(*b*) locked rotor current list per IEEE 112A and NEMA MG-1-12.51

(*c*) high potential test per NEMA MG-1-12.02 and 12.03

(*d*) insulation resistance test per ANSI/IEEE 43

RA-5224.2 All valve and vane operators shall be given a type test on each device except when more than one is supplied, in which case only the first need be tested. This type test shall determine efficiency, power factor, locked rotor torque and current, breakdown torque, rated load current and slip, rated load temperature rise, and rated voltage speed torque and speed current. This test shall be performed in accordance with IEEE 112A.

RA-5224.3 An inspection of direction of rotation and, if applicable, the airflow of unidirection cooling fans shall be performed on each valve operator.

RA-5300 EXAMINATION

RA-5310 NONDESTRUCTIVE EXAMINATION

RA-5311 ASME Code, Section III, Components

Nondestructive examination of ASME Code, Section III, pressure retaining components and Section III, Subsection NF, component supports shall be in accordance with Section III, Articles NCA-5000, ND-5000, and NF-5000, and Code Section V.

RA-5312 ASME Code, Section VIII, Components

Nondestructive examination of ASME Code, Section VIII, pressure retaining components shall be in accordance with Section VIII, Division 1, UG-103.

RA-5313 Non-ASME Pressure Vessels

Nondestructive examination of non-ASME Code pressure retaining components and component supports shall be in accordance with the design specification and AA-6334. As a minimum, nondestructive examination shall consist of visual examination of weldments of pressure retaining components and component supports in accordance with ANSI/AWS D1.1, and shall be documented by a Certificate of Conformance.

ARTICLE RA-6000
FABRICATION AND INSTALLATION

The requirements of Article AA-6000 shall apply except where expanded upon, modified, or otherwise exempted by the following.

RA-6100 WELDING AND BRAZING

RA-6110 WELDING AND BRAZING PERFORMED ON ASME CODE, SECTION III, PRESSURE-RETAINING COMPONENTS AND SUPPORTS

Welding and brazing performed on ASME Code, Section III, pressure-retaining components and Section III, Subsection NF, component supports shall be in accordance with Code Sections III and IX.

RA-6120 WELDING AND BRAZING PERFORMED ON ASME CODE, SECTION VIII, PRESSURE-RETAINING COMPONENTS

Welding and brazing performed on Section VIII pressure-retaining components shall be in accordance with Code Sections VIII and IX.

RA-6130 WELDING AND BRAZING OF NON-ASME BOILER AND PRESSURE VESSEL CODE PRESSURE RETAINING COMPONENTS AND SUPPORTS

RA-6131 General

RA-6131.1 Scope. The requirements of this paragraph apply to the preparation of welding and brazing procedure specifications, the qualification of welding and brazing procedures, welders, brazers, and welding operators for all types of manual and machine welding and brazing processes, and the workmanship, weld quality, brazing quality, and inspection of weldments and brazed joints produced during the manufacture of refrigeration equipment and components.

RA-6131.2 Responsibility. Each Manufacturer is responsible for the welding and brazing done by his organization and shall conduct the tests required by this subparagraph to qualify the procedures used in the construction of the weldments and brazed joints built under this Code, the performance of brazers, welders, and welding operators who apply these procedures, and the inspections required for workmanship and quality verification.

RA-6131.3 Base Metal. Base metals to be joined by welding or brazing shall be one of those listed in Article RA-3000 or a combination of the base metals listed in Article RA-3000, provided the requirements of RA-6131.2 are met.

RA-6132 Welding Procedures

Qualification of the Manufacturer's welding procedure specifications shall be in accordance with the requirements of this section and either the ASME Code, Section IX, or ANSI/AWS D1.1. Once a choice is made between Section IX or ANSI/AWS D1.1, all qualifications shall be consistent with that particular document.

RA-6133 Welder and Welding Operator Qualifications

RA-6133.1 Welder or welding operator qualification testing, or both, shall be performed in accordance with the ASME Code, Section IX, or ANSI/AWS D1.1. Welding of the qualification test specimens shall be performed in accordance with the Manufacturer's welding procedure specification qualified in accordance with RA-6132.

RA-6133.2 Once a choice is made between Section IX or ANSI/AWS D1.1, all qualification shall be consistent with that particular document.

RA-6200 CLEANING, FINISHING, AND COATING

RA-6210 CLEANLINESS

Equipment internals shall be shop cleaned and be prepared for shipment per the requirements of ASME NQA-1. Cleanliness levels shall be the same as for the fluid systems of which the equipment is a part. The Design Specification shall identify the internal cleanliness levels of the associated fluid system. ASME NQA-1, Subpart 2.1, Class D cleanliness level shall apply.

RA-6220 SURFACE PREPARATION, FINISHING, AND COATING

Surface preparation, finishing, and coating of all equipment and components shall be in accordance with the design specification. In lieu of specified standards, cleaning, finishing, and coating shall be in accordance with the Manufacturer's written procedures. Surface preparation, finish, and coatings that are compatible with the environmental conditions stated in RA-4200(b) shall be provided in accordance with the design specification.

RA-6300 INSTALLATION

Installation and start-up of the equipment shall be performed under the Manufacturer's supervision and the requirements of AA-6600.

ARTICLE RA-7000
PACKAGING, SHIPPING, STORAGE, AND HANDLING

RA-7100 GENERAL REQUIREMENTS

(a) Packaging, shipping, receiving, storage, and handling requirements shall be in accordance with AA-7000, ASME NQA-1 Requirement 13, ASME NQA-1, Subpart 2.2, and the specific requirements of this Article.

(b) When different levels of classification are required for different parts of the machine, the Manufacturer's procedures shall state how this will be addressed. If the Owner has specific requirements, the design specification shall so state.

RA-7200 PACKAGING

All relevant equipment listed in ASME NQA-1, Subpart 2.2, paras. 302.2 and 302.3, shall meet the requirements of Packaging Levels B or C, as applicable, of ASME NQA-1, Subpart 2.2, para. 300. The balance of the machine shall meet the requirements of Packaging Level D of ASME NQA-1, Subpart 2.2, para. 300.

RA-7300 SHIPPING

All relevant equipment listed in ASME NQA-1, Subpart 2.2, paras. 302.2 and 302.3, shall meet the requirements of Shipping Levels B or C, as applicable, of ASME NQA-1, Subpart 2.2, para. 400. The balance of the machine shall meet the requirements of Shipping Level D of ASME NQA-1, Subpart 2.2, para. 400.

RA-7400 STORAGE

All relevant equipment listed in ASME NQA-1, Subpart 2.2, paras. 302.2 and 302.3, shall meet the requirements of Storage Levels B or C, as applicable, of ASME NQA-1, Subpart 2.2, para. 600. The balance of the machine shall meet the requirements of Storage Level D of ASME NQA-1, Subpart 2.2, para. 600.

RA-7500 HANDLING AND RIGGING

Handling and rigging requirements shall be in accordance with AA-6610 and the following.

All relevent equipment listed in ASME NQA-1, Subpart 2.2, paras. 302.2 and 302.3, shall meet the requirements of Handling Levels B or C, as applicable, of ASME NQA-1, Subpart 2.2, para. 700. The balance of the machine shall meet the requirements of Handling Level D of ASME NQA-1, Subpart 2.2, para. 700.

RA-7600 ASSEMBLY, ERECTION, AND START-UP

RA-7610 FIELD-ASSEMBLED OR FIELD-ERECTED EQUIPMENT

Where equipment requires component assembly during final installation, the equipment manufacturer shall provide detailed written procedures for making the proper final assembly in accordance with AA-6620.

RA-7620 EXTERNAL CONNECTIONS AND SERVICES

(a) All external connections and services essential to the proper and safe operation of the refrigeration equipment supplied by the Owner or his designee shall be, as a minimum, governed by the same criteria as those specified as applicable to the refrigeration equipment itself.

(b) The equipment manufacturer shall be responsible for advising the Owner or his designee of connections or services required for the proper and safe operation of the equipment as specified in the design specification.

RA-7630 START-UP AND PERIODIC TESTING

The equipment Manufacturer shall provide detailed start-up, inspection, and testing procedures with his equipment. Post-startup and periodic testing shall be the responsibility of the Owner.

The information required by RA-9200 shall be applied to a separate, corrosion-resistant namplate permanently attached to the machine by suitable means. The method of attachment shall not affect the structural or operational integrity of the machine.

ARTICLE RA-8000
QUALITY ASSURANCE

RA-8100 GENERAL

Equipment and materials fabricated under this section shall be manufactured in accordance with the provisions of the Manufacturer's quality assurance program. The Manufacturer's program shall be in accordance with the requirements of Article AA-8000 and ASME NQA-1, except for those materials covered by RA-3120(b), RA-3140, RA-3151, RA-3152(b), RA-3153, RA-3154, RA-3160(c), and RA-3160(d). For RA-3120(b), RA-3140, RA-3151, RA-3152(b), RA-3153, RA-3154, RA-3160(c), and RA-3160(d), the requirements of RA-8110 shall apply.

Where component material traceability is not obtainable per RA-3110(c), the refrigeration equipment Manufacturer shall take the following actions.

(a) Designate and document which parts of the refrigeration equipment are nuclear safety related and which parts are nonnuclear safety related. This designated and documented listing shall be furnished at the initial (proposal) stage of procurement for the Engineer's review.

(b) For nonnuclear safety-related parts, no further action on the part of the Manufacturer is required, and the provisions of Article AA-8000 are not applicable.

(c) For nuclear safety-related parts, the Manufacturer shall prepare a procurement specification, drawing(s), or purchased material or part specification; maintain an inspection program to ensure that the parts agree with the requirements of the procurement specification, drawing(s), or purchased part specification; segregate these parts; and test these parts in accordance with the applicable articles of this section.

ARTICLE RA-9000
NAMEPLATES, STAMPING, AND RECORDS

RA-9100 GENERAL REQUIREMENTS

(a) Portions of refrigeration equipment manufactured under the rules of ASME Boiler and Pressure Vessel Code, Section III or Section VIII, shall be stamped in accordance with the applicable rules of those sections.

(b) Authorization to use the symbol stamp for those portions of the equipment covered by the rules of Section III and Section VIII must be obtained from the Society. The method for obtaining such authorization is covered in those sections.

RA-9200 NAMEPLATES AND STAMPING

The requirements given in AA-9100 shall apply for nameplates, in addition to the following requirements:

(a) Components of the refrigeration machine built in accordance with sections of the ASME Boiler and Pressure Vessel Code shall be marked in accordance with the rules of those sections.

(b) A nameplate shall be applied to each refrigeration machine and shall be marked as required by AA-9120 and as follows:

(1) the Owner's name and the name of the Owner's facility

(2) the year of manufacture

(c) The information required by RA-9200 shall be applied to a separate, corrosion-resistant nameplate permanently attached to the machine by suitable means. The method of attachment shall not affect the structural or operational integrity of the machine.

RA-9300 DATA REPORTS

(a) For ASME Boiler and Pressure Vessel Code stamped components, the applicable Code Data Reports (N-1, U-1, etc.) shall be completed, signed, and dated by the manufacturer's representative and the authorized inspector.

(b) For non-ASME Code components, the Data Report Form RA-1 shall be completed and signed by the manufacturer's representative and his inspector.

(c) The completed data report form shall be the inspector's authority to ship the machine.

FORM RA-1 MANUFACTURER'S DATA REPORT FOR SECTION RA NON-ASME NUCLEAR VESSELS[1] (CUSTOMARY)

1. Manufactured by ______________________________
(Name and address of Manufacturer)

2. Manufactured for ______________________________
(Name and address of Purchaser)

3. Type ____________ (Horiz. or vert.) Kind ____________ (Tank, jacketed, heat ex.) Vessel No. ____________ (Mfrs. serial no.) Year built ____________

Items 4–7 inclusive to be completed for single-wall vessels, jackets of jacketed vessels, or shells of heat exchangers.

4. Shell: Material ____________ (Kind and spec. no.) TS ________ (Min. of range specified) Nom. thkns. ____ in. Corr. allow. ____ in. Diam. ____ ft ____ in. Length ____ ft ____ in.

5. Seams: Long ____________ HT[2] ____________ Girth ____________ HT[2] ____________ No. of courses ____________

6. Heads: (a) Material ____________ TS ________ (b) Material ____________ TS ________

Location (Top, bottom, ends)	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)								
(b)								

If removable, bolts used ____________ (Material, spec. no., TS, size, number) Other fastening ____________ (Describe or attach sketch)

Charpy impact ____________ ft-lb at temp. of ____________ °F Drop weight ____________

7. Design Pressure[3] ________ psi at ________ °F Pneumatic, hydrostatic, or combination test pressure ________ psi

Items 8 and 9 to be completed for tube sections.

8. Tubesheets: Material ____________ (Kind and spec. no.) Diam. ____________ (Subject to pressure) in. Thickness ______ in. Attachment ____________ (Welded, bolted)

9. Tubes: Material ____________ (Kind and spec. no.) O.D. ______ in. Thkns. ______ in. or Gage ______ No. ______ Type ____________ (Straight or U)

Items 10–13 inclusive to be completed for channels of heat exchangers.

10. Shell: Material ____________ (Kind and spec. no.) TS ________ (Min. of range specified) Nom. thkns. ____ in. Corr. allow. ____ in. Diam. ____ ft ____ in. Length ____ ft ____ in.

11. Seams: Long ____________ (Welded, dbl., single) HT[2] ________ (Yes or no) Girth ____________ HT[2] ________ No. of courses ________

12. Heads: (a) Material ____________ TS ____ (b) Material ____________ TS ____ (c) Material ____________ TS ____

Location	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a) Top, bottom, ends								
(b) Channel								

If removable, bolts used (a) ____________ (b) ____________ (Material, spec. no., TS, size, number) Other fastening ____________ (Describe or attach sketch)

Charpy impact ____________ ft-lb at temp. of ____________ °F Drop weight ____________

13. Design Pressure[3] ________ psi at ________ °F Pneumatic, hydrostatic, or combination test pressure ________ psi

FORM RA-1 MANUFACTURER'S DATA REPORT FOR SECTION RA NON-ASME NUCLEAR VESSELS[1] (CUSTOMARY) (CONT'D)

Items below to be completed for all vessels where applicable.

14. Safety valve outlets: Number ______ Size ______ Location ______

15. Nozzles:

Purpose (inlet, outlet, drain)	Number	Diam. or Size	Type	Material	Thickness	Reinforcement Material	How Attached

16. Inspection manholes: No. ______ Size ______ Location ______
Openings: Handholes No. ______ Size ______ Location ______
Threaded No. ______ Size ______ Location ______

17. Supports: Skirt ______ (Yes or no) Lugs ______ (Number) Legs ______ (Number) Other ______ (Describe) Attached ______ (Where and how)

18. Remarks: ______

(Brief description of service for which vessel was designed)

CERTIFICATION OF DESIGN

We certify that the statements made in this report are correct and that this nuclear vessel conforms to the rules of Section RA of ASME AG-1.

Date ______ Signed ______ (Manufacturer) By ______

CERTIFICATION OF SHOP INSPECTION

Vessel made by ______ at ______
I, the undersigned, ______ employed by ______ of ______
have inspected the pressure vessel described in this Manufacturer's data report and state that to the best of my knowledge and belief the Manufacturer has constructed this pressure vessel in accordance with the certified drawings.

Date ______ Signed ______ (Inspector's signature)

GENERAL NOTE: List all other supporting forms and note that Manufacturer has reviewed and signed them.

NOTES:
(1) Supplemental sheets in form of lists, sketches, or drawings may be used, provided:
(a) size is 8½ in. × 11 in.;
(b) information on Items 1–3 on this data report is included on each sheet; and
(c) each sheet is numbered, and number of sheets is recorded in Item 18, Remarks.
(2) If postweld heat treated.
(3) List other internal or external pressures with coincident temperature when applicable.

FORM RA-M1 MANUFACTURER'S DATA REPORT FOR SECTION RA NON-ASME NUCLEAR VESSELS[1] (SI)

1. Manufactured by ____________________
(Name and address of Manufacturer)

2. Manufactured for ____________________
(Name and address of Purchaser)

3. Type ________ (Horiz. or vert.) Kind ________ (Tank, heat ex.) Vessel No. ________ (Mfrs. serial no.) Year built ________

Items 4–7 inclusive to be completed for single-wall vessels or shells of heat exchangers.

4. Shell: Material ________ (Kind and spec. no.) TS ________ Pa (Min. of range specified) Nom. thkns. ________ cm

5. Seams: Long ________ HT[2] ________ Girth ________ HT[2] ________ No. of courses ________

6. Heads: (a) Material ________ TS ________ Pa (b) Material ________ TS ________ Pa

Location (Top, bottom, ends)	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a) ________	________	________	________	________	________	________	________	________
(b) ________	________	________	________	________	________	________	________	________

If removable, bolts used ________ (Material, spec. no., TS, size, number) Other fastening ________ (Describe or attach sketch)

Charpy impact ________ N at temp. of ________ °C Drop weight ________

7. Design Pressure[3] ________ Pa at ________ °C Pneumatic, hydrostatic, or combination test pressure ________ Pa

Items 8 and 9 to be completed for tube sections.

8. Tubesheets: Material ________ (Kind and spec. no.) Diam. ________ (Subject to pressure) cm Thickness ________ cm Attachment ________ (Welded, bolted)

9. Tubes: Material ________ (Kind and spec. no.) O.D. ________ cm Thkns. ________ cm or Gage ________ No. ________ Type ________ (Straight or U)

Items 10–13 inclusive to be completed for channels of heat exchangers.

10. Shell: Material ________ (Kind and spec. no.) TS ________ Pa (Min. of range specified) Nom. thkns. ________ Corr. in. allow. ________ cm Diam. ________ m Length ________ m

11. Seams: Long ________ (Welded, dbl., single) HT[2] ________ (Yes or no) Girth ________ HT[2] ________ No. of courses ________

12. Heads: (a) Material ________ TS ________ Pa (b) Material ________ TS ________ Pa

Location	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a) Top, bottom, ends	________	________	________	________	________	________	________	________
(b) Channel	________	________	________	________	________	________	________	________

If removable, bolts used (a) ________ (b) ________ (Material, spec. no., TS, size, number) Other fastening ________ (Describe or attach sketch)

Charpy impact ________ N at temp. of ________ °C Drop weight ________

13. Design Pressure[3] ________ Pa at ________ °C Pneumatic, hydrostatic, or combination test pressure ________ Pa

FORM RA-M1 MANUFACTURER'S DATA REPORT FOR SECTION RA NON-ASME NUCLEAR VESSELS[1] (SI) (CONT'D)

Items below to be completed for all vessels where applicable.

14. Safety valve outlets: Number ______ Size ______ Location ______

15. Nozzles:

Purpose (inlet, outlet, drain)	Number	Diam. or Size	Type	Material	Thickness	Reinforcement Material	How Attached

16. Inspection manholes: No. ______ Size ______ Location ______
Openings: Handholes No. ______ Size ______ Location ______
Threaded No. ______ Size ______ Location ______

17. Supports: Skirt ______ (Yes or no) Lugs ______ (Number) Legs ______ (Number) Other ______ (Describe) Attached ______ (Where and how)

18. Remarks: ______

(Brief description of service for which vessel was designed)

CERTIFICATION OF DESIGN

We certify that the statements made in this report are correct and that this nuclear vessel conforms to the rules of Section RA of ASME AG-1.

Date ______ Signed ______ (Manufacturer) By ______

CERTIFICATION OF SHOP INSPECTION

Vessel made by ______ at ______
I, the undersigned, ______ employed by ______ of ______
have inspected the pressure vessel described in this Manufacturer's data report and state that to the best of my knowledge and belief the Manufacturer has constructed this pressure vessel in accordance with the certified drawings.

Date ______ Signed ______ (Inspector's signature)

GENERAL NOTE: List all other supporting forms and note that Manufacturer has reviewed and signed them.

NOTES:
(1) Supplemental sheets in form of lists, sketches, or drawings may be used, provided:
(a) size is 21.6 cm × 28 cm;
(b) information on Items 1–3 on this data report is included on each sheet; and
(c) each sheet is numbered, and number of sheets is recorded in Item 18, Remarks.
(2) If postweld heat treated.
(3) List other internal or external pressures with coincident temperature when applicable.

FORM RA-2 CENTRIFUGAL COMPRESSOR TEST RECORD

Manufacturer ____________________

Serial No. ____________________

Model No. ____________________

Mechanical Run-in

Test duration	____________	min
Speed	____________	rpm
Oil pressure, bearing supply	____________	psig (Pa)
Bearing oil supply temperature	____________	°F (°C)
Bearing oil outlet temperature	____________	°F (°C)
Compressor suction temperature	____________	°F (°C)
Compressor discharge temperature	____________	°F (°C)
Compressor suction pressure	____________	psig (Pa)
Compressor discharge pressure	____________	psig (Pa)
Test fluid	____________	

Vibration ____________________

____

____

Manufacturer's test technician ____________________

Date ____________

Manufacturer's Q.A. inspector ____________________

Date ____________

Owner's representative (1) ____________________

Date ____________

NOTE:

(1) Optional. If witness test, prior written agreement must be in effect.

FORM RA-2a CENTRIFUGAL COMPRESSOR OIL PUMP PRESSURE TEST

Manufacturer ____________________
Serial No. ____________________
Model No. ____________________
Hydrostatic ________ or pneumatic ________ test (check which) ________ psig (Pa)
Test duration ________ min

Manufacturer's test technician ____________________
Date ____________________
Manufacturer's Q.A. inspector ____________________
Date ____________________
Owner's representative (1) ____________________
Date ____________________

NOTE:
(1) Optional. If witness test, prior written agreement must be in effect.

FORM RA-2b CENTRIFUGAL COMPRESSOR PRESSURE TEST RECORD

Manufacturer ____________________

Serial No. ____________________

Model No. ____________________

Hydrostatic __________ or pneumatic __________ test (check which)

Time ____________ min

____________ psig (Pa)

Leak test

Time ____________ min

Manufacturer's test technician ____________

Date ____________

Manufacturer's Q.A. inspector ____________

Date ____________

Owner's representative (1) ____________

Date ____________

NOTE:
(1) Optional. If witness test, prior written agreement must be in effect.

FORM RA-3 RECIPROCATING SCROLL/SCREW COMPRESSOR TEST RECORD

Manufacturer ____________________
Serial No. ____________________
Model No. ____________________

Mechanical Run-in

Test duration	________	min
Speed	________	rpm
Oil pressure	________	psig (Pa)
(a) Lubrication		
(b) Unloader (if oil operated)	________	psig (Pa)
Compressor suction pressure	________	psig (Pa)
Compressor discharge pressure	________	psig (Pa)
Test fluid	________	

Manufacturer's test technician ____________________
Date ____________________
Manufacturer's Q.A. inspector ____________________
Date ____________________
Owner's representative (1) ____________________
Date ____________________

NOTE:
(1) Optional. If witness test, prior written agreement must be in effect.

FORM RA-3a RECIPROCATING SCROLL/SCREW COMPRESSOR PRESSURE TEST RECORD

Manufacturer ________________________________

Serial No. ________________________________

Model No. ________________________________

Pressure test

(a) High side ________________ psig (Pa)

(b) Low side ________________ psig (Pa)

Leak test

(a) High side ________________ psig (Pa)

(b) Low side ________________ psig (Pa)

Manufacturer's test technician ________________

Date ________________

Manufacturer's Q.A. inspector ________________

Date ________________

Owner's representative (1) ________________

Date ________________

NOTE:

(1) Optional. If witness test, prior written agreement must be in effect.

FORM RA-4 ELECTRICAL TEST RECORD — CONTROLS AND CONTROL PANELS

Manufacturer ______________________________

Serial No. ______________________________

Model No. ______________________________

Controls/control panels functional test, continuity, and megger tests:

Tests acceptable ______ Yes ______ No

If test is not acceptable, state reasons, retest, and redocument.

____

____

____

____

Manufacturer's test technician ______________________________

Date ______________________________

Manufacturer's Q.A. inspector ______________________________

Date ______________________________

Owner's representative (1) ______________________________

Date ______________________________

NOTE:

(1) Optional. If witness test, prior written agreement must be in effect.

FORM RA-5 PERFORMANCE TEST RECORD (CUSTOMARY)
(See Mandatory Appendix RA-I)

Manufacturer ______________________________
Serial No. ______________________________
Model No. ______________________________

Chilled Water Refrigeration Equipment	Minimum Design Load [Note (1)]	Intermediate Load Point 1 [Note (2)]	Intermediate Load Point 2 [Note (2)]	Full Load [Note (1)]
1. Net cooling capacity (Btu/hr) (tons)				
2. Specified evaporator fouling factor (hr-ft^2-°F/Btu)				
3. Specified condenser fouling factor (hr-ft^2-°F/Btu)				
4. Chilled water flow (gal/min)				
5. Entering chilled water temperature (°F)				
6. Leaving chilled water temperature (°F)				
7. Condenser water flow (gal/min)				
8. Entering condenser water temperature (°F)				
9. Leaving condenser water temperature (°F)				
10. Condensing temperature (°F)				
11. Subcooled liquid temperature (°F)				
12. Suction temperature (°F)				
13. Power input to compressor motor (kW)				
14. Adjusted condensing temperature increase (°F)				
15. Approximate condenser water temperature to maintain condensing temperature				
Entering (°F)				
Leaving (°F)				
16. Adjusted suction temperature decrease (°F)				
17. Approximated chilled water temperature to maintain adjusted suction temperature				
Entering (°F)				
Leaving (°F)				
18. $q(e_v)$: net cooling capacity of liquid cooler (Btu/hr)				
19. q(kW input): electrical energy input to compressor (kW)				
20. $q(c)$: net heat rejected by condenser (Btu/hr)				

FORM RA-5 PERFORMANCE TEST RECORD (CUSTOMARY) (CONT'D) (See Mandatory Appendix RA-I)

Chilled Water Refrigeration Equipment	Minimum Design Load [Note (1)]	Intermediate Load Point 1 [Note (2)]	Intermediate Load Point 2 [Note (2)]	Full Load [Note (1)]
21. Measured heat balance (within 5%) ________				
22. T_e — temperature of water entering unit (°F)				
23. T_d — temperature of water leaving unit (°F)				
24. Tons ________				
25. Power input (kW) ________ (within 5% of Mfrs. proposed input)				

Manufacturer's test technician ________

Date ________

Q.A. inspector ________

Date ________

Owner's representative (3) ________

Date ________

GENERAL NOTE: All calculations for these values must be included with this test record.

NOTES:
(1) Mandatory test point.
(2) Optional test point. If desired, must be so specified by the Engineer in the design specification.
(3) Optional. If witness test, prior written agreement must be in effect.

FORM RA-M5 PERFORMANCE TEST RECORD (SI) (See Mandatory Appendix RA-MI)

Manufacturer ____________________

Serial No. ____________________

Model No. ____________________

Chilled Water Refrigeration Equipment	Minimum Design Load [Note (1)]	Intermediate Load Point 1 [Note (2)]	Intermediate Load Point 2 [Note (2)]	Full Load [Note (1)]
1. Net cooling capacity (kW) (tons)				
2. Specified evaporator fouling factor (m^2 – °kW)				
3. Specified condenser fouling factor (m^2 – °kW)				
4. Chilled water flow (L/min)				
5. Entering chilled water temperature (°C)				
6. Leaving chilled water temperature (°C)				
7. Condenser water flow (L/min)				
8. Entering condenser water temperature (°C)				
9. Leaving condenser water temperature (°C)				
10. Condensing temperature (°C)				
11. Subcooled liquid temperature (°C)				
12. Suction temperature (°C)				
13. Power input to compressor motor (kW)				
14. Adjusted condensing temperature increase (°C)				
15. Approximate condenser water temperature to maintain condensing temperature				
Entering (°C)				
Leaving (°C)				
16. Adjusted suction temperature decrease (°C)				
17. Approximated chilled water temperature to maintain adjusted suction temperature				
Entering (°C)				
Leaving (°C)				
18. $q(e_v)$: net cooling capacity of liquid cooler (Btu/hr)				
19. q(kW input): electrical energy input to compressor (kW)				
20. $q(c)$: net heat rejected by condenser (kW)				

FORM RA-M5 PERFORMANCE TEST RECORD (SI) (CONT'D)
(See Mandatory Appendix RA-I)

Chilled Water Refrigeration Equipment	Minimum Design Load [Note (1)]	Intermediate Load Point 1 [Note (2)]	Intermediate Load Point 2 [Note (2)]	Full Load [Note (1)]
21. Measured heat balance (within 5%) ____________				
22. T_e — temperature of water entering unit (°C)				
23. T_d — temperature of water leaving unit (°C)				
24. Tons ____________				
25. Power input (kW) ____________ (within 5% of Mfrs. proposed input)				

Manufacturer's test technician ____________

Date ____________

Manufacturer's Q.A. inspector ____________

Date ____________

Owner's representative (3) ____________

Date ____________

GENERAL NOTE: All calculations for these values must be included with this test record.

NOTES:
(1) Mandatory test point.
(2) Optional test point. If desired, must be so specified by the Engineer in the design specification.
(3) Optional. If witness test, prior written agreement must be in effect.

MANDATORY APPENDIX RA-I
PERFORMANCE TESTING OF CHILLED WATER REFRIGERATION UNIT (CUSTOMARY)

ARTICLE RA-I-1000 GENERAL

The performance of the chilled water refrigeration equipment shall be certified by conducting a factory performance test as required by RA-5222. The performance test shall be conducted in accordance with ARI 550/590, Appendix A, with modifications to its paragraphs as outlined in RA-I-1100 through RA-I-1700.

This Appendix provides mandatory requirements for equipment to be installed in the United States or any other country that invokes United States regulatory administrative and quality assurance rules. This Appendix only provides guidance for countries that do not invoke these rules.

RA-I-1100 PARAGRAPH A4.1.1

The conditions to be used in this test shall be as shown in Table RA-I-1100.

RA-I-1200 EFFECT OF FOULING FACTORS

The fouling factors to be used for the evaporator and condenser shall be as given in the design specification. The method used for determining the adjusted suction and condensing temperatures at these fouling factors shall be the analytical method as described in ARI 450 and 480, using the Manufacturer's certified data. The adjusted condensing temperature increase and suction temperature decrease shall be calculated at the time of the test based on the actual cleaned tube condensing and suction temperatures (determined from averaging the three tests in accordance with para. 5.4.1 of ARI 450 and 480) and tabulated on Form RA-5 as shown in Table RA-I-1200.

RA-I-1300 PARAGRAPH A7.3.1

The general heat balance equation shall be as follows:

$$q(e_v) + q(\text{kW input}) = q(c)$$

and shall be tabulated on Form RA-5. See also Table RA-I-1300.

RA-I-1400 PARAGRAPH A7.3.3

The measured heat balance for the tests shall be within 5% of that specified for the full load condition and within 7½% of the other test points.

RA-I-1500 PARAGRAPH A8.1.1

The capacity in tons shall be obtained by the following:

$$\text{tons} = (W)(t_e - t_d)/12{,}000$$

where

t_d = temperature of water leaving unit, °F
t_e = temperature of water entering unit, °F
W = weight flow rate of chilled water (lb/hr)
= (gal/min) (62.4 lb/ft^3) (60 min/hr)/(7.48 gal/ft^3) where the specific heat of water is 1 Btu/lb–°F

and shall be tabulated on Form RA-5 according to Table RA-I-1500.

RA-I-1600 POWER INPUT

The power input expressed in kW/ton of refrigeration shall be within 5% of the Manufacturer's proposed power input for the full load test.

RA-I-1700 REFRIGERATION MACHINES EQUIPPED WITH SUBCOOLERS

Subcooler performance will be adversely affected when the condensing water temperature is increased to simulate fouling. To compensate, it is acceptable to add 0.1% to the kW/ton of refrigeration tolerance of 5% for each Fahrenheit degree of adjustment made to the entering condenser water temperature.

TABLE RA-I-1100

	Minimum Design Load [Note (1)]	Intermediate Load Point 1 [Note (2)]	Intermediate Load Point 2 [Note (2)]	Full Load [Note (1)]
Net cooling capacity (Btu/hr)	Note (3)	Note (3)	Note (3)	Note (3)
Specified evaporator fouling factor (hr-ft-°F/Btu)	Note (3)	Note (3)	Note (3)	Note (3)
Specified condenser fouling factor (hr-ft-°F/Btu)	Note (3)	Note (3)	Note (3)	Note (3)
Chilled water flow (gal/min)	Note (3)	Note (3)	Note (3)	Note (3)
Entering chilled water temperature (°F)	Note (3)	Note (3)	Note (3)	Note (3)
Leaving chilled water temperature (°F)	Note (3)	Note (3)	Note (3)	Note (3)
Condenser water flow (gal/min)	Note (3)	Note (3)	Note (3)	Note (3)
Entering condenser water temperature (°F)	Note (3)	Note (3)	Note (3)	Note (3)
Leaving condenser water temperature (°F)	Note (3)	Note (3)	Note (3)	Note (3)
Power input to compressor motor (kW)	NA	NA	NA	Note (3)

GENERAL NOTE: NA = not applicable

NOTES:
(1) Mandatory test point.
(2) Optional test point. If desired, must be so specified by the engineer in the design specification.
(3) Refer to the design specification for these factors.

TABLE RA-I-1200

	Minimum Design Load [Note (1)]	Intermediate Load Point 1 [Note (2)]	Intermediate Load Point 2 [Note (2)]	Full Load [Note (1)]
Adjusted condensing temperature increase (°F)	Note (3)	Note (3)	Note (3)	Note (3)
Approximate condenser water temperature to maintain the adjusted condensing temperature	Note (3)	Note (3)	Note (3)	Note (3)
Adjusted suction temperature decrease (°F)	Note (3)	Note (3)	Note (3)	Note (3)
Entering	Note (3)	Note (3)	Note (3)	Note (3)
Leaving	Note (3)	Note (3)	Note (3)	Note (3)
Approximate chilled water temperature to maintain adjusted suction temperature (°F)				
Entering	Note (3)	Note (3)	Note (3)	Note (3)
Leaving	Note (3)	Note (3)	Note (3)	Note (3)

NOTES:
(1) Mandatory test point.
(2) Optional test point. If desired, must be so specified by the engineer in the design specification.
(3) To be calculated at the time of test.

TABLE RA-I-1300

	Minimum Design Load	Intermediate Load Point 1	Intermediate Load Point 2	Full Load
$q(e_v)$ — net cooling capacity of liquid cooler (Btu/hr) after correction for fouling	Note (1)	Note (1)	Note (1)	Note (1)
q(kW input) — electrical energy input to compressor (kW) (Btu/hr equivalent)	Note (1)	Note (1)	Note (1)	Note (1)
$q(c)$ — net heat rejected by condenser (Btu/hr)	Note (1)	Note (1)	Note (1)	Note (1)

NOTE:
(1) To be measured by test.

TABLE RA-I-1500

	Minimum Design Load [Note (1)]	Intermediate Load Point 1 [Note (2)]	Intermediate Load Point 2 [Note (2)]	Full Load [Note (1)]
t_e — temperature of water entering unit after correction for fouling (°C)	Note (3)	Note (3)	Note (3)	Note (3)
t_d — temperature of water leaving unit after correction for fouling (°C)	Note (3)	Note (3)	Note (3)	Note (3)

NOTES:
(1) Mandatory test point.
(2) Optional test point. If desired, must be so specified by the engineer in the design specification.
(3) To be calculated at the time of test.

MANDATORY APPENDIX RA-MI
PERFORMANCE TESTING OF CHILLED WATER REFRIGERATION UNIT (SI)

ARTICLE RA-MI-1000 GENERAL

The performance of the chilled water refrigeration equipment shall be certified by conducting a factory performance test as required by RA-5222. The performance test shall be conducted in accordance with ARI 550/590, Appendix A, with modifications to its paragraphs as outlined in RA-MI-1100 through RA-MI-1700.

RA-MI-1100 PARAGRAPH A4.1.1

The conditions to be used in this test shall be as shown in Table RA-MI-1100.

RA-MI-1200 EFFECT OF FOULING FACTOR

The fouling factors to be used for the evaporator and condenser shall be as given in the design specification. The method used for determining the adjusted suction and condensing temperatures at these fouling factors shall be the analytical method as described in ARI 450 and 480, using the Manufacturer's certified data. The adjusted condensing temperature increase and suction temperature decrease shall be calculated at the time of the test based on the actual cleaned tube condensing and suction temperatures (determined from averaging the three tests in accordance with paragraph 5.4.1 of ARI 450 and 480) and tabulated on Form RA-M5 as shown in Table RA-MI-1200.

RA-MI-1300 PARAGRAPH A7.3.1

The general heat balance equation shall be as follows:

$$q(e_v) + q(\text{kW input}) = q(c)$$

and shall be tabulated on Form RA-M5. See also Table RA-MI-1300.

RA-MI-1400 PARAGRAPH A7.3.3

The measured heat balance for the tests shall be within 5% of that specified for the full load condition and within $7\frac{1}{2}\%$ of the other test points.

RA-MI-1500 PARAGRAPH A8.1.1

The capacity in kW shall be obtained by the following:

$$\text{kW} = (W)(t_e - t_d)/859{,}845$$

where

t_d = temperature of water leaving unit (°C)
t_e = temperature of water entering unit (°C)
W = weight flow rate of chilled water (g/hr)
= (L/min) (g/cm^3) (60 min/h)/(L/1000 cm^3) where the specific heat of water is 1 Cal/gm–°C

and shall be tabulated on Form RA-M5 according to Table RA-MI-1500.

RA-MI-1600 POWER INPUT

The power input expressed in kW/kW of refrigeration shall be within 5% of the Manufacturer's proposed power input for the full load test.

RA-MI-1700 REFRIGERATION MACHINES EQUIPPED WITH SUBCOOLERS

Subcooler performance will be adversely affected when the condensing water temperature is increased to simulate fouling. To compensate, it is acceptable to add 0.1% to the kW/kW of refrigeration tolerance of 5% for each degree Celsius of adjustment made to the entering condenser water temperature.

TABLE RA-MI-1100
ALLOWABLE MATERIALS

	Minimum Design Load [Note (1)]	Intermediate Load Point 1 [Note (2)]	Intermediate Load Point 2 [Note (2)]	Full Load [Note (1)]
Net cooling capacity, kW (tons)	Note (3)	Note (3)	Note (3)	Note (3)
Specified evaporator fouling factor (m^2 – °k/W)	Note (3)	Note (3)	Note (3)	Note (3)
Specified Condenser fouling factor (m^2 – °k/W)	Note (3)	Note (3)	Note (3)	Note (3)
Chilled water flow (L/min)	Note (3)	Note (3)	Note (3)	Note (3)
Entering chilled water temperature (°C)	Note (3)	Note (3)	Note (3)	Note (3)
Leaving chilled temperature (°C)	Note (3)	Note (3)	Note (3)	Note (3)
Condenser water flow (L/min)	Note (3)	Note (3)	Note (3)	Note (3)
Entering condenser water temperature (°C)	Note (3)	Note (3)	Note (3)	Note (3)
Leaving condenser water temperature (°C)	Note (3)	Note (3)	Note (3)	Note (3)
Power input to compressor motor, kW	NA	NA	NA	Note (3)

GENERAL NOTE: NA = not applicable

NOTES:
(1) Mandatory test point.
(2) Optional test point. If desired, must be so specified by the engineer in the design specification.
(3) Refer to the design specification for these factors.

TABLE RA-MI-1200
ALLOWABLE MATERIALS

	Minimum Design Load [Note (1)]	Intermediate Load Point 1 [Note (2)]	Intermediate Load Point 2 [Note (2)]	Full Load [Note (1)]
Adjusted condensing temperature increase (°C)	Note (3)	Note (3)	Note (3)	Note (3)
Approximate condenser water temperature to maintain the adjusted condensing temperature	Note (3)	Note (3)	Note (3)	Note (3)
Adjusted suction temperature decrease (°C)	Note (3)	Note (3)	Note (3)	Note (3)
Entering	Note (3)	Note (3)	Note (3)	Note (3)
Leaving	Note (3)	Note (3)	Note (3)	Note (3)
Approximate chilled water temperature to maintain adjusted suction temperature (°C)				
Entering	Note (3)	Note (3)	Note (3)	Note (3)
Leaving	Note (3)	Note (3)	Note (3)	Note (3)

NOTES:
(1) Mandatory test point.
(2) Optional test point. If desired, must be so specified by the engineer in the design specification.
(3) To be calculated at the time of test.

TABLE RA-MI-1300

	Minimum Design Load	Intermediate Load Point 1	Intermediate Load Point 2	Full Load
$q(e_v)$ — net cooling capacity of liquid cooler (kW) after correction for fouling	Note (1)	Note (1)	Note (1)	Note (1)
q(kW input) — electrical energy input to compressor (kW) (Btu/hr equivalent)	Note (1)	Note (1)	Note (1)	Note (1)
$q(c)$ — net heat rejected by condenser (kW)	Note (1)	Note (1)	Note (1)	Note (1)

NOTE:
(1) To be measured by test.

TABLE RA-MI-1500

	Minimum Design Load [Note (1)]	Intermediate Load Point 1 [Note (2)]	Intermediate Load Point 2 [Note (2)]	Full Load [Note (1)]
t_e — temperature of water entering unit after correction for fouling (°C)	Note (3)	Note (3)	Note (3)	Note (3)
t_d — temperature of water leaving unit after correction for fouling (°C)	Note (3)	Note (3)	Note (3)	Note (3)

NOTES:
(1) Mandatory test point.
(2) Optional test point. If desired, must be so specified by the engineer in the design specification.
(3) To be calculated at the time of test.

MANDATORY APPENDIX RA-II

MANDATORY LIST OF INSTRUMENTATION FUNCTIONS AND CONTROL FUNCTIONS

TABLE RA-II-1000
MANDATORY LIST OF INSTRUMENTATION FUNCTIONS AND CONTROL FUNCTIONS

Control Functions	Manufacturers Panel	Remote Panel
1. On, stop	Push button	Provisions for push button
2. Start	Push button	Provisions for push button
3. Ready	Pilot light or digital display	Provisions for pilot light or digital display
4. Oil pump on (if applicable)	Pilot light or digital display	Note (1)
5. Power on	Pilot light or digital display	Note (1)
6. Compressor high burning oil temperature (if applicable)	Pilot light or digital display	Note (1)
7. Compressor high motor temperature	Pilot light or digital display	Note (1)
8. Evaporator low refrigerant pressure	Pilot light or digital display	Note (1)
9. Condenser high refrigerant pressure	Pilot light or digital display	Note (1)
10. Evaporator low water flow	Pilot light or digital display	Note (1)
11. Compressor low oil pressure (if applicable)	Pilot light or digital display	Note (1)
12. Evaporator low chilled water (recycle)	Pilot light or digital display	Note (1)
13. Oil heater on (if applicable)	Pilot light or digital display	Note (1)
14. Evaporator pressure	Gage or digital display	
15. Condenser refrigerant pressure	Gage or digital display	
16. Compressor oil pressure high (if applicable)	Gage or digital display	
17. Compressor oil pressure low (if applicable)	Gage or digital display	Note (1)
18. High condenser water temperature	Pilot light or digital display	Note (1)
19. High chilled water temperature	Pilot light or digital display	Note (1)
20. Purge system on (if applicable)	Pilot light or digital display	Note (1)

NOTE:
(1) Provisions for transmitting signal, remote equipment trouble alarm.

NONMANDATORY APPENDIX RA-A
DIVISION OF RESPONSIBILITY

This Nonmandatory Appendix is intended to identify the roles normally assumed by the organizations responsible for fulfilling Code requirements when not specifically addressed in an article or subarticle. These are guidelines to assist with Code compliance and are not to be construed as legal or contractual responsibilities unless so invoked by the Owner or designee.

TABLE RA-A-1000
DIVISION OF RESPONSIBILITY

RA-	Item	Responsibility
3100(a)	Properties and composition of materials	Engineer
	Prohibited or limited materials	Engineer
	Specific materials	Engineer
(b)	Effects of service conditions on properties of material	Engineer
4200	Purpose (design function)	Engineer
	Safety classification	Engineer
	External interface safety classification	Engineer
4200(a)	Performance under all nuclear power plant operating modes	Engineer
4200(b)(1)	Temperature	Engineer
(2)	Pressure	Engineer
(3)	Humidity	Engineer
(4)	Radiation levels	Engineer
(5)	Chemicals	Engineer
(6)	Structural design criteria	Engineer
(7)	Electrical transients	Engineer
(8)	Cooling load requirements	Engineer
(9)	Cooling load profile and time history	Engineer
(10)	Restart conditions	Engineer
(11)	Water-side design pressures for evaporator and condenser	Engineer
(12)	Environmental condition time histories for refrigeration equipment exposed to harsh environments	Engineer
4200(c)	Magnitude of the loads	Engineer
4300(a)	Design load, tons of refrigeration	Engineer
(b)	Entering and leaving evaporator fluid temperature	Engineer
(c)	Entering condenser fluid	Engineer
(d)	Evaporator and condenser flow rates	Engineer
(e)	Evaporator and condenser fouling factors	Engineer
(f)	Tube material and nominal wall thickness for evaporator and condenser	Engineer
(g)	Fluid to be cooled and condensing fluid	Engineer
(h)	Electrical characteristics	Engineer
(i)	Pressure drop for liquid	Engineer
(j)	Maximum tube velocities	Engineer

TABLE RA-A-1000
DIVISION OF RESPONSIBILITY (CONT'D)

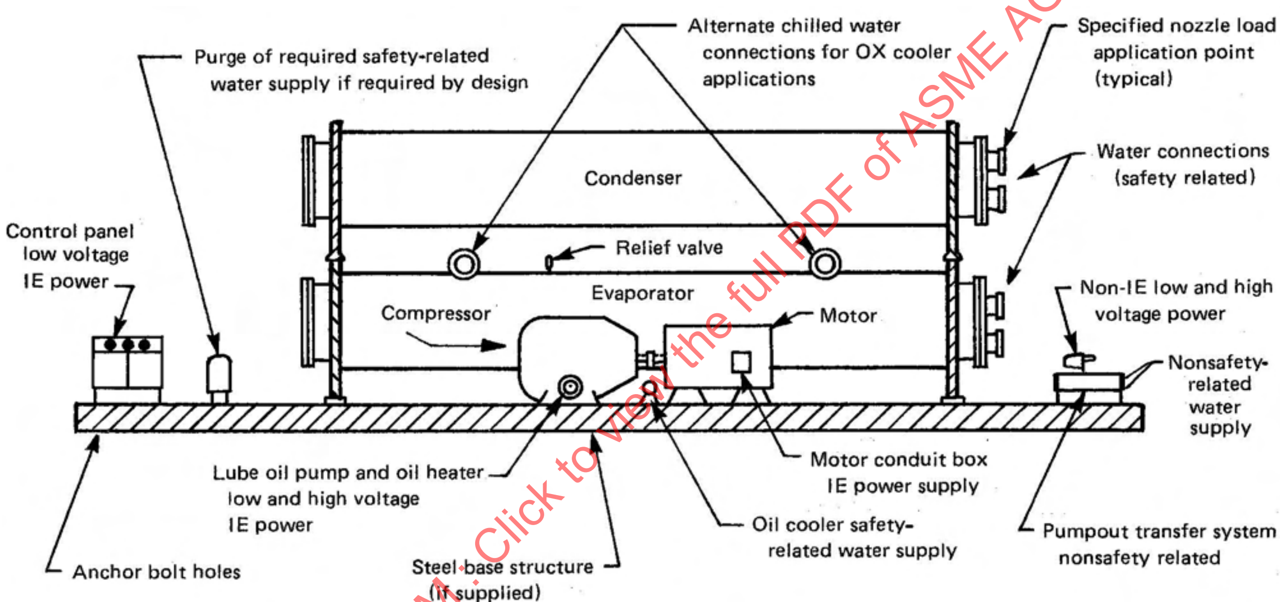
RA-	Item	Responsibility
4411	Water-side pressure vessel components and respective fluid systems	Engineer
4412	Boundaries of water-side pressure vessels	Engineer
4620	Non-Class 1E vane and valve operators	Engineer
4630	NEMA enclosure designation, including control functions or provisions for functions, non-Class 1E components	Engineer
4630(b)	Equipment monitoring	Engineer
	Interface between machine electrical systems and external electrical systems	Engineer
4700(a)	Ensures equipment is accessible for repair	Manufacturer
(b)	Provides maintenance and access criteria	Manufacturer
	Performance ratings based on design conditions	Engineer
	All required testing to be delineated	Engineer
5213.1	Non-ASME pressure vessel testing	Engineer
5213.2	Code data from Form RA-1	Manufacturer
5214	Keeping a test log	Manufacturer
5221.1	Commercial routine test	Manufacturer
5221.2	Performance data from prototype	Manufacturer
5222	Active refrigeration machine components test	Manufacturer
5223	Electrical control components, assembled control panels, and systems testing	Manufacturer
5224	Valve and vane operator functional testing	Manufacturer
5313	Nondestructive pressure retaining components and component supports	Engineer
6100	Welding and brazing on non-ASME pressure retaining components	Manufacturer
6133.2	Qualifications consistent with ASME Code, Section IX, or ANSI/AWS D1.1	Manufacturer

TABLE RA-A-1000
DIVISION OF RESPONSIBILITY (CONT'D)

RA-	Item	Responsibility
6210	Cleanliness levels of fluid systems	Engineer
6220	Surface preparation, finishing, and coating (all components, equipment)	Engineer
	Specified standards, cleaning, finishing, and coating	Manufacturer
	Surface preparation, finish, and coatings compatible with environmental conditions provided by RA-4200(b)	Engineer
7200	Packaging	Manufacturer
7300	Shipping	Manufacturer
7400	Storage	Manufacturer
7500	Handling and rigging	Manufacturer
7600	Assembly, erection, and start-up procedures	Manufacturer
9100(b)	Authority to use stamp	Society
9300(a)	Data Report Form RA-1	Manufacturer/Inspector
9300(b) and Form RA-1	Completed data form, witness of stamping his own inspection report	Inspector/Manufacturer
Form RA-2	Centrifugal compressor test record	Inspector/Manufacturer
Form RA-2a	Centrifugal compressor oil pump pressure test record	Manufacturer
Form RA-2b	Centrifugal compressor pressure test record	Manufacturer
Form RA-3	Reciprocating scroll/screw compressor test record	Manufacturer
Form RA-3a	Reciprocating scroll/screw compressor test record	Manufacturer
Form RA-4	Electrical test record	Manufacturer
Form RA-5	Optional capacity test points, performance test record	Engineer/Manufacturer
Mandatory Appendix RA-I	Optional capacity test points	Engineer

NONMANDATORY APPENDIX RA-B
TYPICAL EXTERNAL INTERFACE DIAGRAMS

FIG. RA-B-1000 INTERFACE POINTS — TYPICAL TWO-VESSEL DESIGN



GENERAL NOTES:

(a) Shaded portions are NF boundaries.

(b) A power panel with oil pump starter may be utilized as a single connection point for IE circuits (except main motor) if specified.

(c) Open motor shown. Identical connections required when hermetic motor furnished.

(d) Main motor starter located remotely from refrigeration equipment. Starter to include magnetic over-current device, control relay, and current transformer and resistor for motor overload control.

(e) Location of equipment and boundaries is shown only for schematic purposes. Manufacturer shall provide exact boundaries and equipment locations to engineer.

SECTION CA
CONDITIONING EQUIPMENT

Tables

Mandatory Appendices

Nonmandatory Appendices

ARTICLE CA-1000
INTRODUCTION

CA-1100 SCOPE

CA-1110 GENERAL REQUIREMENTS

This section establishes requirements for the design, manufacture, testing, and documentation for forced circulation air cooling and heating coils, air washers, evaporative coolers, and electric heating coils used in nuclear safety-related (AA-1130) air conditioning and air and gas treatment systems in nuclear facilities. Nonmandatory Appendix A may be used for the determination of responsibilities under this section.

CA-1120 PURPOSE

The purpose of this Section is to ensure that the equipment and components included herein are adequate for use in nuclear safety-related systems.

CA-1130 APPLICABILITY

This section shall be applied to the design, manufacture, testing, and documentation of all nuclear safety-related forced circulation air cooling and heating coils, air washers, evaporative coolers, and electric heating coils used in nuclear safety-related air conditioning and air and gas treatment systems used in nuclear facilities.

CA-1131 Clarification of Code Applicability

Pressure retaining parts whose design, materials, manufacture, test, and documentation are covered by the ASME Code shall be in accordance with the applicable requirements of that Code. When conflict exists between this section and the Code, the latter shall take precedence.

CA-1132 Exclusion of Components

Conditioning equipment and associated accessories not included in this section are humidifiers, dehumidifiers of the adsorption type, infrared heating devices, controllers, valves, strainers, traps, pumps, refrigerant expansion valves, shell- and tube-type refrigerant evaporators and condensers, and compressors.

CA-1133 Interfacing Boundaries

The requirements of this section are limited to the flange face of the coil, the air washer or evaporative cooler inlet and outlet airside connection, the piping connections on the fluid side, and the electrical control cabinet for electrical connections.

CA-1200 DEFINITIONS AND TERMS

CA-1210 GENERAL

Only specialized terminology not defined elsewhere is listed below. Also see the Section AA Glossary and ASHRAE *Terminology of Heating, Ventilation, Air-Conditioning, & Refrigeration.*

CA-1220 WATER, STEAM, AND VOLATILE REFRIGERANT COILS

brackish water: water with a high dissolved solid content, equal to or greater than 5,000 ppm (mg/L).

building structure: that part of a power plant whose purpose is to support, house, and protect nuclear safety class systems or components.

coil ratings: ratings derived from performance data corresponding to specified operating conditions. These are determined by extension of test data to operating conditions other than test, and for different coil sizes and row depths of a particular coil line by the methods established in ASHRAE 33.

component support: a structural element that carries the component weight and transmits loads from the ASME Code stamped component to the building structure.

fresh water: water with a low to moderate dissolved solid content, less than 5,000 ppm (mg/L).

intervening element: a structure in the support load path of an ASME Code stamped component that is not designed to the requirements of that Code, but is located between the component support and the nuclear facility building structure.

nozzle: inlet or outlet connections located between the header and system piping.

return bend: a U-shaped section of the tube located on the tube ends.

CA-1230 AIR WASHERS AND EVAPORATIVE COOLERS

baffles: a section of formed blades or screen at the air entrance of an air washer. They produce a uniform flow by their resistance and, in the case of formed blades, prevent upstream flow of airborne water from the spray chamber.

carryover: unevaporated water droplets passing through the eliminator.

eliminators: a section of parallel blades having contours that will remove water drops from the airstream; this section is located downstream from the spray chamber.

fill: wetted surface media in evaporative coolers.

header: the manifold for water distribution in the spray chamber of the washer, located at the end of the pump discharge line.

nipples: extensions that lead from the standpipe (manifold) to the nozzles.

side blanks: barriers extending from the side panels to the eliminator section that prevent water and drops from escaping around the eliminators and into the discharge plenum.

spacers: notched plates or other devices that hold baffles and eliminators equidistant and parallel.

standpipes: extensions providing vertical distribution of water from the header manifold.

top blanks: barriers, equidistant and parallel, extending from the top panel to the eliminators.

CA-1240 ELECTRIC HEATING COILS

coil, finned tubular: a helically wound coil of resistance wire, insulated and centered in a metal sheath that has extended surface (fins) mechanically bonded to the sheath.

coil, heating: an electric coil for use in an airstream whose circulation is caused by a difference in pressure produced by a fan or blower; the electric coil is used for heating.

coil, open: coil of bare resistance wire.

element support bracket: a formed bracket that supports the heating elements and maintains design clearance between elements.

element terminal: a device crimped to the end of resistance wire.

frit: a glazed porcelain–glass coating with a thermal coefficient of expansion similar to the metal of the sheath and fin over the operating range of the heating element.

heater frame, flanged: a heater frame designed to be installed between sections of ductwork or air handling equipment by bolting between the heater flange and mating flange.

heater frame, slip-in: a heater frame designed to be installed through an opening in the ductwork or air handling equipment housing.

heater terminal box: a metal enclosure, with a hinged or removable cover, that is attached to the heater frame. The heater terminal box contains the heating element terminations and thermal cutouts; the terminal box may also contain the heater controls.

heating element: an electric resistance element, either open coil or finned tubular type, connected across line voltage to produce heat.

insulator bushing: a high-temperature ceramic or phenolic sleeve staked into the element support bracket through which open heating elements are strung.

remote control panel: a metal enclosure, with a hinged or removable cover, mounted independently of the heater frame; the control panel contains the heater controls.

ARTICLE CA-2000
REFERENCED DOCUMENTS

The codes and standards referenced below shall supplement those documents listed in Section AA. The latest edition shall be used if no publication date is specified.

ANSI/ARI 410-01, Forced Circulation Air-Cooling and Air Heating Coils

Publisher: Air Conditioning and Refrigeration Institute (ARI), 4100 North Fairfax Drive, Arlington, VA 22203

ANSI/SAE AMS 3410J-1998 Flux, Silver Brazing

ANSI/SAE AMS 3411D-1998, Flux, Silver Brazing, High Temperature

Publisher: Society of Automotive Engineers (SAE), 400 Commonwealth Drive, Warrendale, PA 15096-0001

ARI 430-99, Central Station Air Handling Units

ASHRAE 33-00, Methods of Testing Forced Circulation Air Cooling and Air Heating Coils

ASHRAE Terminology of Heating, Ventilation, Air-Conditioning, & Refrigeration, Second Edition, 1991

Publisher: American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329

ASME B16.5-97, Pipe Flanges and Flanged Fittings: NPS ½ through 24

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

SSPC-Vis 1-00, Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning

SSPC-PA1-00, Shop, Field, and Maintenance of Steel

SSPC-SP6-00, Commercial Blast Cleaning

Publisher: The Society for Protective Coatings (SSPC), 40 24th Street, Pittsburgh, PA 15222-4656

UL 1996.3-2004, Standard for Duct Heaters

Publisher: Underwriters Laboratories, Inc. (UL), 333 Pfingsten Road, Northbrook, FL 60062-2096

ARTICLE CA-3000
MATERIALS

CA-3100 GENERAL REQUIREMENTS

CA-3110 MATERIAL SPECIFICATIONS

The ASME and ASTM specifications listed in Tables CA-3230, CA-3310, and CA-3410 contain requirements for the chemical composition, material thickness limits, minimum yield strength, and tensile strength for each grade designation covered. Where a grade designation is not assigned a minimum yield strength and a tensile strength, tests in accordance with ASTM A 370 shall be conducted in order to obtain these values. Maximum allowable design stress values shall be calculated by the procedures in Article AA-4000.

CA-3200 WATER, STEAM, AND VOLATILE REFRIGERANT COIL MATERIALS

CA-3210 PRESSURE-RETAINING MATERIALS FOR WATER AND STEAM COILS

Allowable stresses and yield strengths of materials for all pressure-retaining items shall conform to the requirements given in the ASME Code for the appropriate class of service. For Codes of Record prior to the 1992 Edition, use Section III Appendices, Tables I-7.0, I-8.0, or I-13.3, as applicable. For Codes of Record beginning with the 1992 Edition, use Section II, Part D, Subpart 1, Tables 1A, 1B, and Y-1, as applicable.

WARNING: Exposure to freshly generated fumes from cadmium-bearing silver brazing alloys has resulted in documented cases of occupational disease. Such fumes are toxic and contain cadmium oxide which is a suspected carcinogen. Refer to SFA-5.8 for alloys in this category. Strict safety and ventilation rules shall be observed if these alloys are used.

CA-3220 PRESSURE-RETAINING MATERIALS FOR VOLATILE REFRIGERANT COILS

Material for all pressure-retaining items shall conform to the material requirements of ANSI/ASME B31.5, Table 502.3.1. In addition to this Table, the materials shall meet the requirements of this Code. All materials selected shall be suitable for the intended service.

WARNING: Exposure to freshly generated fumes from cadmium-bearing silver brazing alloys has resulted in documented cases of occupational disease. Such fumes are toxic and contain cadmium oxide which is a suspected carcinogen. Refer to SFA-5.6 for alloys in this category. Strict safety and ventilation rules shall be observed if these alloys are used.

CA-3230 NONPRESSURE-RETAINING MATERIALS

Materials for safety-related extended fin coils shall be selected from Table CA-3230.

CA-3240 LOAD-BEARING MEMBERS

Materials that are part of the water coil casing and are used for component support and transmission of loads from the pressure-retaining boundary to the intervening element structure shall conform to the requirements of the ASME Code, Section III, Table NF-2122(a)-1. Applicable ASME Code Cases in effect on the date of the Code edition and addenda listed in the certified design specification may be used by mutual consent of the Owner or his designee and the Certificate Holder. Boundary definitions and limits shall be per NF-1130. Bolts and nuts transmitting loads shall be supplied in accordance with Subsection NF.

CA-3250 NONLOAD-CARRYING MEMBERS

Materials that are part of the coil casing or tube support and for which no structural credit is taken do not have to comply with the ASME Code, Section III, Subsection NF; however, they shall be selected from Table CA-3230.

CA-3300 AIR WASHER AND EVAPORATIVE COOLER MATERIALS

CA-3310 GENERAL REQUIREMENTS

Materials for air washers, evaporative coolers, and accessories shall be capable of meeting all requirements of CA-4320. Materials shall be in conformance with the ASME or ASTM specifications listed in Table CA-3310, as a minimum. Materials that exceed the requirements in Table CA-3310 may be used when required by the design specification or Article AA-4000.

CA-3400 ELECTRIC HEATING COIL MATERIALS

CA-3410 GENERAL REQUIREMENTS

Materials for electric heating coils and accessories shall meet all requirements of CA-4400. Materials shall be in conformance with the ASME or ASTM specifications listed in Table CA-3410, as a minimum. Materials that exceed the requirements in Table CA-3410 may be used subject to the approval of the Owner or his designee.

CA-3500 CERTIFICATION OF MATERIALS

CA-3510 GENERAL REQUIREMENTS

Certification of materials shall be in accordance with Articles AA-3000 and AA-8000, and the specific requirements of the following subparagraphs.

(a) The materials supplied shall be in full compliance with the appropriate ASME, AWS, or ASTM specification. The thickness shall be as specified in the Design specification or as required in Article CA-4000.

(b) The coil Manufacturer shall supply to the Purchaser, as a minimum, certified material test reports (CMTR) of chemical and physical properties of all materials that form pressure boundaries. The pressure boundary includes the coil tubing, headers, return bends, nozzles, and flanges. A Material Manufacturer's Certificate of Compliance with the material specification, grade, class, and heat-treated condition, as applicable, may be provided in lieu of a CMTR for the coil material defined below:

(1) pipe, fittings, flanges, material for valves and tubes (except heat exchanger tubes) NPS $^3/_4$ and less;

(2) bolting of 1 in. nominal diameter and less.

(c) ASME Code, Section III, Subsection NF, materials shall be supplied with CMTRs, except as designated in NF-2600.

(d) For nonpressure boundary coil material, electric heaters, air washers, and evaporative coolers, a Material Manufacturer's Certificate of Compliance with the material specification, grade, class, and heat-treated condition, as applicable, is acceptable in lieu of a CMTR.

TABLE CA-3230 **(09)**
ALLOWABLE MATERIALS — NONPRESSURE-RETAINING COMPONENTS FOR WATER, STEAM, AND VOLATILE REFRIGERANT COILS

ASME Designator	ASTM Designator	Publication Title
Plate, Sheet, and Strip		
. . .	A 90/A 90M	Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
SA-240	A 240	Heat-Resisting Chromium and Chromium–Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels
SA-414	A 414	Carbon Steel Sheet for Pressure Vessels
. . .	A 653/A 653M	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
. . .	B 122	Copper–Nickel–Zinc Alloy (Nickel Silver), and Copper–Nickel Alloy Plate, Sheet, Strip, and Rolled Bar
SB-152	B 152	Copper Sheet, Strip, Plate, and Rolled Bar
SB-209	B 209	Aluminum-Alloy Sheet and Plate
Hardware		
SA-193	A 193	Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
SA-194	A 194	Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service
SA-307	A 307	Carbon Steel, Externally Threaded Standard Fasteners
SA-325	A 325	High-Strength Bolts for Structural Steel Joints
SA-354	A 354	Quenched and Tempered Alloy-Steel Bolts, Studs, and Other Externally Threaded Fasteners
SA-449	A 449	Quenched and Tempered Steel Bolts and Studs
SA-563	A 563	Carbon and Alloy-Steel Nuts
. . .	F 436	Hardened Steel Washers
Structurals		
SA-36	A 36	Structural Steel
SA-479	A 479	Stainless and Heat-Resisting Steel Wire, Bars, and Shapes for Use in Boilers and Other Pressure Vessels
SB-62	B 62	Composition Bronze or Ounce Metal Castings
SB-98	B 98	Copper–Silicon Alloy Rod, Bar, and Shapes
SB-133	B 133	Copper Rod and Bar

(09)

TABLE CA-3310
ALLOWABLE MATERIALS — AIR WASHERS AND EVAPORATIVE COOLERS

ASME Designator	ASTM Designator	Publication Title
Plates, Sheet, and Strip		
. . .	A 90/A 90M	Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
SA-240	A 240	Heat-Resisting Chromium and Chromium–Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels
. . .	A 653/A 653M	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
Structurals and Bars		
SA-36	A 36	Structural Steel
SA-479	A 479	Stainless and Heat-Resisting Steel Wire, Bars, and Shapes for Use in Boilers and Other Pressure Vessels
Pipe		
SA-53	A 53	Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
SA-351	A 351	Austenitic Steel Castings for High-Temperature Service
SA-376	A 376	Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service
. . .	A 120	Pipe, Steel, Black and Hot-Dipped, Zinc-Coated (Galvanized) Welded and Seamless, for Ordinary Uses
Hardware		
SA-193	A 193	Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
SA-194	A 194	Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service
SA-307	A 307	Carbon Steel, Externally Threaded Standard Fasteners
SA-325	A 325	High-Strength Bolts for Structural Steel Joints
SA-354	A 354	Quenched and Tempered Alloy-Steel Bolts, Studs, and Other Externally Threaded Fasteners
SA-449	A 449	Quenched and Tempered Steel Bolts and Studs
SA-563	A 563	Carbon and Alloy-Steel Nuts
. . .	F 436	Hardened Steel Washers
. . .	F 568	Carbon and Alloy-Steel Externally Threaded Metric Fasteners
Coatings		
. . .	A 123	Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed, and Forged Steel Shapes, Plates, Bars, and Strip

TABLE CA-3310
ALLOWABLE MATERIALS — AIR WASHERS AND EVAPORATIVE COOLERS (CONT'D)

ASME Designator	ASTM Designator	Publication Title
Flanges and Fittings		
SA-105	A 105	Carbon Steel Forgings, Carbon Steel, for Piping Components
SA-181	A 181	Forgings, Carbon Steel, for General Purpose Piping
SA-182	A 182	Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
SA-234	A 234	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures
SA-403	A 403	Wrought Austenitic Stainless Steel Piping Fittings
SA-420	A 420	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service

TABLE CA-3410 (09)
ALLOWABLE MATERIALS — ELECTRIC HEATING COILS

ASME Designator	ASTM Designator	Publication Title
Plate, Sheet, and Strip		
. . .	A 90/A 90M	Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
SA-240	A 240	Heat-Resisting Chromium–Nickel Stainless Steel Plate, Sheet, and Strip Pressure Vessels
. . .	A 366	Steel, Carbon, Cold-Rolled Sheet, Commercial Quality
. . .	A 569	Steel, Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip, Commercial Quality
. . .	A 653/A 653M	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
Elements		
. . .	A 269	Seamless and Welded Austenitic Stainless Steel Tubing for General Service
. . .	B 344	Drawn or Rolled Nickel–Chromium and Nickel–Chromium–Iron Alloys for Electrical Heating Elements
Hardware		
. . .	. . .	See Table CA-3300 for allowable materials
Structurals		
SA-36	A 36	Structural Steel
. . .	A 500	Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes

ARTICLE CA-4000
DESIGN

CA-4100 DESIGN CONDITIONS FOR WATER AND STEAM COILS

CA-4110 DESIGN SPECIFICATION

A design specification shall be prepared and certified by the Owner or his designee in accordance with NCA-3255 of the ASME Code, in sufficient detail to provide a complete basis for coil design in accordance with this Code. The design specification shall include, as a minimum, the following data:

(a) ASME Code edition, addenda, class, and applicable Code Cases

(b) coil type

(c) corrosion allowance per ASME Code, Section III, NX-3121

(d) fouling factor — fluid side

(e) safety classification per ASME Code, Section III, NCA-2110(d)

(f) boundaries of jurisdiction per NCA-3254

(g) tube, fin, minimum material thickness

(h) maximum allowable fin spacing

(i) materials of construction

(j) conditions of operation — normal, accident, containment pressurization (leak) test

(1) entering air temperature, dry bulb/wet bulb, °F (°C)

(2) leaving air temperature, dry bulb/wet bulb, °F (°C)

(3) entering fluid temperature, °F (°C)

(4) air density, lb/ft^3 (kg/m^3)

(5) fluid-side flow rate, gal/min (m^3/s)

(6) entering airflow rate, standard ft^3/min (m^3/s)

(7) maximum fluid-side pressure drop, ft of H_2O (Pa)

(8) maximum air-side pressure drop, in. wg (Pa)

(9) minimum total heat transfer, Btu/hr (kW)

(10) maximum face velocity, ft/min (m/min)

(11) maximum environmental design pressure, psia (Pa)

(k) design and service loadings per ASME Code, Section III, NCA-2140

(l) radiation, total integrated dosage, rads

(m) coating system requirements

CA-4111 Additional Requirements

In addition to the requirements of CA-4110, the design specification shall contain a complete cooling water analysis, including tests for ammonium compounds.

CA-4120 TECHNICAL REQUIREMENTS

CA-4121 General

(a) The fluid side of the coil shall be designed, constructed, tested, and stamped in accordance with the ASME Code, Section III.

(b) All fluid-side coil components shall be, as a minimum, the same ASME code class as the fluid system in which they are to be installed. The design specification shall identify this code class.

(c) Coils shall be capable of meeting the design requirements of CA-4122 through CA-4134.

(d) Inspection and testing shall be in accordance with CA-5100.

CA-4122 Tubes

(a) All water coils shall be designed for a minimum tube velocity of 2 ft/sec (0.61 m/s)

(b) Maximum velocities for copper alloy UNS C12200 and copper-nickel alloys UNS C70600 and UNS C71500 shall be as shown in Table CA-4122.

(c) Any other water coil tube material permitted for Section III service by Section II, Part D, of the ASME Boiler and Pressure Vessel Code, but not explicitly listed in CA-4122, may be used. These materials shall be listed in the Coil Design Specification. For these materials, the manufacturer shall document by calculation that the waterside pressure drop limits delineated in the Design Specification are met.

TABLE CA-4122
MAXIMUM WATER VELOCITIES IN WATER COILS

	Maximum Velocity			
	Fresh Water		Brackish Water	
Alloy	ft/sec	m/s	ft/sec	m/s
Copper (UNS C12200)	7	2.13	Not recommended	
90–10 Copper–Nickel (UNS C70600)	10	3.05	9	2.74
70–30 Copper–Nickel (UNS C71500)	15	4.57	12	3.66

(d) Steam coils shall be capable of withstanding twice the maximum fluid-side pressure.

CA-4123 Return Bends

(a) Separate noncleanable return bends are allowed.

(b) Where a minimum wall thickness is specified, separate return bends shall be formed from a tube with an increased wall thickness sufficient to maintain the required wall thickness in the bends. As a minimum, such increased wall thickness shall be the equivalent of 1 gage heavier than the wall thickness required for straight tube.

(c) Hairpin (or U-bend) return bends are permitted only when wall thinning is allowed by the design specification. The amount of thinning in the outside fibers of a hairpin shall be in accordance with the ASME Code, Section II, Part B, SB-395, 14.3.

(d) Cleanable return bends shall be cast or machined fittings with plugs and gaskets.

CA-4124 Nozzles and Header Assembly

(a) Carbon steel nozzles, tubular headers, and water box headers shall have a minimum corrosion allowance of $^1/_{16}$ in. (1.6 mm).

(b) The water and steam header assembly shall be provided with a vent and drain connection.

(c) Cleanable tube coils shall be of the removable header type or the plug type with O-ring gaskets.

(d) Loading considerations shall be in accordance with CA-4130.

(e) Joints shall be brazed or welded in accordance with Article CA-6000.

(f) Nozzles shall be furnished with weld end preparation or flanges, as specified.

CA-4125 Fins

(a) Fins shall have a minimum thickness of 0.009 in. (0.23 mm).

(b) Fins shall be permanently bonded to the tubes by a mechanical expansion or tensioning process or by brazing.

(c) Fin spacing shall be specified in the design specification.

CA-4126 Casing and Tube Support

(a) The casing and tube supports shall be designed to withstand, without causing permanent distortion or breach of integrity, stresses, and external overpressure as defined in Article AA-4000. Structural requirements for coils are given in CA-4130.

(b) Casings and tube supports shall be of approved material from Table CA-3230.

CA-4127 Design Recommendations

Design recommendations for safety-related coils are contained in Nonmandatory Appendix CA-B.

CA-4130 STRUCTURAL REQUIREMENTS FOR WATER, STEAM, AND VOLATILE REFRIGERANT COILS

CA-4131 General

Coils shall be designed in accordance with the structural requirements given in Article AA-4000. Structural requirements and load definitions specific to water and steam coils are given in CA-4132 through CA-4134.

CA-4132 Support Boundaries for Coils

Coils may be supported as a unit (as part of an air handling system) or line supported (as in an assembly inserted into a run of ductwork).

(a) In a unit supported coil assembly, the support boundary for the coil shall consist of the attachment and interface points between the air handling equipment housing and the coil.

(b) In a line supported coil assembly, the support boundary for the coil shall consist of the interface flanges or other mechanical connections between the coil and ductwork that are designed to transfer all components of load across the joints.

(c) The coil supplier shall be responsible for specifying all information necessary to define the support boundary interfaces. This information shall include, but not necessarily be limited to

(1) configuration, size, and type of support attachments required.

(2) magnitudes and directions of all loads imposed on the anchorage points, including all static, dynamic, and operational loads resulting from the installed coil assembly. Loads shall be provided in a form that shall allow combinations to be considered as required in AA-4212.

(3) any limitations, such as allowable nozzle loads, or other interface load requirements necessary to ensure that the coil can perform its required safety function under all design conditions.

CA-4133 Load Definition

Loads to be considered in the structural design of equipment are given in AA-4211 and AA-4212 with the following additions.

(a) Normal loads N shall include

(1) *deadweight load:* including any added weight due to water or the heat transfer medium.

(2) *operating pressure load:* the load resulting from the maximum pressure differential that may occur during normal operation. Included are loads imposed by normal design airflows and impact pressures resulting from rapid change of other airflow control devices in a system.

(3) *nozzle loads:* the shear and bending moments associated with the attached piping system.

(4) *normal equipment interface load:* the normal externally applied load or loads from adjacent equipment or ductwork attached to the coils.

(b) Thermal loads T shall include temperature induced loads resulting from constraint of force and displacements.

(c) Design and service limits shall be as follows:

(1) Pressure boundary limits shall conform to the ASME Code, Section III, NCA-2142.2, and Tables NC/ND-3321-1.

(2) For Subsection NF casings, limits shall be in accordance with NCA-2142.2, NF-3321, NF-3350, NF-3360, and Table NF-3523.2-1.

CA-4134 Structural Verification

CA-4134.1 Verification by Analysis. When verification of design by analysis is appropriate (see AA-4310 through AA-4340), the results of the analysis shall be compiled by the Manufacturer and submitted to the Owner or his designee in the form of a design verification stress report (DVSR). The DVSR shall identify the objectives, assumptions, analysis results, and the conclusions. Equipment shall be considered structurally verified if the stress conditions identified in Article AA-4000 are not exceeded under the applicable load combination.

CA-4134.2 Verification by Testing. When verification by testing is appropriate (see AA-4350), a design verification test procedure shall be compiled and submitted to the Owner or his designee. Upon completion of the tests, a design verification test report (DVTR) shall be prepared by the Manufacturer and submitted to the Owner or his designee. The DVTR, as a minimum, shall identify the objectives, design criteria, assumptions, test results data, and conclusions of the design verification test (DVT). Equipment shall be considered structurally verified if before, during, and after the qualification test the equipment performs its safety-related function.

CA-4134.3 Verification by Comparison. When equipment to be structurally verified is of similar design to other equipment that has been verified in accordance with CA-4134.1 or CA-4134.2, and when all elements of the unverified equipment are shown to be equal to or more rigid than the similar, verified equipment, and when it can be shown that the previously verified equipment has greater loading conditions, the equipment may be verified by comparison in lieu of analysis or tests. When verification by this method is selected, a design verification by comparative evaluation report (DVCER) shall be submitted to the Owner or his designee. The DVCER shall identify the specific equipment to be verified, and include a copy of the appropriate DVSR or DVTR and a detailed comparative evaluation between the two pieces of equipment.

CA-4134.4 Design Reports

(a) For coils designed and fabricated in accordance with the ASME Code, Section III, the design report requirements of NCA-3550 shall be met.

(b) For casings designed to ASME Code Section III, Subsection NF, the requirements of NF-3132 and CA-4134.4(a) shall be met.

CA-4134.5 Design Verification Acceptance Criteria

(a) Coils designed and fabricated in accordance with the ASME Code shall be considered structurally verified if the stress limits identified in Tables NC/ND-3321-1 are not exceeded under the applicable load combinations.

(b) Coil casings designed to ASME Code, Section III, Subsection NF, shall be considered structurally verified if the stress limits given in NF-3321, NF-3350, NF-3360, and Table NF-3523.2-1 are not exceeded under the applicable load combinations.

(c) Equipment not designed and fabricated in accordance with the ASME Code shall be considered structurally verified if the stress limits of Table AA-4323 are not exceeded under the load combinations of Table AA-4212.

CA-4134.6 Deflection Acceptance Criteria. Deflection is not a failure mode applicable to installed coils. No acceptance criteria are therefore required.

CA-4200 DESIGN CONDITIONS FOR VOLATILE REFRIGERANT COILS

CA-4210 DESIGN SPECIFICATION

A design specification shall be prepared by the Owner or his designee and certified by a registered professional engineer in sufficient detail to provide a complete basis for coil design. The specification shall include, but not be limited to, the following items as required for proper design and construction of the coil in accordance with this and other applicable codes and the Owner's requirements:

(a) design and testing standards
(b) materials of construction
(c) refrigerant type
(d) safety classifications per ANSI/ASHRAE 15
(e) maximum allowable fin spacing
(f) conditions of operation — normal, accident
(1) total heat transfer, Btu/hr (kW)
(2) sensible heat transfer, Btu/hr (kW)
(3) entering air temperature, dry bulb/wet bulb, °F (°C)
(4) leaving air temperature, dry bulb/wet bulb, °F (°C)
(5) minimum refrigerant suction temperature, °F (°C)
(6) entering airflow rate, standard ft^3/min (m^3/s)
(7) maximum air-side pressure drop, in. wg (Pa)
(8) maximum face velocity, ft/min (m/min)
(9) design loadings
(10) radiation, total integrated dosage, rads
(11) coating system requirements

CA-4220 TECHNICAL REQUIREMENTS

CA-4221 General

(a) Volatile refrigerant coils shall be designed in accordance with the structural requirements given in Article AA-4000. Structural requirements and load definitions specific to volatile refrigerant coils are given in CA-4132.1 through CA-4134.6.

(b) The fluid side of the volatile refrigerant coil shall be designed, constructed, rated, and tested in accordance with the design specification and ANSI/ASME B31.5, ARI 410, and ASHRAE 33.

(c) Inspection and testing shall be in accordance with CA-5100.

(d) Materials of construction will be in accordance with CA-3100.

(e) Volatile refrigerant coils shall be capable of meeting the design requirements of CA-4222 through CA-4227.

(f) Welding and brazing shall be in accordance with Article CA-6000.

CA-4222 Tubes

Volatile refrigerant coil tubes shall be capable of withstanding $1\frac{1}{2}$ times the maximum fluid-side pressure defined in the design specification.

CA-4223 Return Bends

Hairpin (or U-bend) return bends are permitted only when wall thinning is allowed by the design specification. The amount of thinning in the outside fibers of a hairpin shall be in accordance with the ASME Code, Section II, Part B, SB-395, 14.3.

CA-4224 Distributors

(a) Distributors shall be utilized when required to disperse the refrigerant evenly through the coil.

(b) Distributor feed tubes shall be oriented in a nonuniform configuration and shall be exactly the same length for each circuit.

(c) Each distributor and distributor feed tube shall be constructed of materials compatible with other adjoining materials and with CA-3100.

CA-4225 Suction Header Assembly

Vertical headers shall have a bottom outlet to allow gravity drainage of refrigerant oil in the suction line. The suction header shall be nearest the entering air face of the coil.

CA-4226 Fins

Fins shall be designed in accordance with CA-4125. Fin spacing shall be as specified in the design specification.

CA-4227 Casing and Tube Support

(a) The casing and tube support shall be designed in accordance with CA-4126.

(b) Casings and tube supports shall be of approved material from Table CA-3230.

CA-4228 Design Recommendations

Design recommendations for safety-related coils are contained in Nonmandatory Appendix B.

CA-4229 Structural Requirements for Volatile Refrigerant Coils

Structural requirements for volatile refrigerant coils shall be in accordance with CA-4130 through CA-4134.

CA-4300 DESIGN CONDITIONS FOR AIR WASHERS AND EVAPORATIVE COOLERS

CA-4310 DESIGN SPECIFICATION

A design specification shall be prepared by the Owner or his designee in sufficient detail to provide a complete basis for equipment design in accordance with this Code. The design specification shall include, as a minimum, the following data:

(a) equipment type

(1) air washer

(2) evaporative cooler

(b) materials of construction

(c) conditions of operation, normal and accident

(1) entering temperature, dry bulb/wet bulb, °F (°C)

(2) leaving temperature, dry bulb/wet bulb, °F (°C)

(3) total heat transfer, Btu/hr (kW)

(4) operating air density, lb/ft^3 (kg/m^3)

(5) minimum and maximum airflow rate, standard ft^3/min (m^3/s)

(6) minimum and maximum air velocity, ft/min (m/min)

(7) air pressure loss, in. wg (Pa)

(8) humidifying effectiveness, %

(d) pump flow rate, gal/min (L/s)

(e) pump head, ft (Pa)

(f) makeup water flow, gal/min (L/s)

(g) space limitations

(h) drain connections, types and sizes

(i) insulation requirements

(j) design loadings

(k) radiation, total integrated dosage, rads

(l) electrical characteristics

(m) maximum specified design temperature

CA-4320 TECHNICAL REQUIREMENTS

CA-4321 General

(a) Air washers and evaporative coolers shall be capable of meeting the design requirements of CA-4322 through CA-4328 and the structural requirements of CA-4330.

(b) Spray-type air washers shall consist of a chamber or casing (including spray system), a water tank, a recirculating water pump, and, when required, a moisture eliminator section.

(c) Cell-type air washers shall consist of an array of cells packed with glass, metal, or fiber media held in place with wire mesh screens. Cells shall be arranged in tiers. Each tier shall be equipped with a spray header and drain pan, and with the exception of the bottom tier, a drain pipe. This type of washer also consists of a water tank, pump, and downstream moisture eliminator section if required.

(d) Wetted media evaporative air coolers shall consist of a casing housing, evaporative pack, water tank, recirculating pump, and water distribution system.

(e) Rigid media evaporative coolers shall use a rigid corrugated material as the wetted surface.

(f) Other types of air washers and evaporative coolers shall be acceptable, provided the design and performance criteria meet the requirements of the design specification.

(g) When required by the design specification, units shall be insulated or contain air distribution baffles, or both.

CA-4322 Chamber

(a) The panels and tank shall be sealed and fastened to provide a leak-tight joint.

(b) Side and top blanks attached to the panels and extending to the eliminator bank shall minimize the bypass of air and spray around the eliminator section.

(c) Intermediate spacers shall provide the spacing and support functions for the eliminators and baffles.

(d) When required, access doors located on spray chamber panels shall be watertight or provided with an outside drain that can be directed back into the chamber.

(e) Internal bracing in the spray pattern shall not be located closer than 6 in. (152 mm) from the orifice of a nozzle.

(f) The spray chamber shall be accessible for maintenance.

CA-4323 Eliminators

(a) Spray removal from the airstream shall be accomplished by a bank of eliminators designed to capture and drain spray water into the washer tank.

(b) Eliminators shall be formed and properly spaced to provide effective spray removal at the velocity and pressure drop stated in the design specification.

(c) The material shall be a minimum of 24 gage steel in accordance with ASTM 653/653M Coating Designation G90, or 26 gage stainless steel.

(d) The material shall be capable of maintaining its shape at the maximum specified temperature and velocity.

(e) The eliminator bank shall be designed to provide easy access for cleaning each blade.

(f) The eliminator bank shall be provided with a plate extending below the water level at the intake to prevent the bypass of air and spray under the bank.

(g) Scum plates located at the bottom of the eliminator bank on the discharge side shall be provided to prevent foam from escaping into the airstream.

CA-4324 Fill

(a) Rigid and semirigid fill media shall be designed to provide wetted surfaces from which water evaporates and excess water drains into the tank.

(b) Fill media shall be of resilient fibrous glass or cellulose material, or of rigid, corrugated material of cellulose or glass fiber sheet that has been impregnated with suitable material to provide rigidity and shape-holding characteristics without destroying its hygroscopic properties. The media may be chemically treated to increase wettability. The fill shall be treated to resist bacteria, fungi, and other microorganisms. Fill media shall be selected to perform in accordance with the design conditions.

CA-4325 Baffles

(a) Baffles shall provide uniform airflow to the spray chamber.

(b) Broken plate baffles shall be a minimum of 24 gage steel in accordance with ASTM 653/653M Coating Designation G90, or 26 gage stainless steel.

(c) The material shall be capable of maintaining its shape at the maximum specified temperature and velocities.

(d) The baffle bank shall be designed for easy access for cleaning each blade.

(e) Perforated metal baffles with greater than 65% net free area shall be not less than 18 gage steel in accordance with ASTM 653/653M Coating Designation G90, or 20 gage stainless steel.

CA-4326 Spray Bank

(a) Uniform spray distribution shall be provided in the spray chamber of the air washers and evaporative coolers to produce 90% saturation efficiency at 500 FPM face velocity. Distribution headers for soaking the media shall extend the full length of and be above the media, be equally spaced, and have uniform distribution of water at each orifice to produce the stated efficiency.

(b) Water flow shall not exceed 10 ft/sec (3 m/s) in the piping.

(c) Piping shall be not less than Schedule 40 galvanized or stainless steel.

(d) Welding of piping shall be in accordance with CA-6120(c).

(e) Nozzles shall be made from materials compatible with piping materials.

(f) The header shall be attached by bolting or welding to the tank, supports, or panels. Welding shall be in accordance with Article CA-6000.

(g) Cleanout provisions, such as pipe caps or blind flanges, shall be provided to flush the header and standpipes if required by the design specification.

(h) Headers shall be not less than NPS 4 and standpipes NPS $1\frac{1}{2}$. Nipples shall not be less than NPS $\frac{3}{8}$. Headers for fill-type evaporative coolers shall not be less than NPS $1\frac{1}{2}$, Schedule 80.

(i) Bolted flanges for the header section shall be as follows:

(1) stainless steel Type 304 (UNS S30400), ANSI/ASME B16.5 Class 150 flange

(2) forged steel ANSI/ASME B16.5 Class 150 flange

(3) forged steel flanges shall be galvanized in accordance with ASTM A 123

CA-4327 Tanks

(a) The tank shall provide a sump for the spray system, a mount for accessories such as makeup, quick-fill, and level control.

(b) The tank plate material shall not be less than 10 gage steel in accordance with ASTM 653/653M Coating Designation G90, or 12 gage stainless steel.

(c) Supports for eliminators, fill, and baffles shall be spaced to allow no greater deflection than $\frac{1}{16}$ in.

(1.6 mm) of the span between supports during anticipated construction, normal or accident conditions.

(d) The pump suction shall be threaded, flanged, and bolted or welded through the wall. If the pump is mounted with a vertical shaft, it shall be bolted to a submerged suction plate.

(e) All welding on the tank shall be in accordance with CA-6120(c).

CA-4328 Miscellaneous Requirements

(a) Welds on galvanized steel shall be cleaned and coated with a zinc-rich inorganic paint in accordance with AA-6535.

(b) Electrical installation for lighting, power, and control wiring shall be in accordance with ANSI/NFPA 70, UL 1096, and the design specification.

(c) Air washers and evaporative coolers shall be designed in modules and field erected where size precludes shipment by common carriers.

CA-4329 Design Recommendations

Design recommendations for air washers and evaporative coolers are contained in Nonmandatory Appendix CA-B.

CA-4330 STRUCTURAL REQUIREMENTS

CA-4331 General

Air washers and evaporative coolers shall be designed in accordance with structural requirements given in Article AA-4000. Structural requirements and load definitions specific to air washers and evaporative coolers are given in CA-4332 through CA-4334.

CA-4332 Support Boundary for Air Washers and Evaporative Coolers

(a) The support boundary for air washers or evaporative coolers shall consist of the interface flanges, pipe nozzles, mounting bolts, or other mechanical connections between the air washer or evaporative cooler and adjacent ductwork or equipment that are designed to transfer all components of load.

(b) The air washer or evaporative cooler Manufacturer shall be responsible for specifying all information necessary to define the support boundary interfaces. This information shall include, but not necessarily be limited to

(1) configuration, size, and type of support attachments required.

(2) magnitudes and directions of all loads imposed on the anchorage points, including all static, dynamic, and operational loads. Loads shall be provided in a form that shall allow combinations to be considered, as required in AA-4212.

(3) any limitations, such as allowable nozzle loads, deflection limits, or other interface load requirements necessary to ensure that the assembly can perform its required safety function under all design conditions.

CA-4333 Load Definition

Loads to be considered in the structural design of air washers and evaporative coolers are given in AA-4211 and AA-4212, with the following additions:

(a) Normal loads *N*, which shall include

(1) deadweight load: including any added weight due to water or other medium.

(2) operating pressure load: the load resulting from the maximum pressure differential that may occur during normal operation. Included are loads imposed by normal design airflows and impact pressures resulting from rapid change of other devices in a system.

(3) nozzle loads: the shear and bending moments associated with the attached piping systems.

(4) normal equipment interface load: the normal externally applied loads from interfacing equipment or ductwork attached to the equipment.

(5) attachment loads: the deadweight load associated with any unit attachments such as actuators or gages.

(b) Sloshing effects of liquids used in air washer or evaporative cooler spray systems.

(c) Thermal loads *T* that shall include temperature-induced loads resulting from constraint of force and displacements.

CA-4334 Structural Verification

(a) Air washers and evaporative coolers and all of their components shall be capable of remaining functional under the structural loadings given in CA-4333.

(b) Structural verification shall be in accordance with CA-4134.

CA-4400 DESIGN CONDITIONS FOR ELECTRIC HEATING COILS

CA-4410 DESIGN SPECIFICATION

A design specification shall be prepared by the Owner or his designee in sufficient detail to provide a complete basis for electric heating coil design in accordance with this Code. Design specifications shall include, as a minimum, the following data:

(a) entering temperature, dry bulb, °F (°C)
(b) relative humidity, percent
(c) leaving temperature, dry bulb, °F (°C)
(d) entering airflow, standard ft^3/min (m^3/s)
(e) air entering velocity, ft/min (m/min)
(f) line voltage, phase, Hz
(g) control voltage, phase, Hz
(h) coil type
  (1) flange
  (2) slip-in
(i) element type
  (1) open coil
  (2) fin tubular
(j) heater capacity, Btu/hr (kW)
(k) number of stages
(l) materials of construction
(m) location of controls
  (1) integral
  (2) remote
(n) type of controls
  (1) electric
  (2) pneumatic
(o) design loadings
(p) radiation, total integrated dosage, rads

CA-4420 TECHNICAL REQUIREMENTS

CA-4421 General

(a) Electric heating coils shall be designed following the guidelines of ANSI/NFPA 70 and UL 1096, but need not bear the UL label.

(b) Electric heating coils shall be capable of meeting the design requirements of CA-4422 through CA-4429 and the structural requirements of CA-4430.

CA-4422 Elements

(a) Elements shall be of open coil or finned tubular design. The resistance wire shall be in accordance with ASTM B 344.

(b) Open coil heating elements shall be 80% nickel and 20% chromium resistance wire centered in a high temperature ceramic or phenolic sleeve.

(c) Finned tubular elements shall have 80% nickel and 20% chromium resistance wire centered in a metal sheath and insulated from the sheath by magnesium–oxide refractory.

(d) Sheath and fins shall be stainless steel, monel, or copper clad carbon steel. Carbon steel elements shall be coated with high-temperature aluminum paint or ceramic frit finish.

(e) Element hardware shall be stainless steel or monel. Insulators and bracket bushings shall be nonporous ceramic and securely positioned. Terminals shall be machine crimped to elements.

(f) Element support brackets shall be positioned not more than 4 in. (100 mm) apart for open coil elements and 18 in. (457 mm) apart for finned tubular elements. Stiffening ribs and gussets shall be provided for rigidity.

(g) Open and finned heating stages shall be arranged to prevent stratification when operating at less than full capacity. A minimum of the first one-third of heating elements shall be spread evenly across the heater face.

CA-4423 Frames

(a) Frames shall be flanged or slip-in.

(b) Stacking flanges shall be furnished when multiple sections are required.

(c) Frames, supports, and flanges shall be of approved materials from Table CA-3410.

CA-4424 Thermal Cutouts

(a) Primary and secondary temperature thermal cutouts shall be provided in accordance with UL 1096 and ANSI/NFPA 70 requirements. The primary thermal protection shall be the automatic reset type. The secondary thermal protection shall be the manually reset type, or replaceable.

(b) Heaters in multizone or dual-duct air handling units and heaters with frame widths over 36 in. (914 mm) shall be furnished with linear thermal cutouts that extend the full length of the frame.

CA-4425 Fan Interlock

Each heater shall be provided with a fan interlock, which can be either a fan relay or a built-in pressure differential-type airflow switch. Switches shall be provided in accordance with the requirements of UL 1096 and wired in series with the primary thermal protector.

CA-4426 Terminal Boxes

The terminal boxes shall meet NEMA standards. The enclosures shall be NEMA 1, 4, or 12, as required by the design specification. The terminal boxes shall be fabricated from stainless steel or carbon steel not less than 16 gage.

CA-4427 Electrical Requirements

(a) Electric heating coils shall be constructed in accordance with applicable requirements of ANSI/

NFPA 70 and UL 1996. All internal wiring shall be factory installed and terminated at conveniently located terminal blocks to facilitate field wiring. No more than two wires shall be terminated on any one terminal block. Power and control terminals shall be clearly marked. Power and control wiring shall be terminated on different terminal blocks and shall not be intermixed. Grounding lugs for incoming ground wire shall be provided.

(b) The electric heating unit and components shall be qualified to ANSI/IEEE 323 and ANSI/IEEE 344. The units shall be qualified to operate at the specified environmental conditions, such as relative humidity, radiation dose, temperature, etc. Based on the heater qualification test results, the heater Manufacturer shall provide a recommended replacement schedule for any components that do not achieve the specified life conditions.

(c) Control and power wiring located in electric heating coil enclosures and terminal boxes shall be UL listed, certified to meet the vertical flame test per VW-1 per section 1080 of UL 1581 and marked with VW-1 on the wire insulation. Control and power wiring located in open trays shall be UL listed and certified to the ANSI/IEEE 383 flame test. Wiring shall be continuous between the terminal, with no splicing permitted. All wiring terminations for wire smaller than AWG No. 6 shall be made with crimp-type, preinsulated ring tongue, solderless terminal lugs. For AWG No. 6 and heavier wiring, pressure or clamp-type terminals shall be used. Insulation shall be the radiation resistant type. Spade-type quick-connect terminals may be used where required for component wiring.

(d) Terminal blocks shall be the molded phenolic type with screw-type terminals with barriers between the terminals. Pressure or clamp-type terminals are not acceptable except for AWG No. 6 and heavier wires.

(e) Fuse blocks shall be the molded phenolic type with reinforcement clips.

(f) A built-in, full capacity, safety, unfused disconnect switch or molded case switch shall be provided. The switch shall be designed so that the terminal box door cannot be opened unless the switch is in the off position.

(g) Contactors shall be of the full line-break magnetic disconnect type and shall be capable of holding without overheating within ±10% of the specified supply voltage.

(h) Elements shall have a maximum watt density of 45 W/in.^{2} (0.07 W/mm^2).

(i) Heating coils that are rated at more than 48 A shall be divided into circuits of not more than 48 A each.

CA-4428 Built-In Control Sequencers

(a) Silicon control rectifier (SCR) power controllers, when required, shall be solid state, utilizing zero voltage firing. They shall be able to vary the output from 0% to 100% with respect to the input signal.

(b) The SCR power controller shall be designed such that, when the thermostat or other external control leads are shorted or opened, the SCR is de-energized. All units operating at 480 V and above shall be equipped with transient/surge absorbers.

(c) Step controllers, when required, shall recycle to zero on loss of power. Each step shall have both on and off actuation points that are field adjustable at any point.

(d) When a pneumatic control signal is used, the range shall be specified in the design specification. On loss of pneumatic signal, the heater shall be deenergized.

CA-4429 Remote Control Panels

(a) The enclosure for remote controls shall be suitable for free standing or wall mounting, as required by the design specification. The enclosures shall be fabricated from stainless steel, galvanized steel, or painted carbon steel not less than 16 gauge. The enclosures shall be NEMA type 1, 4, 4X, 12, or 13. The device mounting panel for the remote control enclosure shall be stainless steel or painted carbon steel not less than 14 gauge. The carbon steel mounting panels shall be painted.

(b) Remote control enclosures shall meet the applicable requirements of CA-4427 and CA-4428. Additionally, control panels shall be equipped with a disconnect switch mechanically interlocked to the enclosure door in accordance with ANSI/NFPA 70 requirements. When the terminal box is separate from the remote control enclosure, it shall be provided with an integral switch set to disconnect the heater when the terminal box door is opened.

CA-4430 STRUCTURAL REQUIREMENTS FOR ELECTRIC HEATING COILS

CA-4431 General

Electric heating coils shall be designed in accordance with the structural requirements given in Article AA-4000. Structural requirements and load definitions specific to electric heating coils are given in CA-4133 through CA-4134.

CA-4432 Support Boundary for Electric Heating Coils

Electric heating coils may be supported as a unit (as part of an air handling housing) or line supported (as in an assembly inserted into a run of ductwork).

(a) Unit Supported Coils. The support boundary for the heater shall consist of the attachment and interface points between the air handling equipment housing and the heater.

(b) Line Supported (In-Duct) Heater Assembly. The support boundary for the heater shall consist of the interface flanges, control box attachment to ductwork, or other mechanical connections between the heater and ductwork that are designed to transfer all components of load across the joints.

(c) Documentation. The heater Manufacturer shall be responsible for specifying all information necessary to define the support boundary interfaces. This information shall include, but not necessarily be limited to

(1) configuration, size, and type of support attachment required.

(2) magnitude and directions of all loads imposed on the anchorage points, including all static, dynamic, and operational loads resulting from the installed heater assembly. Loads shall be provided in a form that allows combinations to be considered as required in Article AA-4000.

(3) any information such as deflection limits or interface load requirements necessary to ensure that the heater can perform its required safety function under all design conditions.

ARTICLE CA-5000
INSPECTION AND TESTING

CA-5100 GENERAL REQUIREMENTS

CA-5110 INTRODUCTION

Examination, testing, and inspection shall be in accordance with Article AA-5000 and the requirements of this section.

CA-5200 TESTING OF WATER, STEAM, AND VOLATILE REFRIGERANT COILS

CA-5210 GENERAL REQUIREMENTS

There are two acceptable methods for coil performance verification. Method 1 is the minimum requirement of coil performance certification. Certified copies of the results of computerized coil selection programs shall be acceptable certification. Method 2 does not require testing of every coil size. When correlation between the test series and a coil selection program has been documented by a topical report or other means acceptable to the Owner or his designee, no additional performance testing is required. For coils in containment, such documentation shall include results of tests showing the effects on coil performance as a result of condensate flooding of the coil surfaces under accident conditions.

CA-5211 Performance Verification

The performance of air coils shall be verified by one of the following methods as determined from the design specification.

CA-5211.1 Method 1. The air coil rating shall have been derived from tests conducted in accordance with ASHRAE 33. The coil Manufacturer shall issue a coil certification or an ARI certification. In either case, the certification shall state

(a) the coil capacity based on design parameters.

(b) the fouling factor used in the computation.

(c) the coil data identified in ASHRAE 33, Section 8.2. A certification report shall be issued for each coil. For each model number coil, serial numbers shall be listed on the certification.

CA-5211.2 Method 2. A laboratory test on a prototype coil in accordance with ASHRAE 33 shall be conducted by the coil Manufacturer to determine performance ratings. The results of the test shall be documented in a test report. The report shall include

(a) design conditions

(b) description of test method

(c) test procedure

(d) computation

(e) a statement of coil capacity

CA-5220 PRESSURE TESTING FOR WATER AND STEAM COILS

Components that comply with the ASME Code, Section III, shall be hydrostatically or pneumatically tested in accordance with the requirements of Section III, NC/ND-6000.

CA-5230 PRESSURE TESTING FOR VOLATILE REFRIGERANT COILS

All refrigerant coils shall be pneumatically tested for a minimum of 10 min at $1\frac{1}{2}$ times the maximum allowable pressure. The test shall be conducted under water. Any loss of pressure or visible air bubbles shall not be acceptable.

CA-5240 NONDESTRUCTIVE EXAMINATION

CA-5241 Material Examination

Coil tubing material shall be eddy current tested when required by the design specification. For water and steam coils designed and fabricated in accordance with the ASME Code, this examination shall comply with the ASME Code, Section III, NC/ND-2510 and NC/ND-2552, and with Section V, Article 8 and Article 26, SE-243. For volatile refrigerant coils, ASTM E 243 shall be used.

CA-5242 Visual Examination of Brazed Joints

(a) For coils designed and fabricated in accordance with the ASME Code, brazed joints shall be visually inspected in accordance with AA-5200. Visual examination shall also comply with Section III, NC/ND-4540, NC/ND-5275, and NC/ND-5360, and with Section V, Article 9. Acceptance criteria shall be as given in NC/ND-5360.

(b) For non-ASME coils, brazed joints shall be inspected in accordance with AA-5200. To be acceptable, brazing metal shall give evidence of having flowed uniformly through a joint by the appearance of an uninterrupted, narrow, visible line of brazing alloy at the joint.

CA-5300 TESTING OF AIR WASHERS AND EVAPORATIVE COOLERS

CA-5310 GENERAL REQUIREMENTS

Performance testing of air washers or evaporative coolers shall be conducted at the factory in accordance with AA-5700 and Mandatory Appendix CA-II.

CA-5320 NONDESTRUCTIVE EXAMINATION

Nondestructive examination and inspection of air washers and evaporative coolers shall be conducted at the factory in accordance with Article AA-5000. Minimum acceptance criteria shall be in accordance with Article AA-6000.

CA-5400 TESTING OF ELECTRIC HEATING COILS

CA-5410 GENERAL REQUIREMENTS

Electric heating coils shall be inspected and tested to verify there are no defects in design or manufacture. Tests and inspections shall include, as a minimum, those indicated in this Subarticle. Test reports shall be furnished in accordance with CA-5500.

CA-5420 FUNCTIONAL TEST

Heaters with step controllers or SCRs, or both, shall be functionally tested by simulating a call for heat and verifying that these components function correctly.

CA-5430 DIELECTRIC WITHSTAND TEST

A 60 Hz potential in compliance with UL 1996 as indicated below shall be applied between high-voltage live parts and dead metal parts for a period of 1 min, except that the time of application of the potential may be reduced to 1 sec if the value of the test potential is 120% of the following value:

(a) 1,000 V for heaters rated 250 V or less

(b) 1,000 V plus twice the rated voltage, or 2,000 V, whichever is greater

CA-5440 RESISTANCE TEST

(a) The resistance test shall be done with an ohmmeter calibrated by an approved vendor with standards traceable to the National Institute of Standards and Technology.

(b) The readings shall be taken from the load side of the device that energizes each stage of heater elements. On three-phase heaters, all legs shall be checked by reading from L1 to L2, L2 to L3, and L3 to L1.

(c) Resistance measured must be within 5% of the Manufacturer's design resistance for the specified application.

CA-5450 NONDESTRUCTIVE EXAMINATION

(a) The configuration and dimensions of the electric heating coils shall be in accordance with approved design drawings.

(b) Wiring shall be in accordance with approved wiring diagrams. Wire gages shall be suitable for heater amperage.

(c) Welds shall be visually inspected for pits, cracks, or other surface defects.

(d) The nameplate for compliance with heater ratings shall include kilowatts, voltage, phase, control voltage, and number of stages.

(e) Electrical connections shall be tight.

(f) Built-in components shall be verified as having proper ratings (voltage, amperage, etc.) for the intended purpose.

(g) Metal gages shall be checked with a calibrated micrometer for conformance to design drawings.

(h) Paint shall be checked for meeting the minimum thickness requirements, if applicable.

CA-5500 TEST REPORTS

Sufficient records shall be provided to show documentary evidence of all testing. Records shall include inspections and test reports, and shall show the date of inspection or test, the inspector or data recorder, the type of observation, and the results and their acceptability. Requirements and responsibilities for record transmittal, retention, and maintenance shall conform to those established by the design specification and CA-8120.

ARTICLE CA-6000
FABRICATION AND INSTALLATION

CA-6100 GENERAL REQUIREMENTS

CA-6110 INTRODUCTION

(a) Fabrication and installation shall be in accordance with Article AA-6000 and the specific requirements of this section.

(b) Welding and welding qualification shall be in accordance with AA-6300 and CA-6120. Brazing and brazing qualification shall be in accordance with AA-6400 and CA-6130. Mechanical joints shall be in accordance with AA-6250 and CA-6140.

CA-6120 WELDING

(a) Welding for pressure retaining components designed and fabricated in accordance with the ASME Code shall meet the requirements of Section III and of Section IX, Part QW.

(b) Welds and welded joints in coil frames designed and fabricated in accordance with the ASME Code, Section III, Subsection NF, shall meet the requirements of NF-3324.5, NF-4240, and NF-4300, and of Section IX, Part QW.

(c) Welding for air washers and evaporative coolers, and electric heating coils shall be in accordance with AA-6300.

CA-6130 BRAZING

Brazing for pressure retaining components designed and fabricated in accordance with the ASME Code shall meet the requirements of Section III and of Section IX, Part QB.

(a) Base metals shall be listed in Tables I-7.0 and I-8.0 of the Section III Appendices (for ASME Codes of Record prior to 1992) or Section II, Part D, Subpart 1, Tables 1A and 1B (for Codes of Record beginning with the 1992 edition). They shall also be listed under P-No. 101 and P-No. 107 in Section IX, QB-422. (For Codes of Record prior to the 1994 Addenda of the 1992 Edition) or QW/QB-422 (For Codes of Record beginning with the 1994 Addenda of the 1992 Edition).

(b) Filler metals shall be in accordance with the ASME Code, Section II, Part C, SFA-5.8, Classification BAg. Fluxes shall be AWS Type FB 3A or FB 3C, SAE Specifications AMS 3410 or 3411, or both.

(c) Fitting and joining of parts to be brazed shall be in accordance with the ASME Code, Section III, NC/ND-4530.

(d) Brazing procedure specifications shall conform to the rules for brazing listed in the ASME Code, Section III, NC/ND-4510, and in Section IX, Articles XI and XIV.

(e) Brazing qualifications shall conform to the ASME Code, Section III, NC/ND-4520, and Section IX, Articles XII and XIII.

(f) For examination of coils, see CA-5240.

CA-6140 MECHANICAL JOINING

(a) Bolts and bolted joints in coil frames designed and fabricated to the requirements of the ASME Code, Section III, Subsection NF, shall be in accordance with NF-3324.6 and NF-4700.

(b) Other coils shall comply with AA-4360.

(c) Mechanical joints for all equipment shall conform to the provisions of AA-6250.

CA-6200 CLEANING, FINISHING, AND COATING

CA-6210 CLEANING AND FINISHING

This subarticle covers the cleaning prior to surface preparation, coating, or painting. Surfaces shall meet the following requirements.

(a) Surfaces shall be free of particle contaminants such as sand, metal chips, weld slag, or weld spatter.

(b) All surfaces to be coated shall be clean and free from oil, grease, soil, dust, or foreign matter before further mechanical or chemical surface preparation.

Solvent cleaning shall be in accordance with the requirements of SSPC-SP1. Halogen based materials or chlorinated degreasers shall not be used for surface preparation.

CA-6220 FINISHING AND SURFACE PREPARATION

(a) Surface preparation of metal surfaces located inside the containment building shall conform to the following requirements.

(1) All welds shall be continuous where feasible, free from sharp projections and spatters, and blended smoothly into the base metal. The surface shall be cleaned in accordance with SSPC-SP10, as appropriate. The abrasive shall be selected to produce an anchor pattern that is compatible with the substrate and the coating system used and acceptable to the coating manufacturer.

(2) All loose foreign material shall be removed. Crevices, gouges, deep pitting, and joints shall be filled, where required, with a suitable material compatible with the substrate and the coating system used.

(3) The primer shall be applied only to dry surfaces and shall be applied before the prepared surface rusts.

(4) Where special circumstances make it impractical to employ blasting, alternative methods of surface preparation may be used, provided the surface preparation is adequate for the coating system and the intended service.

(b) Surface preparation of metal surfaces located outside the containment building shall conform to the following requirements.

(1) All welds shall be continuous, free from spatter and sharp projections, and blended smoothly into the base metal.

(2) The minimum surface preparation shall be commercial blast cleaning as specified in SSPC-SP6 and to a visual degree of cleanness as described in SSPC-Vis 1.

(3) The abrasive shall be selected to produce an anchor pattern that is compatible with the coating system used and acceptable to the coating manufacturer.

(4) Where special circumstances make it impractical to employ blasting, alternative methods of surface preparation may be used, provided the surface preparation is adequate for the coating system and the intended service.

CA-6230 COATING AND APPLICATION

Coating and application shall be in accordance with the following requirements:

(a) Coating material mixing and thinning procedures shall conform to those outlined in SSPC-PA1 and to the recommendations of the coating manufacturer.

(b) Application equipment, its use, and its maintenance shall conform to the requirements of SSPC-PA1 and to the recommendations of the coating manufacturer.

(c) Coating materials and application equipment shall be suitable for the intended purpose and shall be maintained in satisfactory operating condition for the proper coating application.

(d) Application of coating shall conform to the requirements of SSPC-PA1 and to the recommendations of the coating manufacturer.

(e) The dry film thickness of each coat and of the entire coating system shall conform to the requirements of the project specification.

(f) No coating materials shall be applied to the coil heat transfer surfaces unless specifically required by the design specification.

(g) Quality assurance and quality control for coating materials, surface preparation, and coating application, including procedures and personnel qualifications necessary to provide specified documentation and adequate confidence that the coating work will satisfy service conditions, shall conform to the requirements of ASTM D 3843.

ARTICLE CA-7000
PACKAGING, SHIPPING, STORAGE, AND HANDLING

CA-7100 GENERAL REQUIREMENTS

CA-7110 INTRODUCTION

(a) Packaging, shipping, and storage requirements shall be in accordance with Article AA-7000, ASME NQA-1 Requirement 13 and the specific requirements of this article.

(b) When different levels of classification are required for different parts of the equipment, the Manufacturer's procedures shall state how this will be addressed. If the Owner has specific requirements, the design specification shall so state.

CA-7200 PACKAGING

CA-7210 EQUIPMENT REQUIREMENTS

(a) Water, steam, volatile refrigerant coils, air washers, and evaporative coolers shall meet the requirements of Packaging Level C of ASME NQA-1, Subpart 2.2, para. 300.

(b) Electric heating coils, control panels, and terminal boxes shall meet the requirements of Packaging Level B of ASME NQA-1, Subpart 2.2, para. 300.

CA-7300 SHIPPING

CA-7310 EQUIPMENT REQUIREMENTS

(a) Water, steam, and volatile refrigerant coils, air washers, and evaporative coolers shall meet the requirements of Shipping Level C of ASME NQA-1, Subpart 2.2, para. 400.

(b) Electric heating coils, control panels, and terminal boxes shall meet the requirements of Shipping Level B of ASME NQA-1, Subpart 2.2, para. 400.

CA-7400 STORAGE

CA-7410 EQUIPMENT REQUIREMENTS

(a) Water, steam, and volatile refrigerant coils, air washers, and evaporative coolers shall meet the requirements of Storage Level C of ASME NQA-1, Subpart 2.2, para. 600.

(b) Electric heating coils, control panels, and terminal boxes shall meet the requirements of Storage Level B of ASME NQA-1, Subpart 2.2, para. 600.

CA-7500 HANDLING

CA-7510 EQUIPMENT REQUIREMENTS

Handling and rigging requirements shall be in accordance with AA-6610 and the following:

(a) Water, steam, and volatile refrigerant coils, air washers, and evaporative coolers shall meet the requirements of Handling Level C of ASME NQA-1, Subpart 2.2, para. 700.

(b) Electric heating coils, control panels, and terminal boxes shall meet the requirements of Handling Level B of ASME NQA-1, Subpart 2.2, para. 700.

ARTICLE CA-8000
QUALITY ASSURANCE

CA-8100 GENERAL REQUIREMENTS

CA-8110 INTRODUCTION

(a) Quality assurance comprises all those planned and systematic actions required to provide confidence that equipment will perform its required function. This applies to control of both materials and fabricated assemblies, and is applicable to both factory and field fabrication work. Quality control is a part of quality assurance by providing controls on the physical characteristics of components or materials to meet specified requirements.

(b) The organizations responsible for a project shall establish documented quality assurance programs in accordance with the requirements of Article AA-8000. A project includes design, fabrication, assembly, shipping, packaging, and storage; and the various organizations that will be involved in the steps of the project. The quality assurance program shall define the organizational structure within which the program is to be implemented. The program shall delineate the authority and responsibility of the persons and organizations involved in various activities affecting quality. Provision shall be made in the program for review and evaluation of its effectiveness. Correction of deficiencies shall be an integral part of the program.

CA-8120 DOCUMENTATION AND RETENTION

The lifetime and nonpermanent quality assurance records shall be in accordance with Tables CA-8120-1 and CA-8120-2.

(a) Water Coils. For coils designed and fabricated in accordance with the ASME Code, Section III, permanent and nonpermanent records shall be in conformance with ASME NQA-1 as amended by NCA-4134.17, and Tables NCA-4134.17-1 and NCA-4134.17-2. Documentation package requirements shall be as listed in the certified design specification.

(b) Steam and Volatile Refrigerant Coils, Evaporative Coolers, Air Washers, and Electric Heating Coils. For other equipment designed and fabricated in accordance with this Code, the provisions of the design specification shall identify the requirements for classification, retention of records, and facility storage. Such records as identified in Table CA-8120-1 shall be maintained as a minimum.

TABLE CA-8120-1
LIFETIME QUALITY ASSURANCE RECORDS

Record	Water, Steam, and Volatile Refrigerant Coil	Air Washers and Evaporative Coolers	Electric Heating Coils
1. Index to lifetime records	X	X	X
2. Design specification	X	X	X
3. Design calculations and drawings	X	X	X
4. As-built drawings	X	X	X
5. Certified material test reports (CMTR) and documentation providing traceability to location used, if required	X	X	X
6. Structural integrity test reports	X		
7. Final hydrostatic and pneumatic test results	X		
8. Final nondestructive examination reports	X		
9. Repair records when required by this Code	X		
10. Welding and brazing procedures	X	X	X
11. Factory test reports, as required		X	X
12. Environmental report			X

TABLE CA-8120-2
NONPERMANENT QUALITY ASSURANCE RECORDS

Record	Retention Period
1. QA program manual	3 years after superseded or invalidated
2. Design, procurement, and QA procedures	3 years after superseded or invalidated
3. Installation and NDE procedures	10 years after superseded or invalidated
4. Personnel qualification records	3 years after superseded or invalidated
5. Purchase orders	10 years after superseded or invalidated
6. Audit and survey reports	3 years after completion of report
7. Calibration records	Until recalibrated
8. Process sheets, travelers, or checklists	10 years after completion

ARTICLE CA-9000 NAMEPLATES AND RECORDS

CA-9100 GENERAL REQUIREMENTS

CA-9110 INTRODUCTION

Nameplates and stamping requirements shall meet the requirements of Article AA-9000, except as provided in this article.

CA-9200 COILS

CA-9210 GENERAL REQUIREMENTS

Coils that are designed and fabricated in accordance with the ASME Code, Section III, shall meet the requirements of Article NCA-8000 for nameplates, stamping, certification, and data reports.

CA-9300 INFORMATION ON NAMEPLATES

CA-9310 WATER, STEAM, AND VOLATILE REFRIGERANT COILS

In place of AA-9120, a permanent nameplate of noncorrosive metal shall be affixed to water, steam, and volatile refrigerant coils. The nameplate shall bear the following information:

(a) Manufacturer, model number, year manufactured
(b) total capacity, Btu/hr (kW)
(c) type of fluid
(d) fluid flow rate for water and steam coils
(e) item tag number, if furnished by the purchaser
(f) serial number
(g) type of refrigerant for volatile refrigerant coils

CA-9320 ELECTRIC HEATING COILS

(a) In place of AA-9120, electric heating coils shall be affixed with a permanent nameplate of noncorrosive material bearing, as a minimum, the following information:

(1) Manufacturer, model number, year manufactured
(2) capacity, kW
(3) item tag number, if furnished by the purchaser
(4) electrical characteristics, V/Phase/Hz
(5) serial number

(b) Contactor panels that are mounted remote from the heating coils shall be provided with the same nameplate data as the heating coil.

CA-9330 AIR WASHERS AND EVAPORATIVE COOLERS

In place of AA-9120, air washers and evaporative coolers shall be affixed with a permanent nameplate of noncorrosive material bearing, as a minimum, the following information:

(a) Manufacturer, model number, year manufactured
(b) serial number
(c) total capacity, Btu/hr (kW)
(d) airflow rate, standard ft^3/min (m^3/min)
(e) pump flow rate, gal/min (L/sec)
(f) electrical characteristics, V/Phase/Hz

CA-9400 NAMEPLATE LOCATION

CA-9410 VISIBILITY

In some cases, water, steam, and volatile refrigerant coils are installed inside of housings or ductwork. The nameplate will, therefore, not be visible without removal of a panel, or in some cases, removal of the coil from the housing. In these cases, the visibility requirement of AA-9140 does not apply.

CA-9500 DATA REPORTS

CA-9510 WATER AND STEAM COILS

(a) Coils designed, fabricated, and stamped in accordance with the ASME Code, Section III shall have an N-1 Code Data Report completed for each coil.

(b) For coils not stamped in accordance with the ASME Code, Section III, a Manufacturer's data report shall be provided in accordance with Mandatory Appendix CA-I, Form CA-IA.

CA-9520 VOLATILE REFRIGERANT COILS

For volatile refrigerant coils, a Manufacturer's data report shall be provided in accordance with Mandatory Appendix CA-I, Form CA-IB.

MANDATORY APPENDIX CA-I
MANUFACTURER'S DATA REPORTS

FORM CA-IA MANUFACTURER'S DATA REPORT FOR WATER AND STEAM COILS NOT STAMPED IN ACCORDANCE WITH THE ASME CODE, SECTION III

1. Manufactured and certified by ______________________
(Name and address)

2. Manufactured for ______________________
(Name and address of purchaser)

3. Location of installation ______________________
(Name and address)

4. Type ______ (Horiz. or vert.) ______ (Tank, jacketed, heat ex) ______ (Cert. holder's serial no.) ______ (CRN) ______ (Drawing no.) ______ (Nat'l. Bd. no.) ______ (Year built)

Items 5–11 inclusive to be completed for each coil.

5. Design pressure ______ (psi) at max. temp. ______ (°F) Min. pressure test temp. ______ (°F) Pneu., hydro. or comb. test pressure ______ (psi)

6. Header ______ (Mat'l. spec. no.) ______ [Dia. (in.)] ______ [Thickness (in.)] ______ [Type (Pipe or box)]

7. Tubes: ______ (Mat'l. spec. no.) ______ [OD (in.)] ______ [Thickness (inches or gage)] ______ (no.) ______ [Type (Straight or U)]

8. Fins ______ (Mat'l. spec. no.) ______ (Tensile strength) ______ [Nom. thickness (in.)] ______ [Min. design thickness (in.)] ______ [Fin spacing (FPI)]

9. Coil Casing ______ (Mat'l. spec. no.) ______ (Tensile strength) ______ [Nom. thickness (in.)] ______ [Min. design thickness (in.)]

10. Nozzles, inspection and safety valve openings:

Purpose (inlet, outlet, drain, etc.)	Quantity	Dia. or Size	Type	How Attached	Mat'l.	Thickness	Reinforcement Material	Location

11. Remarks: ______________________

FORM CA-IA MANUFACTURER'S DATA REPORT FOR WATER AND STEAM COILS NOT STAMPED IN ACCORDANCE WITH THE ASME CODE, SECTION III (CONT'D)

Mfr. Serial No. ______________

CERTIFICATE OF SHOP COMPLIANCE

We certify that the statements made in this report are correct and that this nuclear vessel conforms to the rules for construction of AG-1.

Date ____________ , Name ______________________________ Signed ______________________________

(Id certificate holder) (representative)

CERTIFICATE OF SHOP INSPECTION

I, the undersigned ______________________________ employed by ______________________________ ______________________ of ______________________ have inspected the component described in this data report on __________________ , and state that to the best of my knowledge and belief, the manufacturer has constructed this component in accordance with AG-1.

Date __________ Signed ______________________________

(inspector)

FORM CA-IB MANUFACTURER'S DATA REPORT FOR VOLATILE REFRIGERANT COILS
(As Required by the Provisions of the ASME Code)

1. Manufactured and certified by ______________________ (Name and address)
2. Manufactured for ______________________ (Name and address of purchaser)
3. Location of installation ______________________ (Name and address)
4. Type ________ (Horiz. or vert.) ________ (Tank, jacketed, heat ex) ________ (Cert. holder's serial no.) ________ (CRN) ________ (Drawing no.) ________ (Nat'l. Bd. no.) ________ (Year built)

Items 5–13 inclusive to be completed for all volatiles refrigerant coils.

5. Headers ________ (Mat'l. spec. no.) ________ (Tensile strength) ________ [Nom. thickness (in.)] ________ [Min. design thickness (in.)] ________ [Dia. ID (ft & in.)]
6. Complete for all bolts used for coil casing to frame attachment:

   If removable, bolts used ________ (Matl. spec. no., size, quantity) Other fastening ________ (Describe or attach sketch)
7. Design pressure ____ (psi) at max. temp. ____ (°F) Min. pressure test temp. ____ (°F) Pneu., hydro. or comb. test pressure ____ (psi)
8. Tube Supports ________ (Stationary, mat'l. spec. no.) ________ [Dia. in. (subject to press.)] ________ [Thickness (in.)] ________ Attachment (welded, bolted)
9. Tubes ________ (Mat'l. spec. no.) ________ [OD (in.)] ________ [Thickness (inches or gage)] ________ (no.) ________ [Type (Straight or U)]
10. Fins ________ (Mat'l spec. no.) ________ (Tensile strength) ________ [Nom. thickness (in.)] ________ [Min. design thickness (in.)] ________ [Fin spacing (FPI)]
11. Coil Casing ________ (Mat'l. spec. no.) ________ (Tensile strength) ________ [Nom. thickness (in.)] ________ [Min. design thickness (in.)]
12. Constructed for max. allowable working pressure ________ psi at max. temp. ________ °F. Min. temp. (when less than −20°F) ________ °F. Hydrostatic, pnuematic, or combination test pressure ________ psi.

FORM CA-IB MANUFACTURER'S DATA REPORT FOR VOLATILE REFRIGERANT COILS (CONT'D)
(As Required by the Provisions of the ASME Code)

Mfr. Serial No. ____________

13. Nozzles

Purpose (inlet, outlet, drain, etc.)	Quantity	Dia. or Size	Type	How Attached	Mat'l.	Thickness	Reinforcement Material	Location

14. Remarks: ____

____

____

____

____

CERTIFICATE OF SHOP COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to AG-1.

Date __________ Signed ______________________ by ______________________
(manufacturer) (representative)

CERTIFICATE OF SHOP INSPECTION

I, the undersigned being a valid inspector employed by ______________________ ______________________ have inspected the component described in this data report on ______________, and state that to the best of my knowledge and belief, the manufacturer has constructed this component in accordance with AG-1.

Date __________ Signed ______________________

MANDATORY APPENDIX CA-II
FACTORY TESTING OF EVAPORATIVE COOLERS AND AIR WASHERS

ARTICLE CA-II-1000 INTRODUCTION

CA-II-1100 PURPOSE

The purpose of this procedure is to ensure the performance of assembled evaporative coolers and air washers with respect to the design specification.

CA-II-1200 SCOPE

This procedure includes the test method and requirements for testing evaporative coolers and air washers.

CA-II-1300 RELATED DOCUMENTS

(a) AMCA 210
(b) ASHRAE 33
(c) ARI 430

ARTICLE CA-II-2000
INSTRUMENTS

CA-II-2100 TEMPERATURE MEASURING INSTRUMENTS

(a) psychrometers (mercury in glass)
(1) sling
(2) motorized
(b) mercury in glass thermometers
(c) thermocouples
(d) electric resistance thermometers
(e) recorder — two-pen-type measuring dry bulb and relative humidity

CA-II-2200 PRESSURE MEASURING INSTRUMENTS

(a) Bourdon tube gage
(b) manometer or draft gage
(c) mercury column or aneroid barometer

CA-II-2300 ELECTRIC INSTRUMENTS

(a) voltmeter
(b) ammeter
(c) wattmeter
(d) analyzer (containing all of the above and power factor)

CA-II-2400 OTHER INSTRUMENTS

(a) strobe light
(b) revolution counter
(c) stopwatch
(d) velometer (vane, propeller, electrical resistance type, or other similar item)
(e) pitot tube
(f) water flow meter or orifice

CA-II-2500 ACCURACY OF INSTRUMENTS

The accuracy of instruments shall be in accordance with ASHRAE 33, Section 4.

ARTICLE CA-II-3000 TEST SETUP

CA-II-3100 GENERAL REQUIREMENTS

The apparatus for the discharge measuring duct shall be assembled in accordance with AMCA 210. In order to follow this procedure, reasonably constant entering conditions, an electric power supply, an airflow measuring duct, a water supply, a means of water temperature measurement, electrical measuring instruments, and pressure measuring instruments shall be provided.

CA-II-3200 INSTRUMENT REQUIREMENTS

(a) A recorder shall be placed in the intake to measure the stability and to record the condition of the incoming air.

(b) Psychrometers shall be provided to measure the entering and leaving conditions of the air washer or evaporative cooler as shown in Fig. CA-II-3300.

(c) A thermometer shall be provided in the discharge of the pump to measure the nozzle supply water temperature.

(d) A thermometer shall be provided in the tank water at the eliminators to determine the temperature differential between the supply and return water.

(e) A pressure gage top shall be provided at the pump discharge to be used in determining pump discharge header.

(f) A pressure gage shall be located on each nozzle bank, as specified by the vendor, to represent the average nozzle head.

(g) A voltmeter shall be employed to measure the pump and fan voltages.

(h) An ammeter shall be employed to measure the pump and fan amperages.

(i) A means for measuring angular velocity for the pump and fan (strobe light, tachometer, stopwatch, and revolution counters) shall be provided.

(j) Average nozzle pressure shall be used to determine the flow from the pump. The vendor shall provide certified pressure and flow curves, by type, to establish the flow.

(k) A manometer and pitot tube shall be provided to measure static and velocity pressure. A draft gage shall be provided to measure pressure drops across the air washer and fan.

CA-II-3300 PREPARATION

(a) A layout of the measuring pattern on entering and leaving faces of the humidifying or spray chamber shall be provided.

(1) The width and height of the faces shall be divided into equal divisions.

(2) A grid of equal areas shall be constructed by connecting opposing division points.

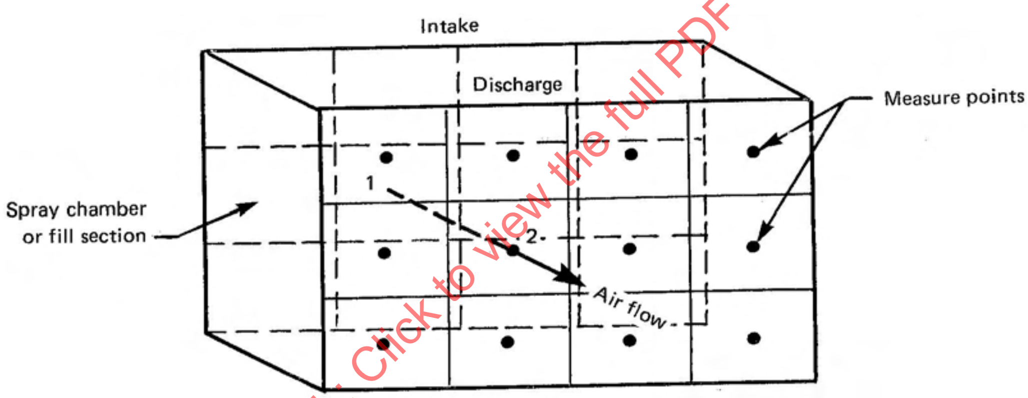
(3) Measurement points shall be in the center of each area. The aspect ratio of the area shall not exceed 1:3.

(4) Measuring points shall be at a minimum of nine locations (see Fig. CA-II-3300).

(b) The pump and fan shall be connected to the electrical supply and jogged to observe that rotation is proper.

(c) Arranagements shall be completed for measuring intake and discharge conditions. Intake and discharge connections shall reasonably stimulate the site configuration, if known.

FIG. CA-II-3300 MEASURING POINTS



ARTICLE CA-II-4000
TESTING

CA-II-4100 TEST PROCEDURE

(a) The airflow through the apparatus shall be established with all equipment running: fan, pump, supply air equipment, and supply water equipment.

(b) The velocity and static pressures shall be measured at the traverse point.

(c) The pressure drop across the air washer and other air path components shall be measured.

(d) Psychrometric data at grid points shall be measured as follows.

(1) Dry bulb and wet bulb readings in the intake and discharge shall be read as quickly as possible at the same corresponding grid point (see Fig. CA-II-3300).

(2) The saturation efficiency shall be calculated from the average of the wet and dry bulb temperatures taken at the grid points.

(e) The velocity at each grid point shall be measured during the air test phase.

(f) The water temperatures at the beginning and at the completion of the grid point readings shall be measured at the locations shown in (1) and (2) below, to establish agreement with the record and to establish stability during readings:

(1) supply at pump discharge

(2) tank at eliminators

(g) The following readings shall be recorded before and after the psychrometric traverse:

(1) pump discharge pressure

(2) standpipe pressure

(3) flow at pump discharge or nozzle pressure

(h) The electrical measurements on the pump shall be recorded as follows:

(1) voltage

(2) amperage

(3) rpm, if accessible

CA-II-4200 ACCEPTANCE

(a) There shall not be any water drops coming from the top and side blanks on the discharge side of the eliminators.

(b) A light beam shall not indicate heavy fog in the airstream at the design wet bulb depression. Fog can be present with high humidity in the intake.

(c) Surfaces and leading edges of equipment in the leaving airstream shall not be wet.

(d) The velocity distribution of the air shall be within ±10% of nominal design air velocity.

(e) Using the apparatus vendor's documented test data, test performance must extrapolate to the design parameters in order to be accepted.

ARTICLE CA-II-5000
TEST REPORTS

CA-II-5100 ITEMS TO BE INCLUDED

The following items are to be included in test reports:

(a) velocity pressures corrected for density, using AMCA 210 calculation, mathematical models, and charts

(b) air quantities calculated from velocities and duct area

(c) pressure drop across the washer

(d) the saturation efficiency from the psychrometric data

(e) pump flow, head, and horsepower, plus all electrical data, such as amperage, voltage, power factor, and wattage

(f) the intake recorder charts marked for each test run

(g) a chart showing distribution at the grid points

(h) acceptance of leaving air conditions such as carryover, leakage, and wetted surfaces

(i) performance of heat transfer

(1) entering and leaving water temperatures

(2) heat load calculations

NONMANDATORY APPENDIX CA-A
DIVISION OF RESPONSIBILITY

This Nonmandatory Appendix is intended to identify the roles normally assumed by the organizations responsible for fulfilling Code requirements when not specifically addressed in an article or subarticle. These are guidelines to assist with Code compliance and are not to be construed as legal or contractual responsibilities unless so invoked by the Owner or designee.

TABLE CA-A-1000
DIVISION OF RESPONSIBILITY

CA-	Item	Responsible Party
3000	Material selection	Owner or designee
3500	Certification of materials	Manufacturer
4100	Design conditions for coils	Owner or designee
4121	Code stamping Code class	Manufacturer Owner or designee
4124	Nozzle loading conditions	Owner or designee
4125	Fin spacing	Owner or designee
4130	Coil design verification report	Manufacturer
4200	Design conditions for volatile refrigerant coils	Owner or designee
4222	Tube design pressure	Owner or designee
4300	Design conditions for air washers and evaporative coolers	Owner or designee
4321	Air washer and evaporative cooler design verification report	Manufacturer
4322	Access doors	Owner or designee
4323	Air velocity and pressure drop	Owner or designee
4324	Fill media	Manufacturer
4326	Cleanout provisions	Owner or designee
4328	Electrical wiring	Manufacturer
4400	Design conditions for electric heating coils	Owner or designee
4421	Electric heating coil design verification report	Manufacturer
4422	Element design	Owner or designee
4423	Frame design	Owner or designee
4426	Terminal box enclosure	Owner or designee

TABLE CA-A-1000
DIVISION OF RESPONSIBILITY (CONT'D)

CA-	Item	Responsible Party
4427	IEEE qualification	Manufacturer
4428	Controller type	Owner or designee
4429	Remote control panel enclosure requirements	Owner or designee
5210	Coil performance verification method	Owner or designee
5211	Performance verification for coils	Manufacturer
5230	Coil pressure tests required	Owner or designee
5240	Nondestructive examination	Owner or designee
5300	Performance test report for air washers and evaporative coolers	Manufacturer
5400	Electric heating coil tests required	Owner or designee
5450	Nondestructive testing report	Manufacturer
5500	Test report	Manufacturer
6100	Welding, brazing, coating, and installation procedures	Manufacturer
7100	Equipment classifications	Owner or designee
8000	Quality assurance program	Manufacturer
8120	Documentation requirements	Owner or designee
9000	Nameplate	Manufacturer

NONMANDATORY APPENDIX CA-B
DESIGN RECOMMENDATIONS

ARTICLE CA-B-1000
RECOMMENDED DESIGN CRITERIA FOR AIR WASHERS AND EVAPORATIVE COOLERS

CA-B-1100 INTRODUCTION

CA-B-1110 SCOPE

The system design parameters, features, or specifications given in this article are recommended for use in air washers or evaporative cooler design.

CA-B-1200 GENERAL

CA-B-1210 RECOMMENDATIONS

(a) Standard velocity eliminators, which are formed by flat, broken, parallel sheets of material, shall be applied at nominal mean velocities through the face of the eliminator area from 300 ft/min to a maximum of 600 ft/min.

(b) High velocity eliminators, which are formed by parallel sheets of nonflat material, shall be applied at nominal face velocities from 600 ft/min to 1,500 ft/min.

(c) Maximum face velocity for fill-type evaporative coolers is 500 ft/min.

(d) Eliminators are to be contained in a holding case that permits cleaning maintenance without disassembly of the entire eliminator module or section.

(e) Location of spray banks relative to an eliminator face and to each other is to be in accordance with the minimum dimensions shown in Fig. CA-B-1210 and Table CA-B-1210.

(f) Nominal water spray density will be 8 gal/min to 10 gal/min per 1,000 ft^3/min of air capacity for air washers that are equipped with standard velocity eliminators.

(g) Nominal water spray density for air washers equipped with high velocity eliminators will be 6 gal/min to 10 gal/min per 1,000 ft^3/min of air capacity.

(h) Nominal water supply density for fill-type evaporative coolers will be in accordance with the Manufacturer's recommendations for design conditions.

(i) Drainage channels or gutters are to be located above and beside the air entrance opening to the eliminator section on air washers that are equipped with high velocity eliminators.

(j) A water surface dam that extends approximately 2 in. above and below the water surface and across the entrance to the eliminator section should be used on air washers that are equipped with high velocity eliminators.

(k) Air washers are to be equipped with discharge blanks or scum covers on the air exhaust side of the eliminator section.

(l) Balancing cocks or valves are to be used to obtain the desired flow distribution between or among spray banks.

(m) Tank drains and floor drains are to be located lower in elevation than the lowest points in the tank and floor.

(n) An overflow drain is to be used in the air washer tank.

(o) All areas of an air washer spray chamber should be accessible without disturbing major components, piping, or other similar items.

(p) The exhaust plenum of a draw-through air washer is to be of sufficient size to permit the placement of

the fan inlet $1\frac{1}{2}$ fan wheel diameters from the discharge surface of the eliminator.

(q) The header for each spray bank is to be equipped with a pressure gage.

(r) The piping for each circulation pump is to be equipped with pressure gages to reflect total pump head.

(s) The operating level of the water will be controlled by a float valve on the makeup water line. A weir or an overflow pipe will be provided in the tank to provide ample drainage capacity in the event of valve, float, or piping failure.

(t) Structural bracing for standpipes will be located out of the water spray pattern.

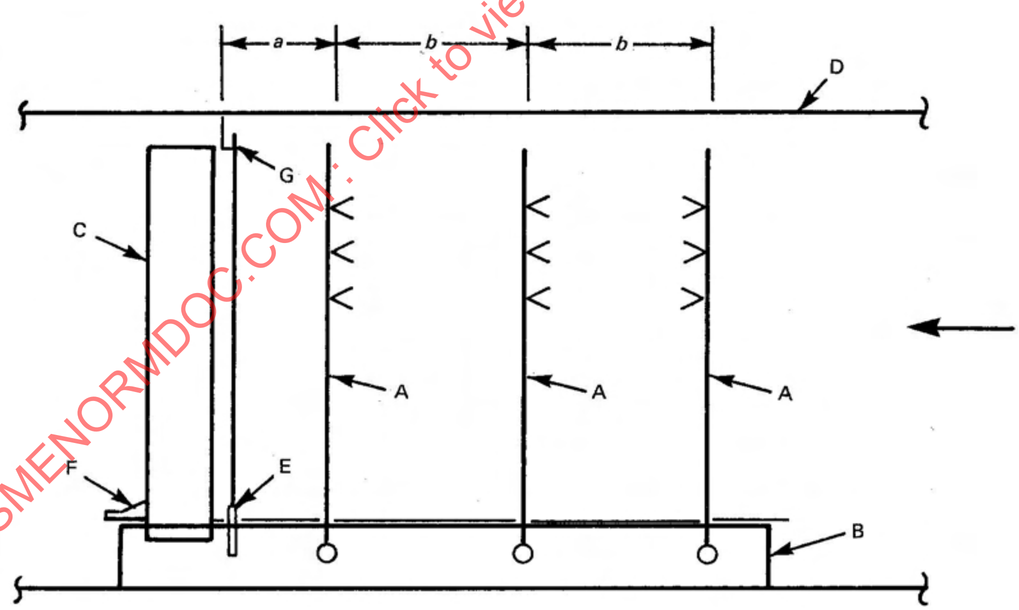
(u) Spray nozzles will be supplied with pressure volume flow curves.

TABLE CA-B-1210

Height of Eliminator Section, in.	Standard Velocity		High Velocity	
	a, Min. [Note (1)]	*b*, Min. [Note (1)]	*a*, Min. [Note (1)]	*b*, Min. [Note (1)]
40	12	36	42	18
60	12	36	56	18
80	12	36	65	18
100	12	36	80	18

NOTE:
(1) Dimensions are shown in Fig. CA-B-1210.

FIG. CA-B-1210 SIDE ELEVATION OF AIR WASHER SPRAY CHAMBER (High Velocity Illustrated)



A = Standpipes
B = Tank
C = Eliminator section
D = Ceiling
E = Surface dam
F = Discharge blank
G = Drainage channels

ARTICLE CA-B-2000
RECOMMENDED DESIGN CRITERIA FOR WATER, STEAM, AND VOLATILE REFRIGERANT COILS

CA-B-2100 INTRODUCTION

CA-B-2110 SCOPE

The system design parameters, features, or specifications given in this article are recommended for water, steam, and volatile refrigerant coils.

CA-B-2200 GENERAL

CA-B-2210 RECOMMENDATIONS

(a) A water analysis should be provided to the coil Manufacturer when nondemineralized water is used for heating or cooling.

(b) Air-side velocity for cooling coils should not exceed 500 ft/min (2.54 m/s).

(c) Air-side velocity for heating coils should not exceed 800 ft/min (4.06 m/s).

(d) Tube wall thickness for water and steam coils should not be less than 0.035 in. (0.90 mm).

(e) Unsupported tube lengths should not exceed 4 ft (1.22 m).

(f) A corrosion allowance of $^1/_{16}$ in. (1.6 mm) should be required for steel tube headers of water and steam coils.

(g) Fin spacing should not exceed 10 fins per inch (mm) of tube length.

SECTION FA
MOISTURE SEPARATORS

Figure

Table

Nonmandatory Appendix

ARTICLE FA-1000 INTRODUCTION

(09)

FA-1100 SCOPE

This section of the section provides requirements for the performance, design, construction, acceptance testing, and quality assurance for moisture separators used in nuclear air treatment systems.

FA-1110 PURPOSE

The purpose of this seciton is to assure that moisture separators used in nuclear applications are acceptable in all aspects of performance, design, construction, acceptance, and testing.

FA-1120 APPLICABILITY

FA-1121 Moisture Separators

This section applies to modular, impingement-type liquid droplet separators in liquid water entrained air streams, which typically employ layers of fibers, layers of mesh, or alternating layers of each.

This section does not cover high efficiency mist eliminators (HEME), which operate on the principle of Brownian diffusion, or wave-plate (louver) liquid droplet separators, which operate on the principle of inertial separation.

FA-1122 Limitations

This section does not cover the integration of moisture separators into a complete air cleaning system.

FA-1130 DEFINITIONS AND TERMS

The following terms have special meaning in the context of this section:

case: structure used to contain and support a pad.

moisture separator: a modular unit consisting of a deep-bed fibrous pad enclosed in a case, used to remove entrained liquid droplets from an air stream.

pad: a porous structure composed of one or more layers of randomly oriented packed fiber beds of graded density glass, metal, and/or corrosion resistant stainless steel.

penetration: concentration of entrained liquid droplets exiting from a moisture separator expressed as percentage of inlet concentration.

Also, see subarticle AA-1130.

(09)

ARTICLE FA-2000
REFERENCED DOCUMENTS

Common application documents referenced in this Code section are detailed in Article AA-2000. Where ASTM materials are specified, the equivalent ASME material specification may be substituted. Unless otherwise shown, the latest edition and addenda are applicable.

ASTM A 240/A 240M-04, Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

ASTM A 380-99, Standard Practice for Cleaning, Descaling and Passivation of Stainless Steel Parts, Equipment, and Systems

ASTM A 581/A 581M-95b, Standard Specification for Free Machining Stainless Steel Wire and Wire Rods

ASTM D 1056-00, Standard Specification for Flexible Cellular Materials—Sponge or Expanded Rubber

Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

UL 900, Standard for Safety for Air Filter Units

Publisher: Underwriters Laboratories, Inc. (UL), 333 Pfingsten Road, Northbrook, IL 60062-2096

ARTICLE FA-3000 MATERIALS

(09)

FA-3100 ALLOWABLE MATERIALS

FA-3110 PADS

The pad shall be constructed of glass fiber and/or corrosion resistant (stainless steel) wire.

FA-3120 FILTER CASES, CROSS GRIDS, AND SUPPORTS

Filter cases, cross grids, and supports shall be ASTM A 240 Type 304, stainless steel.

FA-3130 RIVETS

Rivets shall be 300 series austenitic steel meeting the minimum requirements of ASTM A 581, Type 303.

FA-3140 GASKETS

Gaskets shall be closed cell silicone rubber sponge, Grade 2C3 or 2C4, in accordance with ASTM D 1056.

FA-3150 ADHESIVE

Adhesive used to splice gaskets or to fasten the gasket to the case shall be compatible with the gasket material and appropriate to the intended application.

FA-3200 LIMITATIONS

Alternative materials are acceptable only if they meet the requirements of Article FA-4000, Class 1 filter requirements of UL 900, and pass the qualification test of FA-5100.

FA-3300 MATERIAL CERTIFICATION

The Manufacturer shall supply a certificate of conformance to the purchaser that all materials used in fabrication of the moisture separator conform to Article FA-3000.

(09)

ARTICLE FA-4000
DESIGN

Design conditions for moisture separators include mixtures of air and condensing steam having air relative humidities of up to 100%, operating temperatures of up to 285°F (141°C), and a total integrated radiation environment of 8×10^7 rads, unless otherwise specified in the Design Specifications.

FA-4100 GENERAL DESIGN

Moisture separators shall consist of cases designed to retain the deep bed fibrous pads. The pad shall be held in place in the case by a retaining grid(s) or mechanism. Cases shall be designed to include drain holes to prevent re-entrainment of trapped liquids. Seals shall be provided as necessary to meet the requirements of Table FA-4200-1. Refer to Fig. FA-4100-1 for a typical configuration.

FA-4200 TECHNICAL REQUIREMENTS

FA-4210 DESIGN REQUIREMENTS

The moisture separator shall meet the requirements given in Table FA-4200-1.

FA-4220 MOISTURE SEPARATOR ASSEMBLY

The case shall be formed and assembled in a manner to meet the requirements of Table FA-4200-1. Drain holes shall be provided in the bottom of the case. The design shall include provisions to ensure that the pad is maintained in its operating position and that the pad does not settle, pack down, or pull away from the case when installed.

FA-4300 STRUCTURAL REQUIREMENTS

FA-4310 GENERAL

The moisture separators shall be designed in accordance with the structural requirements given in Article AA-4000 or qualified by test in accordance with subarticle AA-4350.

FA-4320 LOAD DEFINITION

Loads to be considered in the structural design of the moisture separator are defined in subarticle AA-4211.

FA-4330 LOAD COMBINATIONS

Load combinations for Service Levels A, B, and C, applicable to moisture separators, are defined in Table AA-4212.

FA-4340 ACCEPTANCE CRITERIA

The acceptance criteria are listed in Table AA-4321. The design stress allowable values, S, shall be $0.6S_y$.

FIG. FA-4100-1 TYPICAL MOISTURE SEPARATION CONFIGURATION

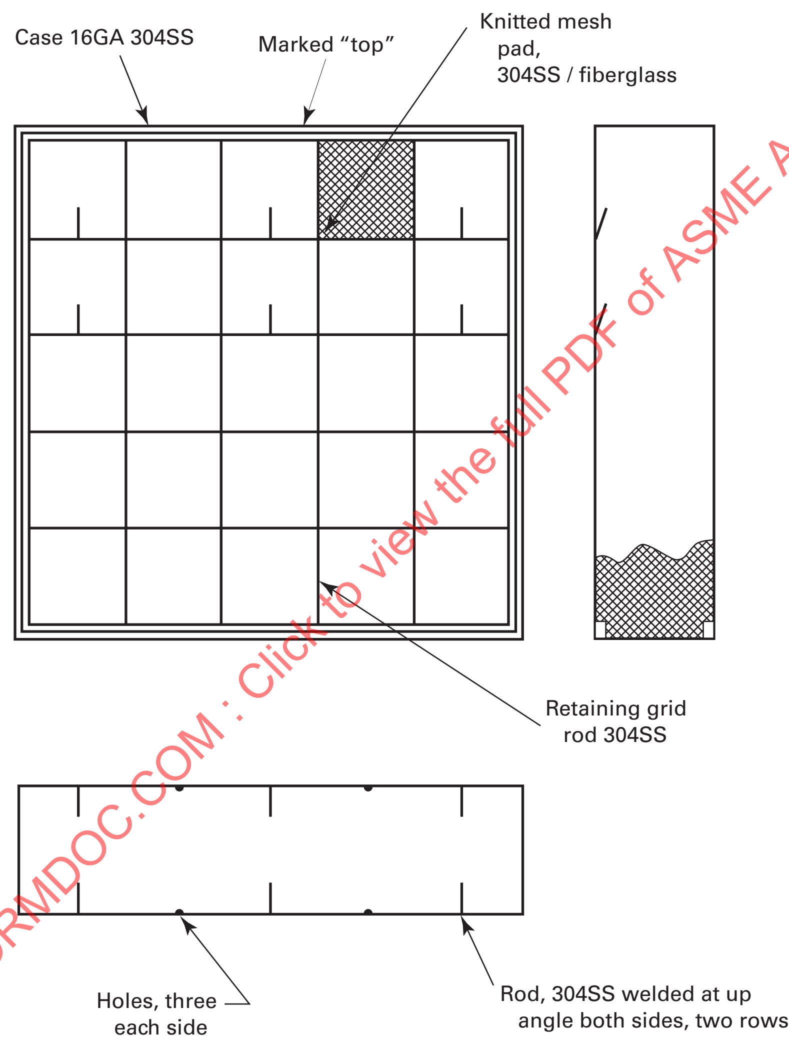


TABLE FA-4200-1
MOISTURE SEPARATOR PERFORMANCE SPECIFICATIONS

Requirement	Value
Air flow rating	
Rated flow shall be within the range of flows at which the separator has been shown to meet the required moisture removal efficiencies (*see below*).	. . .
Pressure drop ratings (at rated flow)	
Maximum pressure drop (clean, dry)	1.0 in. WC (250 Pa)
Maximum pressure drop at rated moisture removal capacity (clean, wet)	2.0 in. WC (500 Pa)
Minimum burst pressure (Clean, Wet)	20.0 in. WC (5 000 Pa)
Moisture removal capacity (Liquid Water in Stream of Air)	2.0 lb H_2O per min per 1,000 CFM (0.9 kg H_2O per minute per 1 700 m^3/hr)
Moisture removal efficiencies (At Rated Flow and Removal Capacity)	
Removal efficiency of entrained water	99% by mass (min.)
Removal efficiency of droplets having diameters of 5 μm to 10 μm	99% by count (min.)

ARTICLE FA-5000 INSPECTION AND TESTING (09)

Inspection and testing of the moisture separator shall conform to the requirements of this section and to specific requirements set forth in article AA-5000.

FA-5100 QUALIFICATION TESTS

New or revised moisture separator designs shall require qualification testing prior to acceptance and production. A design qualification test shall be performed on each specific moisture separator design. Four units of each design shall be tested to all requirements of Article FA-5000. Tests shall be performed and certified by an independent test facility.

FA-5110 MOISTURE SEPARATOR ROUGH HANDLING QUALIFICATIONS

In its service orientation, each of the four moisture separators shall be hard-mounted to a rough-handling machine equipped with sharp cutoff cams, and vibrated individually for 10 min at a frequency of 200 cycles per minute at an amplitude of 0.75 in. (19 mm). As determined by visual inspection, there shall be no settling of the mesh pad, no broken welds or other physical damage as a result of the rough handling.

FA-5120 MOISTURE SEPARATOR AIR FLOW RESISTANCE TEST

After the rough-handling test of FA-5110, each of the four moisture separators shall be individually mounted in its service orientation within a test tunnel, and operated at its rated airflow. The pressure differential across the separator shall not exceed the ratings in Table FA-4200-1 for the clean, dry condition and the clean, wet condition. The separator shall also demonstrate that it can withstand the minimum burst pressure differential given in Table FA-4200-1 without any visible physical damage or change in pressure drop (clean, wet) at rated flow.

FA-5130 MOISTURE SEPARATOR PERFORMANCE TEST

After successfully meeting the requirements of FA-5120, the four separators subjected to the rough-handling test shall be tested to demonstrate compliance with the moisture removal and efficiency requirements of Table FA-4200-1.

FA-5200 PRODUCTION INSPECTION AND TESTING

Each moisture separator to be delivered to the purchaser shall be inspected and tested in accordance wtih section FA-5200.

FA-5210 DIMENSIONAL INSPECTION

Overall dimensions shall be inspected to determine conformity to drawing requirements. Each moisture separator shall be inspected to ensure that it conforms to all dimensional requirements of its design. Any components that will be ‘‘hidden’’ in the final assembly shall be inspected prior to assembly. Location and placement of stiffeners and supports shall be inspected to determine conformance to drawing requirements.

FA-5220 WELDING INSPECTION

FA-5221 Spot Welds

Spot welds shall be inspected visually in accordance with subarticle AA-6332.

FA-5222 Seam (Seal) Welds

Seal welds shall be inspected visually in accordance with subarticle AA-6331.

FA-5223 Fillet Welds

Fillet welds shall be inspected visually in accordance with subarticle AA-6331.

FA-5230 MOISTURE SEPARATOR AIR FLOW RESISTANCE TEST

With the moisture separator oriented in its service orientation within a test tunnel and operating at its rated airflow, the pressure differential across the separator shall not exceed the maximum pressure drop in Table FA-4200-1 for the clean, dry condition.

ARTICLE FA-6000 FABRICATION (09)

The general requirements for fabrication are contained in subarticles AA-6200 and AA-6300.

FA-6100 REPAIRS

All welds shall be repaired in accordance with AA-6300. Damaged materials shall be replaced.

FA-6200 CLEANING

Metal parts of the moisture separator shall be cleaned and degreased in accordance with ASTM A 380 before any welding.

FA-6300 TOLERANCES

FC-6310 Flatness and Squareness

The faces of the case shall be flat and parallel within $^5/_8$ in. (16 mm). The case shall be square within $^1/_8$ in. (3 mm) when measured diagonally across the corners of both faces.

FC-6320 Overall Dimensions

Moisture separators 24 in. × 24 in. × 5 $^1/_2$ in. (600 mm × 600 mm × 140 mm) and larger shall be of +0 in., $^1/_8$ in. (+0 mm, −3 mm) outside dimensions. All moisture separators smaller than the above shall be of +0 in., −$^1/_{16}$ in., – (+0 mm, −1.5 mm) outside dimensions. The above dimensions exclude gaskets.

(09)

ARTICLE FA-7000
PACKAGING, SHIPPING, AND STORAGE

Packaging, shipping, and storage shall be in accordance with Article AA-7000 and ASME NQA-1 Level B. Moisture separators shall be individually packed. Shipping cartons shall have extra shock absorbing material at the corners of the moisture separator.

The carton shall be clearly marked for proper service orientation per FA-9200. Stacking of moisture separators during storage and handling shall not be more than three high.

ARTICLE FA-8000 QUALITY ASSURANCE (09)

The moisture separator manufacturer shall establish and comply with a quality assurance program and quality assurance plan in accordance with Article AA-8000.

FA-8100 RESPONSIBILITY

The Manufacturer shall provide all specified information required by this Code section to the Owner or designee. The Manufacturer shall perform and document the results of all detailed examinations and tests required by this Code section.

FA-8200 DOCUMENTATION

The documentation shall include, but is not limited to, the following:

(a) results of detailed examinations and tests in FA-8100, if required by the purchasing documents

(b) copies of all moisture separator case material certification, if required by the purchasing documents

(c) drawing(s) giving outline and interface dimensions of the separator

(d) installation and maintenance instructions

(e) storage and handling instructions

FA-8300 CERTIFICATE OF CONFORMANCE

The Certificate of Conformance shall state that the moisture separator conforms to AG-1, Section FA.

(09)

ARTICLE FA-9000 NAMEPLATES

FA-9100 MOISTURE SEPARATOR MARKING

Each separator shall have a nameplate permanently attached to the top or side of the case with the following information:

(a) moisture separator
(b) manufacturer's name or symbol
(c) weight of separator
(d) pressure drop across the separator (clean) at airflow velocity specified
(e) serial number (each separator shall be identified by a nonrecurring alpha-numeric symbol, which shall also identify all documentation for the separator)
(f) direction of airflow
(g) mounting orientation
(h) UL label indicating successful testing per UL 900
(i) date of manufacture

FA-9200 PACKAGE MARKING

Marking or labeling of each shipping container (carton containing one moisture separator) shall be no less than $\frac{3}{8}$ in. (10 mm) in size. As a minimum, the following information shall be provided:

(a) manufacturer's name and symbol
(b) arrows and "THIS SIDE UP" indicating service orientation for shipping and storage and "FRAGILE"
(c) moisture separator model number
(d) purchase order number or other identifying mark requested by Purchaser

NONMANDATORY APPENDIX FA-A (09)
DIVISION OF RESPONSIBILITY

This Nonmandatory Appendix is intended to identify the roles normally assumed by the organizations responsible for fulfilling Code requirements when not specifically addressed in an article or subarticle. These are guidelines to assist with Code compliance and are not to be construed as legal or contractual responsibilities unless so invoked by the Owner or designee.

TABLE FA-A-1000
DIVISION OF RESPONSIBILITY

FA-	Item	Responsible Party
3000	Materials	Engineer/Manufacturer
4000	Design	Engineer/Manufacturer
5000	Inspection and testing	Engineer/Manufacturer
6000	Fabrication	Manufacturer
7000	Packaging, shipping, and storage	Manufacturer/Owner
8000	Quality assurance	Manufacturer
9000	Nameplates	Manufacturer

SECTION FB
MEDIUM EFFICIENCY FILTERS

Nonmandatory Appendix

ARTICLE FB-1000
INTRODUCTION

FB-1100 SCOPE

This section of the Code provides minimum requirements for the performance, design, construction, acceptance testing, and quality assurance for medium efficiency filters used in air and gas treatment systems in nuclear facilities.

FB-1110 PURPOSE

The purpose of this Code section is to ensure that medium efficiency filters used in nuclear facilities are acceptable in all aspects of performance, design, and construction.

FB-1120 APPLICABILITY

This section shall be applied to the use of medium efficiency filters installed in nuclear facilities. The normal function of these filters is to reduce the particulate loading to HEPA filters. This Section applies to extended-media, dry-type filters with an average atmospheric dust spot efficiency, per ASHRAE 52.1, greater than 40% but less than 99%.

FB-1121 Limitations

This section does not cover the following:

(a) system design requirements for the use of filters
(b) mounting frames for the medium efficiency filters

FB-1122 Responsibility

Appendix FB-A contains division of responsibility guidelines.

FB-1130 DEFINITIONS AND TERMS

Definitions with common application are contained in Section AA of this Code. The following terms have special meaning in the context of this section.

filter frame: a structure that encloses the edges of the filter media (or filter pack) and provides a filter mounting surface.

filter media: part of the filter designed to remove particulate matter from the air or gas stream.

lot: the quantity of filters produced using the same processes, facilities, equipment, and materials from which the representative units used for inspection and testing are selected.

sealants: materials used for the following purposes:

(a) to hold the media in position in the filter frame
(b) to attach gaskets
(c) to splice media

separator: device used to support and position folds in the filter media to provide air passage.

ARTICLE FB-2000
REFERENCED DOCUMENTS

Common application documents referenced in this Code section are detailed in Article AA-2000. Where ASTM material specifications are specified, the equivalent ASME material specification may be substituted. Where the date is not cited, the latest revision shall be used.

ANSI/ASHRAE 52.1-1992, Gravimetric and Dust Spot Procedures for Testing Air Cleaning Devices Used in General Ventilation for Removing Particulate Matter[1]

Publisher: American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329

[1] May also be obtained from the American National Standards Institute (ANSI), 25 West 43rd Street, New York, NY 10036.

ANSI/ASQ Z1.4-2003, Sampling Procedures and Tables for Inspection by Attributes[1]

Publisher: American Society for Quality (ASQ), P.O. Box 3005, Milwaukee, WI 53201-3005

ASTM D 1056-91, Specification for Flexible Cellular Materials — Sponge or Expanded Rubber

Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

UL 900-94, Standard for Air Filters Units

Publisher: Underwriters Laboratories, Inc. (UL), 333 Pfingsten Road, Northbrook, IL 60062-2096

ARTICLE FB-3000
MATERIALS

FB-3100 ALLOWABLE MATERIALS

FB-3110 MEDIA

The filter media shall be glass fiber based, containing a binder to retain the fibers, with both fiber and binder suitable for the environment as specified in accordance with Article FB-4000.

FB-3120 FILTER FRAME

The filter frames shall consist of corrosion-resistant material suitable for the environment as specified in accordance with Article FB-4000.

FB-3130 SEPARATORS

The separators shall consist of corrosion-resistant material suitable for the environment as specified in accordance with Article FB-4000.

FB-3140 SEALANTS AND ADHESIVES

Sealants and adhesives shall be suitable for the environment as specified in Article FB-4000 and shall qualify as self-extinguishing in accordance with UL 900, Class 1 requirements.

FB-3150 GASKETS

Gasket material shall be oil-resistant, expanded cellular elastomer, that conforms with the requirements of ASTM D 1056, Grade 2C3 or 2C4.

FB-3200 SPECIAL LIMITATIONS OF MATERIALS

A consideration of material deterioration caused by service conditions is outside the scope of this Code. It is the responsibility of the Owner, or Owner's designee, to identify the environment in which the filter must operate and to take appropriate precautions.

ARTICLE FB-4000
DESIGN

FB-4100 GENERAL DESIGN

Medium efficiency filters shall be replaceable, extended media, dry-type, and certified to UL 900, Class 1.

FB-4200 DESIGN CRITERIA

A design criteria shall be prepared by the Owner or his designee in sufficient detail to provide a complete basis for medium efficiency design in accordance with this Code. As a minimum, design criteria shall be specified for the following parameters:

(a) type of gas to be treated

(b) rated flow, nominal, cfm (m^3/hr), per ANSI/ASHRAE 52.1

(c) design pressure, in. wg (Pa)

(d) temperature operating range, °F (°C)

(e) relative humidity operating range, %RH

(f) containments to be removed, lb/scfm/hr (kg/sm^3/hr)

(g) average atmospheric dust spot efficiency as measured by ANSI/ASHRAE 52.1

(h) initial resistance, in. wg (Pa), at rated flow per ANSI/ASHRAE 52.1

(i) rated final resistance, in. wg (Pa), at rated flow per ANSI/ASHRAE 52.1

(j) dust holding capacity, lb (kg), per ANSI/ASHRAE 52.1

(k) medium efficiency filter frame dimensions, in. (mm), (height × width × depth)

FB-4300 STRUCTURAL REQUIREMENTS

See seismic requirements in FB-5240 and FB-5241.

ARTICLE FB-5000
INSPECTION AND TESTING

The inspection and testing of medium efficiency filters shall conform to the requirements of Article AA-5000 and the specific requirements of this Article.

FB-5100 INSPECTION PLAN

FB-5110 PLAN

The Manufacturer shall establish a sampling and inspection plan in accordance with ANSI/ASQ Z1.4 or by another method acceptable to the purchaser.

FB-5120 MINIMUM INSPECTION REQUIREMENTS

The Manufacturer's Quality Assurance Program shall contain measures to ensure that filters packaged for shipment have been inspected in accordance with the following criteria:

(a) inspection of the filter media for splits, tears, or holes

(b) inspection of the connection between the filter media and the filter frame for splits, tears, or holes

(c) inspection for missing or incorrect parts or components

(d) inspection for incorrect fit of parts or components

(e) inspection for workmanship

(f) inspection for cleanliness and appearance

(g) inspection for correct identification on the filter nameplate and carton

FB-5130 REJECTION AND REINSPECTION

An inspection shall be performed on the filter lot. If a lot is rejected, it may be resubmitted for inspection. Following 100% inspection of the rejected lot and repair or removal of all defective units, the lot will be accepted.

FB-5200 QUALIFICATION TESTING

New or revised filter designs shall require qualification testing prior to acceptance and production.

FB-5210 TESTING REQUIREMENTS

To obtain standard ratings three medium efficiency filters of the design to be qualified shall be tested and test results shall be provided in accordance with ANSI/ASHRAE 52.1. The rated performance may be obtained by averaging the results of the tests on the three filters. The rated performance shall be established at airflow rate(s) selected by the Manufacturer for initial resistance, initial atmospheric dust spot efficiency, average atmospheric dust spot efficiency, average synthetic dust weight arrestance, and dust holding capacity. The various parameters at which the filters are rated are defined in ANSI/ASHRAE 52.1.

FB-5220 CERTIFICATION

Medium efficiency filters shall be certified to conform to UL 900, Class 1.

FB-5230 REQUALIFICATION

The filter design must be requalified whenever there is a change in design, material, or manufacturing methods.

FB-5240 SEISMIC QUALIFICATION

Each design of medium efficiency filter shall be qualified by testing in accordance with AA-4350. At least one unit of each design shall be tested.

FB-5241 Acceptance Criteria

The medium efficiency filter shall be visually inspected after testing and shall show no structural damage.

ARTICLE FB-6000
FABRICATION

FB-6100 GENERAL

The medium efficiency filter shall be assembled from materials that conform to Article FB-3000 and meet the design requirements of Article FB-4000. Following assembly, the filter shall be inspected and tested in accordance with the requirements of Article FB-5000.

FB-6200 MANUFACTURE AND ASSEMBLY

The general requirements for fabrication and installation are contained in AA-6200 and AA-6300.

FB-6210 FLATNESS AND SQUARENESS

The faces of the case shall be flat and parallel to within a total allowance of $^1/_{16}$ in. (1.6 mm). The case shall be square to within a total allowance of $^1/_8$ in. (3 mm) when measured diagonally across the corners of both faces.

FB-6220 OVERALL DIMENSIONS

Filters the size of 24 × 24 × 5$^1/_8$ in. (610 × 610 × 149 mm) and larger shall be +0, −$^1/_8$ in. (+0, −3 mm) outside dimensions, except depth, which shall be +$^1/_{16}$, −0 in. (+1.6, −0 mm). All filters smaller than the above shall be +0, −$^1/_{16}$ in. (+0, −1.6 mm) outside dimensions except depth, which shall be +$^1/_{16}$, −0 in. (+1.6, −0 mm). The above dimensions exclude gaskets.

ARTICLE FB-7000
PACKAGING, SHIPPING, RECEIVING, STORAGE, AND HANDLING

FB-7100 GENERAL

Medium efficiency filters shall be placed in protective cartons with pleats arranged vertically. All packaging, shipping, receiving, storage, and handling shall meet the requirements of Article AA-7000 and ASME NQA-1.

ARTICLE FB-8000
QUALITY ASSURANCE

FB-8100 GENERAL

Quality assurance shall be in accordance with AA-8000 of this Code. The manufacturer of this equipment shall develop and maintain a QA program acceptable to the Owner.

FB-8200 DOCUMENTATION

The following documentation shall be made available to the Purchaser, if requested:

(a) a table or drawing giving outline dimensions of the filter

(b) a list of the materials of construction with appropriate specifications

(c) a copy of the qualification test results performed in accordance with FB-5200

(d) Certificate of Conformance to this Code and purchase specifications

ARTICLE FB-9000
LABELS AND MARKING

FB-9100 FILTER MARKINGS

Each filter shall be equipped with a permanent label. The marking on the label shall be legible and shall provide the following information:

(a) Manufacturer's name and location

(b) Manufacturer's designation and part number

(c) date of manufacture (month and year)

(d) rated flow capacity, cfm (m^3/hr)

(e) rated initial pressure drop in inches of water gage (Pa)

(f) recommended maximum pressure drop in inches of water gage (Pa)

(g) rated atmospheric dust spot efficiency

(h) airflow direction arrow (showing both directions if allowable without impacting published ratings)

(i) installation orientation (e.g., "Install This Way Up" or "Install With This Side Vertical")

(j) UL label

(k) temperature operating range, °F (°C)

FB-9200 PACKAGE MARKING

Marking or labeling of each shipping container (carton containing one filter) shall be of a size and type that can be read at a distance of 3 ft (0.9 mm). The following information shall be provided:

(a) Manufacturer's name

(b) Manufacturer's designation and part number

(c) arrows and ''This Side Up'' indication orientation for shipping and storage and "Fragile" in letters no less than ¾ in. (19 mm) high

(d) purchase order number or other identifying markings requested by the Purchaser

NONMANDATORY APPENDIX FB-A
DIVISION OF RESPONSIBILITY

This Nonmandatory Appendix is intended to identify the roles normally assumed by the organizations responsible for fulfilling Code requirements when not specifically addressed in an article or subarticle. These are guidelines to assist with Code compliance and are not to be construed as legal or contractual responsibilities unless so invoked by the Owner or designee.

TABLE FB-A-1000
DIVISION OF RESPONSIBILITY

FB-	Item	Responsible Party
3000	Materials	Manufacturer/Owner
4000	General design	Manufacturer
5000	Inspection and testing	Manufacturer
6000	Fabrication	Manufacturer
7000	Packaging, shipping, receiving, storage, and handling	Manufacturer/Owner
8000	Quality assurance	Manufacturer
9000	Labels and marking	Manufacturer

SECTION FC
HEPA FILTERS

Figures

Tables

Mandatory Appendix

Nonmandatory Appendix

(09)

ARTICLE FC-1000 INTRODUCTION

FC-1100 SCOPE

This section of the Section provides requirements for the performance, design, construction, acceptance testing, and quality assurance for high efficiency particulate air (HEPA) filters used in nuclear air or gas treatment systems.

FC-1110 PURPOSE

The purpose of this section is to ensure that HEPA filters used in nuclear applications are acceptable in all aspects of performance, design, construction, acceptance, and testing.

FC-1120 APPLICABILITY

FC-1121 HEPA Filters

This section applies to extended media dry-type filters for use in air and gas streams operating at no more than 250°F (120°C) maximum continuous temperature and with the size and ratings included in Table FC-4110.

FC-1122 Limitations

This section does not cover

(a) filter mounting frames

(b) integration of HEPA filters into air cleaning systems

(c) HEPA filters larger than 24 in. × 24 in. × 11½ in. (610 mm × 610 mm × 290 mm) case dimensions

(d) filters not listed in Table FC-4110

FC-1130 DEFINITIONS AND TERMS

filter: a device having a porous or fibrous media for removing suspended particles from air or gas.

HEPA filter: high efficiency particulate air filter. A throwaway, extended-media dry type filter with a rigid casing enclosing the full depth of the pleats. The filter shall exhibit a minimum efficiency of 99.97% when tested with an aerosol of 0.3 μm diameter test aerosol particles.

Independent Filter Test Laboratory: an autonomous body not affiliated with a HEPA filter manufacturer or supplier subject to this Code section but capable of performing the tests necessary to demonstrate the ability of HEPA filters to meet this Code section.

media velocity: the linear velocity of the air or gas into filter media.

medium: the filtering material in a filter. The plural form is media.

most penetrating particle size: that particle size for which the penetration of the filter medium by the test aerosol is a maximum at a specified velocity.

particle size: the apparent linear dimension of the particle in the plane of observation, as observed with an optical microscope; or the equivalent diameter of a particle detected by automatic instrumentation. The equivalent diameter is the diameter of a reference sphere having known properties and producing the same response in the sensing instrument as the particle being measured.

penetrometer: a device for generating a test aerosol and for evaluating the aerosol penetration and air resistance of fabricated HEPA filters.

test aerosol: dispersion of particles in air for testing the penetration of filter media or filters.

ARTICLE FC-2000 REFERENCED DOCUMENTS

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Common application documents referenced in this Code section are detailed in Article AA-2000. Where ASTM materials are specified, the equivalent ASME material specification may be substituted. Unless otherwise shown, the latest edition and addenda in effect at the time of product specification are applicable.

ANSI B18.21.1, Internal Tooth Lock Washer

ANSI B18.22.1, Plain Washer

Publisher: American National Standards Institute (ANSI), 25 West 43rd Street, New York, NY 10036

ASTM A 193M-05, Standard Specification for Alloy — Steel and Stainless Steel Bolting Materials for High-Temperature Service

ASTM A 194/A 194M-05, Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service

ASTM A 240/A 240M-05a, Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

ASTM A 320/A 320M-05, Standard Specification for Alloy/Steel Bolting Materials for Low-Temperature Service

ASTM A 325-04b, Standard Specification for Structural, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

ASTM A 449-04b, Standard Specification for Quenched and Tempered Steel Bolts and Studs

ASTM A 563-00/A 563M-04a-latest edition, Standard Specification for Carbon and Alloy Steel Nuts

ASTM A 580/A 580M-06, Standard Specification for Stainless Steel Wire

ASTM A 581/A 581M-95b (2004), Standard Specification for Free Machining Stainless Steel Wire and Wire Rods

ASTM A 740-98 (2003), Standard Specification for Hardware Cloth (Woven or Welded Galvanized Steel Wire Fabric)

ASTM B 209/B 209M-04, Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate

ASTM D 1056-00, Standard Specification for Flexible Cellular Materials — Sponge or Expanded Rubber

ASTM D 3359-02, Test Methods for Measuring Adhesion by Tape Test

ASTM E 84-06, Standard Test Method for Surface Burning Characteristics of Building Materials

Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

FED-STD-141C, Paint, Varnish, Lacquer, and Related Materials; Method of Inspection, Sampling and Testing

FF-N-105B, Nails, Brads, Staples, and Spikes, Cut and Wrought

MIL-STD-282 (1956), Filter Units, Protective Clothing, Gas Mask Components and Related Products: Performance Test Method

Publisher: U.S. Government Printing Office (GPO), 732 North Capitol Street, NW, Washington, DC 20401

IEST-RP-CC007.1 (1992), Testing ULPA Filters

Publisher: Institute of Environmental Sciences and Testing, Arlington Place One, 2340 South Arlington Heights Road, Arlington Heights, IL 60005

UL 586 (1996), Standard for High Efficiency, Particulate Air Filter Units

Publisher: Underwriters Laboratories, Inc. (UL), 333 Pfingsten Road, Northbrook, IL 60062

Voluntary Product Standards PS 1 for Construction and Industrial Plywood (PS 1)

Publisher: APA — The Engineered Wood Association, 7011 South 19th Street, Tacoma, WA 98466

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ARTICLE FC-3000
MATERIALS

FC-3100 ALLOWABLE MATERIALS

FC-3110 CASE MATERIALS

The case shall be made from the following materials:

(a) Stainless steel Type 409, 304, 304L, 316, or 316I per ASTM A 240. Steel sheet, having minimum thickness equal to 0.0720 in. (14 gage USS) (1.83 mm).

(b) Marine plywood, minimum grade A (interior side) and minimum grade B (exterior side), APA PS-1. The minimum thickness shall be $\frac{3}{4}$ in. (19 mm). The grade shall be fire retardant treated. The plywood shall have a flame spread classification of 25 or less when tested as specified in ASTM E 84.

(c) Exterior plywood, minimum grade A (interior side) and minimum grade C (exterior side, APA PS-1). The minimum thickness shall be $\frac{3}{4}$ in. (19 mm). The grade shall be fire retardant treated. The plywood shall have a flame spread classification of 25 or less when tested as specified in ASTM E 84.

FC-3111 Fasteners

Approved fasteners used for the assembly of HEPA filter cases are listed below:

(a) Stainless steel bolts: 300 series per ASTM A 320 or ASTM A 193

(b) Stainless steel nuts: 300 series per ASTM A 194

(c) Stainless steel lock washers: 300 series per ANSI B18.21.1

(d) Stainless steel plain washers: 300 series per ANSI B18.22.1

(e) Carbon steel bolts: per ASTM A 325 or ASTM A 449

(f) Carbon steel nuts: per ASTM A 563

(g) Carbon steel lock washers: per ANSI B18.21.1

(h) Carbon steel plain washers: per ANSI B18.22.1

(i) Nails: carbon steel, galvanized, zinc coated, aluminum, per Fed. Spec. FF-N-105B

(j) Staples: carbon steel, galvanized, zinc coated, aluminum, per Fed. Spec. FF-N-105B

(k) Stainless steel rivets: 300 series per ASTM A 581

Consideration should be given when selecting the proper filter fasteners serving seismic and other unusual requirements.

FC-3120 GASKET MATERIAL

FC-3121 Elastomer

Elastomer shall be of an oil-resistant, closed cell expanded cellular elastomer in accordance with grade 2C3 or 2C4 of ASTM D 1056, with the physical requirements specified for ASTM D 1056 Cellular rubbers classified as Type 2, Class C, Grade 3 (2C3), or Grade 4 (2C4).

FC-3122 Gelatinous Seal

Gelatinous seals shall be self-adhesive and self-healing cured gel seals made of polydimethylsiloxane.

FC-3130 FILTER MEDIA

The filter media shall conform to the requirements of Appendix FC-I.

FC-3140 FACEGUARDS

Metallic faceguards shall be fabricated from 4 × 4 mesh, wire fabric (hardware cloth) made from 0.025 in. (0.64 mm) steel conforming to either galvanized steel ASTM A 740, or 304 stainless steel ASTM A 580.

FC-3150 ADHESIVES

Adhesives used to fasten gaskets to filter case, and seal the filter pack or faceguards to the case, shall be self-extinguishing.

FC-3160 SEPARATORS

(a) Aluminum: Aluminum separators shall be made from corrugated aluminum, 0.0015 in. (0.038 mm)

minimum thickness, conforming to ASTM B 209, Alloy 5052 H38, 3003-H18, or 1100-H18 aluminum. To protect the filter media, the separators shall be provided with a hemmed edge.

(b) Acid Resistant Aluminum: Acid resistant aluminum separators shall be made from corrugated aluminum, 0.0015 in. (0.038 mm) minimum thickness, conforming to ASTM B 209, Alloy 5052-H39, 3003-H19, or 1145 H-19 coated on both surfaces with a vinyl-epoxy coating. The coating should be tinted to verify the coverage of the separator. To protect the filter media, the separators shall be provided with a hemmed edge.

(c) Glass Ribbon: Glass ribbon separators shall be ribbons of glass fiber media bonded to the filter media.

(d) String: String separators shall be threads of noncombustible material bonded to the filter media.

(e) Hot Melt: Hot melt separators shall be a noncombustible material bonded to the filter media.

FC-3200 SPECIAL LIMITATIONS OF MATERIALS

It is the responsibility of the Owner or Engineer to identify the environment in which the filter must operate in accordance with the design requirements of FC-4100 and section AA.

FC-3210 ALTERNATE MATERIALS

Materials, other than those referenced in this Code section, found acceptable by the qualification tests of Article FC-5000, and the design requirements of FC-4100 and section AA shall be acceptable for the fabrication of filters.

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ARTICLE FC-4000 DESIGN

FC-4100 GENERAL DESIGN

Four types of HEPA filters are addressed

(a) Type A: folded filter media with corrugated separator/supports.

(b) Type B: minipleat media with glass ribbon or noncombustible thread separators.

(c) Type C: continuous corrugated filter media folded without separators.

(d) Type D: filter constructed with glass or noncombustible thread separators.

FC-4110 HEPA FILTERS

(a) Filters shall be constructed as depicted in Figs. FC-4100-1, FC-4100-2, FC-4100-3, FC-4100-4, and FC-4100-5. The size and ratings shall be as specified in Table FC-4110. The filter shall be assembled with filter pack Type A, Type B, Type C, or Type D as defined in FC-4100. The filter pack shall be securely fastened to the sides and ends of the filter case with adhesive to completely seal the edges of the filter pack to the filter case. The gasket shall be fixed to the case with an adhesive per FC-3150.

(b) The total media area provided within the filter pack shall be such that maximum media velocity is 5.0 ft/min (2.5 cm/s) at the rated flow.

(c) Filter designs for flows other than those listed in Table FC-4110 are acceptable provided that the minimum ratings of Table FC-4110 and requirements of FC-4200 are met.

FC-4111 Splices and Patches

No splices or patches are allowed.

FC-4120 FILTER CASE

Filter cases are used to house the filter pack. All case joints shall be sealed. Case materials shall be in accordance with FC-3110. Construction shall meet the requirements of Article FC-6000.

FC-4130 FILTER PACK

(a) Type A filter packs shall be made by folding the media to the required depth. The folded filter media

TABLE FC-4110
NOMINAL SIZES AND RATINGS

Number Designation	Size, in.	Size, mm	Minimum Rated Air Flow, scfm	Minimum Rated Air Flow, m^3/hr	Maximum Resistance, in. wg	Maximum Resistance, Pa
1	8 × 8 × $3^1/_{16}$	203 × 203 × 78	25	40	1.3	320
2	8 × 8 × $5^7/_8$	203 × 203 × 150	50	80	1.3	320
3	12 × 12 × $5^7/_8$	305 × 305 × 150	125	210	1.3	320
4	24 × 24 × $5^7/_8$	610 × 610 × 150	500	850	1.0	250
5	24 × 24 × $11^1/_2$	610 × 610 × 292	1000	1700	1.0	250
6	24 × 24 × $11^1/_2$	610 × 610 × 292	1250	2100	1.0	250
7	24 × 24 × $11^1/_2$	610 × 610 × 292	1500	2500	1.3	320
8	24 × 24 × $11^1/_2$	610 × 610 × 292	2000	3400	1.3	320
9	12 × 12 × $11^1/_2$	305 × 305 × 292	250	420	1.3	320

FIG. FC-4100-1 TYPE A METAL CASE SEPARATOR FILTER

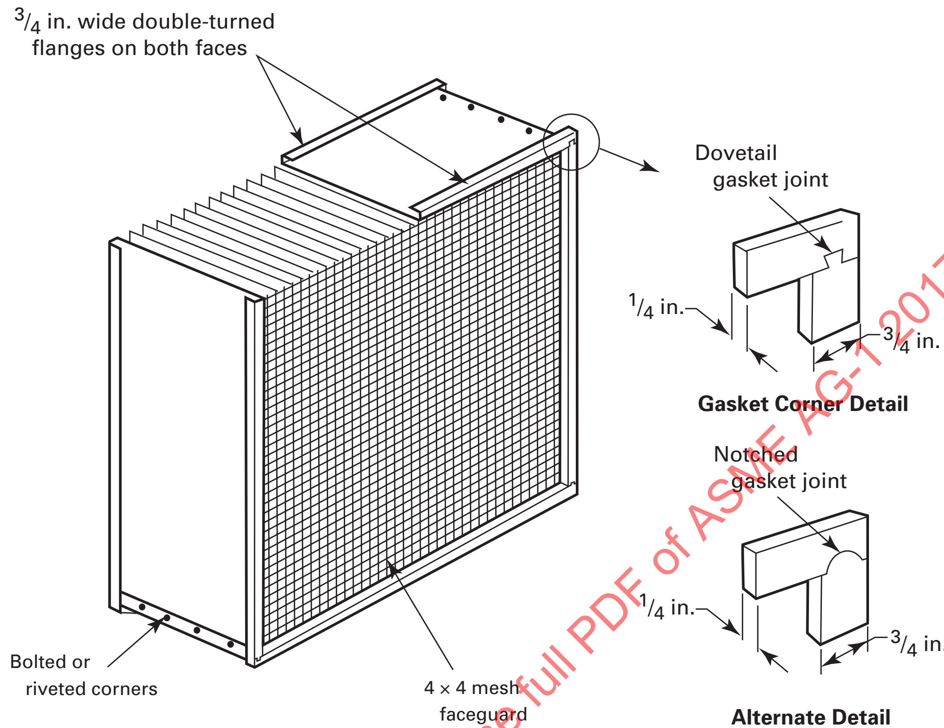


FIG. FC-4100-2 TYPE A WOOD CASE SEPARATOR FILTER

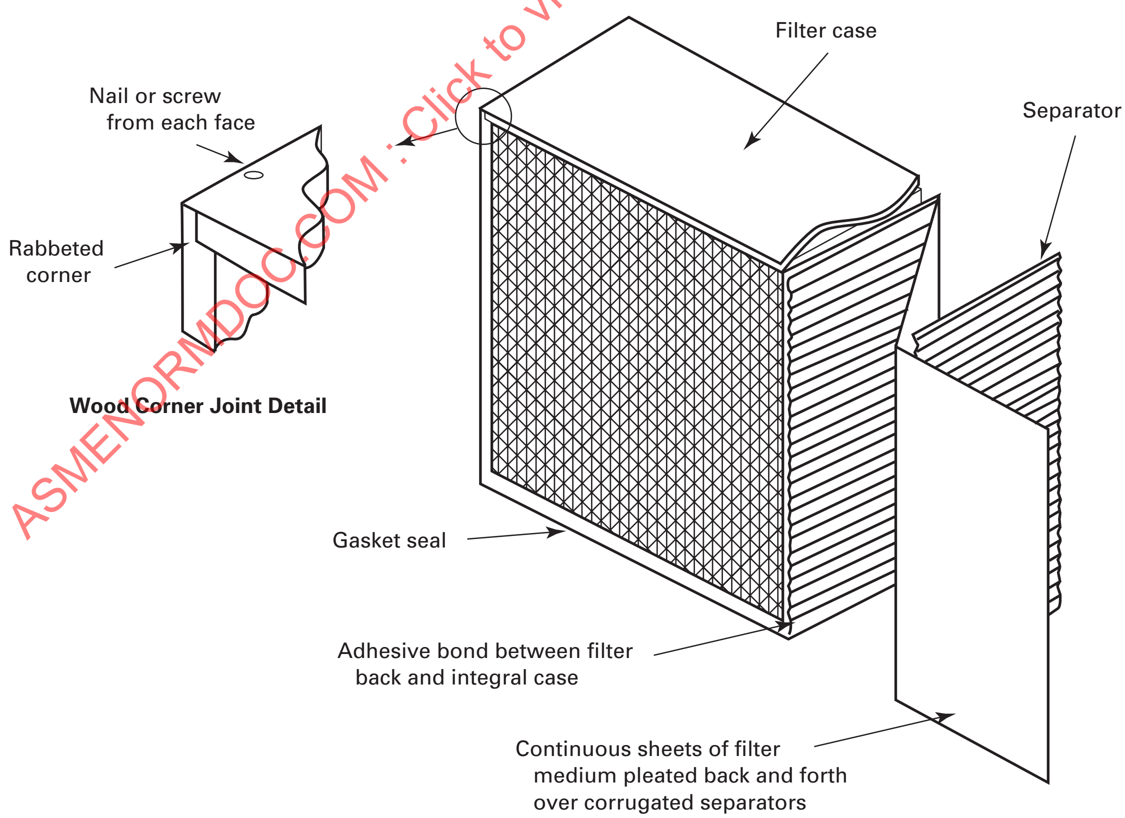


FIG. FC-4100-3 TYPE B MINIPLEAT (GLUE SEPARATOR) FILTER

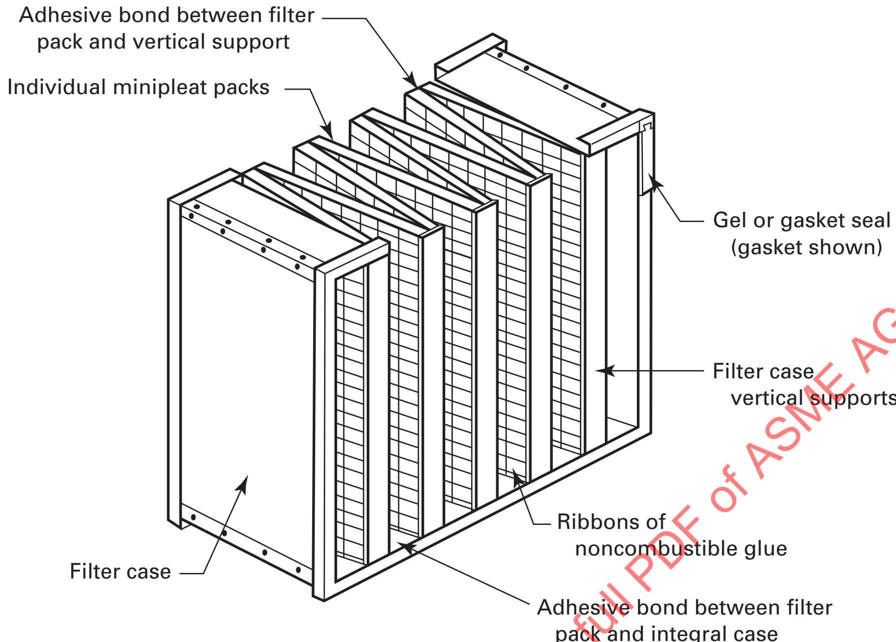


FIG. FC-4100-4 TYPE C SEPARATORLESS FILTER

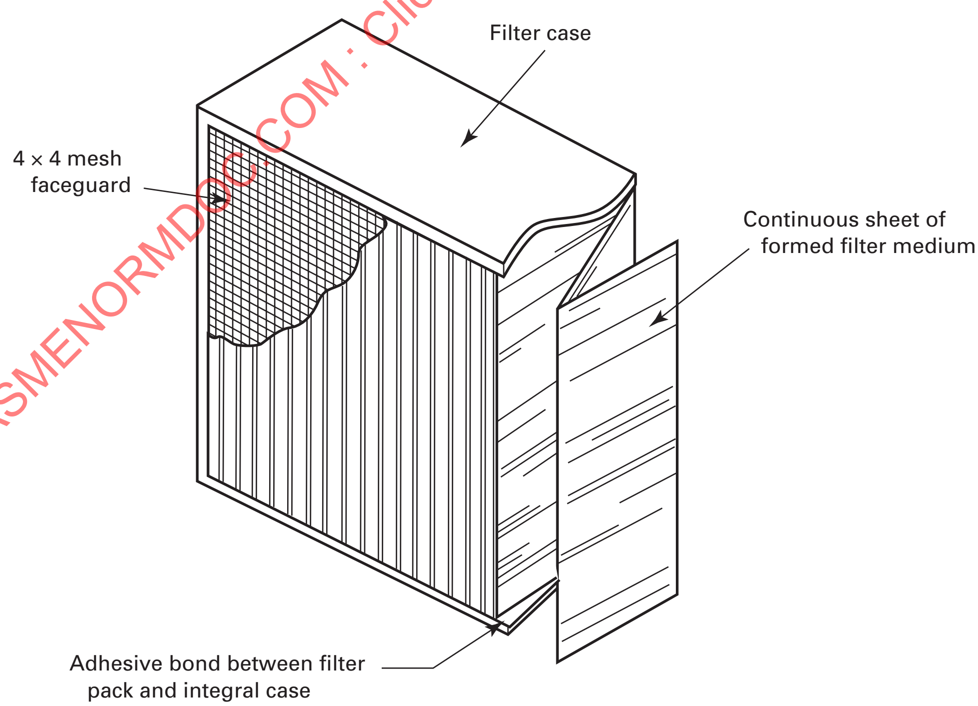
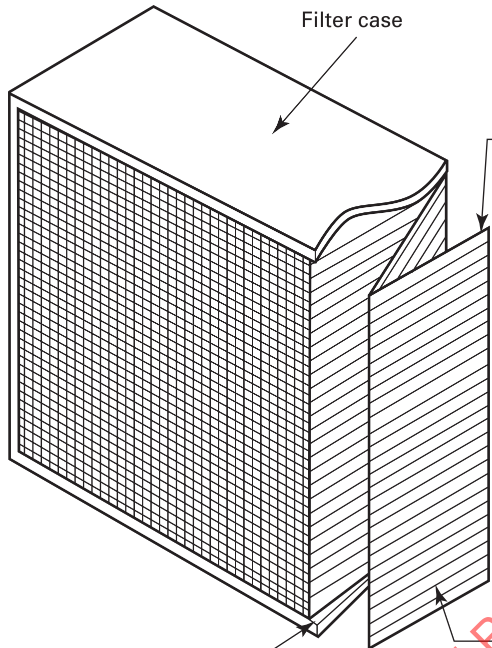


FIG. FC-4100-5 TYPE D THREAD SEPARATOR FILTER



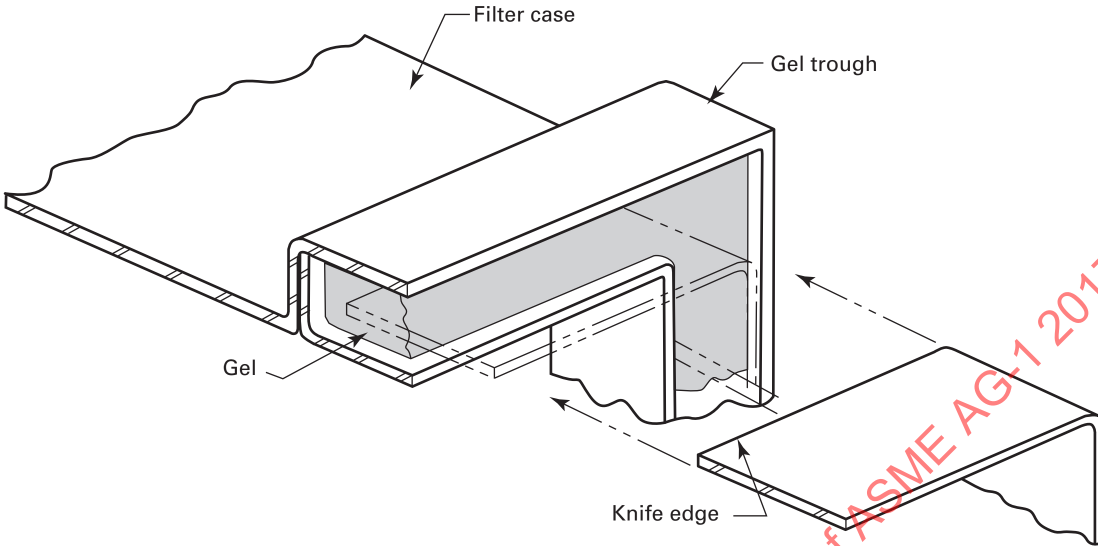
shall be supported with corrugated separators. The filter media pack shall not extend beyond the exposed ends of the separators. Separator fixed ends, when viewed from the upstream and downstream faces, shall be embedded in the adhesive/sealant. The separators shall not extend beyond the ends of the case when the media pack is bonded to the case. The filter pack shall be rigid within the case, and the separators shall be perpendicular to two opposite parallel sides of the case. Separators and media shall not vary more than $^1\!/_4$ in. (6 mm) from a straight line connecting the fixed ends. Abrupt deviations are not acceptable.

(b) Type B filter packs shall be made from a series of flat panels of pleated filter media, which are assembled in a V form. Pleats shall be separated and supported by ribbons of glass fiber media or noncombustible threads bonded to the filter media. When the panels are installed in the filter case, the top and bottom panels shall be sealed. The mating panels shall have a common bonded metal joint. Panel flatness, including separator, shall vary no more than $^1\!/_4$ in. (6 mm). No ribbons or media supports shall vary from a straight line by more than $^1\!/_4$ in. (6 mm). Side panels shall be securely bonded to the side of the filter case with adhesive.

(c) Type C filter packs shall be made by corrugating or embossing a continuous sheet of filter media and folding media to the required depth to make the filter pack. When the panels are installed in the filter case, the top and bottom of the panels shall be sealed. When installed in the case, the self-supporting media convolute or embossed centers shall not vary more than $^3\!/_8$ in. (10 mm) top to bottom from a straight line drawn perpendicular to the top and bottom case. Crest-to-crest contacts on adjacent folds shall not vary by more than $^1\!/_{16}$ in. (1.5 mm). Abrupt deviations in media folds are not acceptable. Filter media or filter media supports, if used, shall not extend beyond the filter case. The filter pack shall be rigid within the case and there shall be no kinked media.

(d) Type D filter packs shall be made by folding the media to the required depth. The folded filter media shall be separated and supported by ribbons of glass fiber media or noncombustible threads, glued to the filter media. The filter pack shall be rigid within the case, and the media pleats shall be perpendicular to two opposite parallel sides of the case. Abrupt deviations in media are not acceptable. When the panels are installed in the filter case, the top and bottom of the

FIG. FC-4100-6 GEL SEAL FILTER CORNER — ISOMETRIC



panels shall be sealed in a reservoir of potting adhesive at least $^1/_{16}$ in. (1.5 mm) deep.

FC-4140 GASKETS

FC-4141 Elastomer

The gasket shall be sealed to the filter case with an adhesive per FC-3150. The edge of the gasket shall not project beyond the outside of the case. If gasket material joints are required, they shall be notched or dovetailed and the edges glued in a manner that ensures no leakage. There shall be no more than four gasket joints per HEPA filter gasket-face. See Fig. FC-4100-1.

FC-4142 Gelatinous Seal

The seal shall be effected by means of a continuous knife-edge on the sealing surface of the holding case that mates into a continuous channel on the case of the HEPA filter. The channel shall be filled with a gelatinous compound per FC-3122 that conforms to the seal knife-edge. See Fig. FC-4100-6.

FC-4150 SEPARATORS

FC-4151 Coated

Acid resistant separators coated in accordance with FC-3160 (b), shall meet the following tests after application of the coating to the separator:

(a) The coating shall meet or exceed a rating of 3A when tested using Method A of ASTM D 3359.

(b) Off-gas volatiles, as determined by thermo-gravimetric analysis, shall not exceed 5% by weight when a 2-in. (50 mm) × 2-in. (50 mm) sample of the coated separator is subjected to temperatures from 20°C to 1 000°C (68°F to 1,800°F).

(c) The coated separator shall pass a flexibility test in accordance with FED-STD-141C, Method 6221.

FC-4160 FACEGUARDS

A faceguard shall be installed in each face of the filter in such a manner that it shall not directly contact the gasket or create a leak path.

FC-4200 PERFORMANCE REQUIREMENTS

The Design Specification shall clearly establish the purpose (design function) of the filter. The Design Specification shall include the following environmental and service conditions at a minimum:

(a) Temperature. The minimum and maximum operating temperature [°F (°C)] that the filter will be subjected to shall be specified.

(b) Air Flow. The minimum and maximum operating airflow to which the filter will be subjected shall be specified.

(c) Humidity. The minimum and maximum operating humidity [percent (%)] to which the filter will be subjected shall be specified.

(d) Chemicals. Corrosion allowances shall be specified for the filter. Concentration of each chemical shall be specified.

(e) Penetration of Particle Sizes Other Than 0.3 μm. The maximum penetration of particle sizes other than 0.30 μm shall be specified if health physics analysis of air to be filtered deems it necessary.

Designs shall be qualified in accordance with Article FC-5000.

FC-4210 TEST AEROSOL PENETRATION

The total test aerosol penetration through the filter media, frame, and gasket shall not be greater than 0.03% of upstream concentration when tested at rated airflow and at 20% of rated flow when tested in accordance with FC-5120.

FC-4220 RESISTANCE TO AIRFLOW

The resistance to airflow at the rated airflow of the clean filter shall meet the requirements of Table FC-4110, when tested in accordance with FC-5110.

FC-4300 SEISMIC QUALIFICATION

The HEPA filters shall seismically qualify by test in accordance with AA-4350.

(09)

ARTICLE FC-5000 INSPECTION

The inspection and testing of HEPA filters shall conform to the requirements in the following paragraphs.

FC-5100 QUALIFICATION TESTING

New or revised filter designs shall require qualification testing prior to acceptance and production. Filter designs shall be requalified at least every 5 yr. Tests shall be performed and certified by an independent test facility.

A qualification sample of 12 filters (8 filters if the manufacturer is providing objective evidence of UL 586 as required in FC-5150 and FC-5160). The HEPA filters shall be manufactured using the same methods, materials, equipment, and processes as will be used during production. Qualification of a filter gasket or a gelatinous seal on one face of the filter qualifies the use of the same gasket or seal on both faces. Qualification of a filter design in Table FC-4110 qualifies all filters with a lower flow rate, which have the same design except for size 4. The size 4 filters shall be qualified separately. The test sequence is detailed in Table FC-5100-1.

Each filter in the qualification sample shall be visually examined for defects.

The qualification samples shall be tested for all the requirements for this section. Objective evidence of conformance to UL 586 will be accepted as testing for compliance to FC-5150 ad FC-5160. Failure of any filter to comply with any of the requirements of this section shall be cause for the rejection of the qualification sample. Manufacturers shall provide the supplier's name and part number and/or name for materials that do not have a referenced industry specification in this document to the Independent Filter Test Laboratory at the time of qualification.

FC-5110 RESISTANCE TO AIRFLOW

The clean filter resistance to airflow shall meet the requirements of Table FC-4110 when tested in accordance with FC-5120.

FC-5120 TEST AEROSOL PENETRATION

The test aerosol penetration shall be determined in accordance with Table FC-5100-1. The test conditions shall be corrected to standard temperature and pressure. The total aerosol penetration through the filter media, case, and gasket shall be no greater than 0.03% of upstream concentration of 0.3 μm particles at rated airflow and at 20% of rated airflow.

Suitable penetrometers include the Q-76 for filter sizes 1, 2, 3, and 9 and the Q-107 for filter sizes 4 and 5. Penetrometers using laser particle counters in accordance with the methods and procedures of IEST-RP-CC-007.1 are also acceptable for each of these sizes as well as sizes 6, 7, and 8. When using a penetrometer with a particle counter the penetration of the 0.3 μm particle size shall be reported.

Acceptable aerosol materials for the Q-76 or the Q-107 penetrometer are dioctylphthalate (DOP), dioctylsebacate (DOS/DEHS), and 4 centisoke poly-alpha olephin (PAO). If using a penetrometer with a particle counter, the aerosol material shall be as defined in IEST-RP-CC-007.1 section 4.2.9.

FC-5130 RESISTANCE TO ROUGH HANDLING

The Type A, C, and D filters shall be tested on a rough-handling machine for 15 min. at $^3/_4$ in. (19 mm) total amplitude at 200 cycles per min in accordance with Test Method 105.10 of MIL-STD-282. The filter shall be placed on the machine with the faces and pleats in a vertical position. Type B filter rough-handling machine test position shall be with the face vertical and pleats horizontal. At the conclusion of the shaking period, the filter shall be visually examined for damage. Cause for rejection shall include cracked or warped cases, loose corners or joints, cracked adhesive, loose or deformed media, separators, or faceguards.

After the rough-handling test, the same filter shall meet the requirements in FC-5110 and FC-5120.

TABLE FC-5100-1
TEST GROUPS AND SEQUENCE

Group	Quantity	Requirement	Test Paragraph
I	4	Resistance to rated airflow	FC-5110
		Test aerosol penetration at rated airflow and at 20% of rated airflow	FC-5120
		Resistance to pressure	FC-5140
		Test aerosol penetration at 20% of rated airflow only	FC-5120
II	4	Resistance to rated airflow	FC-5110
		Test aerosol penetration at rated airflow and at 20% of rated airflow	FC-5120
		Resistance to rough handling	FC-5130
		Test aerosol penetration at rated airflow only	FC-5120
III	1	Resistance to spot flame	FC-5160
IV	3	Resistance to heated air	FC-5110
		Test aerosol penetration at rated airflow only	FC-5120

TABLE FC-5120-1
ACCEPTABLE AEROSOL TEST

Filter Size	Test Mechanism
1–3	Q-76 Penetrometer, Laser
4–9	Q-107 Penetrometer, Laser

TABLE FC-5140-1
TEST CONDITIONS AND REQUIREMENTS

Test Conditions	Test Requirements
Temperature	95°F ± 5°F (35°C ± 3°C)
Relative humidity	95°F ± 5%
Rate of airborne water droplets flowing toward the filter [Note (1)]	1 ± 0.25 lb/min/1000 cfm (2.2 ± 0.6 kg/min/1700 m^3/hr)
Pressure differential across filter	10.0 ± 0.2 in. of water (2.4 ± 0.05 kPa)
Time to reach pressure	0.5 min, max.
Time duration at sustained differential pressure	1 hr, min.
Airflow	That required for producing the above pressure differential

NOTE:
(1) This is defined as the rate of water flowing through the spray orifice less the fallout and drainage from the air duct walls between points of location of the spray orifice and one inch before the face of the filter.

FC-5140 RESISTANCE TO PRESSURE

The filter shall be tested for resistance to pressure on a machine capable of testing in accordance with Table FC-5140-1.

Prior to being tested for resistance to pressure, the filter shall be conditioned at atmospheric pressure for 24 hr. min. in a chamber at 95°F ± 5°F (35°C ± 3°C) and a relative humidity (RH) of 95% ± 5%.

After being conditioned, the filters shall withstand the airflow and water spray environment listed in Table FC-5140-1 without rupture of the filter media.

Within 15 min after completion of the pressure test and while still wet, the filter shall meet the requirement of FC-5120 at 20% airflow.

FC-5150 RESISTANCE TO HEATED AIR

For resistance to heated air, the filter shall be installed in the test chamber and subjected to the rated flow of air heated to 700°F ± 50°F (370°C ± 30°C) for no less than 5 min. Ramping to this temperature shall be accomplished in no more than 15 min.

Following exposure to heated air and cooling of the filter in place, the filter shall be tested at rated flow for test aerosol penetrations through the filter media, case, and elastomer or gelatinous seal. The penetration shall not exceed 3%.

An Underwriters Laboratories label with a traceable control number or UL 586 designation shall be acceptable objective evidence of compliance with FC-5150.

FC-5160 SPOT FLAME RESISTANCE

The filter shall be mounted in the test duct and the airflow adjusted to rated airflow. A gas flame from a Bunsen burner shall be directed against the upstream face of the unit. The Bunsen burner shall be adjusted to produce a flame with a blue cone 2.5 in. (64 mm) long with a tip temperature of 1,750°F ± 50°F (955°C ± 30°C), as measured by a thermocouple inserted in the flame. The tip of the cone shall be so applied that it touches the surface of the filter medium at a distance of not less than 2 in. (50 mm) from the filter case. The flame shall be applied for 5 min at each of three separate locations on the filter face.

The Bunsen burner flame shall then be directed into a top corner of the filter unit in such a manner that the tip of the blue cone contacts the case, filter pack, and sealing materials. The flame shall be applied for a period of 5 min. The test shall be repeated upon the opposite top corner of the sample filter unit.

After removal of the test flame at each point of application, there shall be no sustained flaming on the downstream face of the unit.

An Underwriters Laboratories label with a traceable control number or UL-586 designation shall be acceptable objective evidence of compliance with FC-5160.

FC-5170 STRUCTURAL REQUIREMENTS

Each filter in the sample shall be evaluated for structural integrity. Each filter shall satisfy that

(a) no structural damage shall be evident by visual examination

(b) airflow resistance and aerosol penetration requirements of FC-5110 and FC-5120 shall be met.

FC-5200 INSPECTION

Each HEPA filter shall be visually inspected to show conformance to size specification, and inspection to verify that the sticker indicates it has been tested and meets the flow rate, penetration, and resistance of Table FC-4110. Additional attributes to be inspected are length, depth, height, squareness, and adherence of gaskets. Media shall be inspected to ensure there are no holes, splices, or patches.

FC-5300 PRODUCTION TESTING

Each filter manufactured for delivery shall be tested for test aerosol penetration and resistance to airflow in accordance with FC-5110 and FC-5120. The results of these tests shall be marked on the label of each filter.

ARTICLE FC-6000 FABRICATION (09)

FC-6100 GENERAL REQUIREMENTS

The HEPA filter shall be assembled from the materials designated in FC-3100 in accordance with the design requirements established in Article FC-4000. Following assembly, the filter shall be inspected and qualified in accordance with FC-5100. Production testing of qualified filters shall conform to FC-5300.

FC-6200 MANUFACTURE AND ASSEMBLY

The general requirements for fabrication and installation are contained in AA-6200 and AA-6300.

FC-6210 TOLERANCES

FC-6211 Flatness and Squareness

The faces of the case shall be flat and parallel within $\frac{5}{8}$ in. (16 mm). The case shall be square within $\frac{1}{8}$ in. (3 mm) when measured diagonally across the corners of both faces.

FC-6212 Overall Dimensions

Filters of size 24 in. × 24 in. × $5\frac{7}{8}$ in. (610 mm × 610 mm × 150 mm) and larger shall be +0 in., $-\frac{1}{8}$ in. (+0 mm, −3 mm) outside dimensions, except depth, which shall be $+\frac{1}{16}$ in., −0 in. (+1.5 mm, −0 mm). All filters smaller than the above shall be +0 in., $-\frac{1}{16}$ in., (+0 mm, −1.5 mm) outside dimensions except depth, which shall be $+\frac{1}{16}$ in., −0 in. (+1.5 mm, −0 mm). The above dimensions exclude gaskets.

FC-6220 MEDIA INSTALLATION

The filter media shall be fastened to the sides and ends of the filter case with adhesive to completely seal the edges of the media to the filter case. Patching of holes or tears in the media shall not be permitted.

FC-6300 WORKMANSHIP

The filter shall be free from foreign matter (dirt, oil, or viscous material) and damage, such as distorted or cracked case, deformation or sagging of media, separators and faceguards, cracks in adhesive, and cracks or holes in exposed portions of the media.

(09)

ARTICLE FC-7000
PACKAGING, SHIPPING, AND STORAGE

Packaging, shipping, and storage shall be in accordance with Article AA-7000 and ASME NQA-1 Level B. Filters shall be individually packaged. Cartons shall have extra shock absorbing material at the corners of the filter. Types A, C, and D filters shall be placed in the carton with the pleats vertical, Type B filters shall be placed in the carton with the pleats horizontal. The carton shall be clearly marked for proper orientation per FC-9200. Stacking of filters during storage and handling shall not be more than three filters high.

ARTICLE FC-8000
QUALITY ASSURANCE

Quality assurance shall conform to the requirements of Article AA-8000 and the following.

FC-8100 RESPONSIBILITY

The Manufacturer has the responsibility of providing all specified information and of ensuring that the quality control, and detailed examination and tests required by this Code, are performed at the stages of construction necessary to permit them to be meaningful.

FC-8200 CERTIFICATE OF CONFORMANCE (09)

The Certificate of Conformance shall state that the filters conform to Section FC.

(09)

ARTICLE FC-9000
NAMEPLATES

FC-9100 FILTER MARKING

Marking or labeling of each filter shall be on the top of the filter when the pleats are vertical, of such size and legibility that it can be read at a distance of 3 ft (1 m).

As a minimum, the following information shall be provided:

(a) Manufacturer's name or symbol

(b) model number

(c) serial number

(d) rated flow capacity

(e) direction of airflow for penetration and pressure drop tests no less than $^1/_8$ in. (3 mm) high

(f) pressure drop, in inches of water, at 100% rated flow

(g) overall penetration at rated flow

(h) overall penetration at 20% of rated flow

(i) UL label indicating successful testing per UL 586 if UL 586 is applicable

FC-9200 PACKAGE MARKING

Marking or labeling of each shipping container (carton containing one filter) shall be of such size and type that it can be read at a distance of 3 ft (1 m). As a minimum, the following information shall be provided:

(a) Manufacturer's name or symbol

(b) arrows and "This Side Up" indicating orientation for shipping and storage and "Fragile" in letters no less than $^3/_8$ in. (10 mm) high

(c) filter model number

(d) purchase order number or other identifying marking requested by purchaser

MANDATORY APPENDIX FC-I
FILTER MEDIA: FIRE-RESISTANT, HIGH EFFICIENCY

ARTICLE FC-I-1000 SCOPE

This Mandatory Appendix establishes requirements for the manufacture of high efficiency, fire-resistant, filter media for use in the construction of HEPA filters as described in Section FC. This Appendix supersedes and has been derived from the Military Specification MIL-F-51079D for Fire-Resistant, High Efficiency Filter Media.

(09)

ARTICLE FC-I-2000
REFERENCE DOCUMENTS

In addition to referenced documents in Article FC-2000, the following documents are applicable. Unless otherwise shown, the latest editions and/or addenda of the following specifications, standards, and handbooks are applicable to the extent specified herein.

ASTM D 2986, Standard Practice for Evaluation of Air Assay Media by the Monodisperse DOP (Dioctyl Phthalate) Smoke Test

ASTM D 737, Test Method for Air Permeability of Textile Fabrics

Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

IEST-RP-CC0021, Testing HEPA and ULPA Filter Media

Publisher: Institute of Environmental Sciences and Technology (IEST), Arlington Place One, 2340 South Arlington Heights Road, Arlington Heights, IL 60005

T 411 om, Thickness (Caliper) of Paper, Paperboard, and Combine Board

T 402 om, Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets, and Related Products

T 494 om, Tensile Properties of Paper and Paperboard (Using Constant Rate of Elongation Apparatus)

Publisher: Technical Association of the Pulp and Paper Industry (TAPPI) 15 Technology Parkway South, Norcross, GA 30092

125-8-1, Indicator, Water Repellency Q101

Publisher: U.S. Army Chemical and Biological Defense Command, Edgewood Research, Development, and Engineering Center, Aberdeen Proving Ground, MD 21010

ARTICLE FC-I-3000 REQUIREMENTS (09)

FC-I-3100 FORM AND SIZE

FC-I-3110 FORM

The filter media shall be furnished in rolls. The medium shall be tightly and evenly wound on nonreturnable fiber or paperboard cores with a minimum inside diameter of $3^{1}/_{16}$ in. ± $^{1}/_{8}$ in. (78 mm ± 3 mm) and a minimum wall thickness of $^{3}/_{8}$ in. (9 mm).

FC-I-3120 SIZE

The width of the roll shall be specified at the time of procurement. The tolerance on the specified width shall be +$^{1}/_{4}$ in./–0 in. (+6 mm/–0 mm). The weight or length of media on the roll shall be clearly marked on the outside of the roll.

FC-I-3130 SPLICES

The location of splices within the rolls shall be marked with paper tabs of contrasting color extending from each end of the roll. The number of splices permitted per roll shall not exceed the whole number obtained by dividing the length of the roll in feet by 1,000 (in meters by 300).

FC-I-3200 PHYSICAL AND CHEMICAL

FC-I-3210 AIRFLOW RESISTANCE

The pressure drop across the media shall not exceed 1.6 in. wg (0.4 kPa) with ambient temperature airflow through the media at a minimum velocity of 10.5 ft/min (3.2 m/min), when tested as specified in FC-I-4210.

FC-I-3220 TEST AEROSOL PENETRATION

The penetration of the media by test aerosol of 0.3 μm light scattering particle size shall not exceed 0.03%, or the penetration of the media by the most penetrating particle size (MPPS) shall not exceed 0.10%, as determined by the ratio of the downstream to upstream aerosol concentration when testing in accordance with FC-I-4210 with ambient temperature airflow through the media at a velocity of 10.5 ft/min (5.33 cm/s).

In addition, for testing MPPS penetration using particle counting test methods, the MPPS for a media design should be first determined as follows:

(a) If an electrostatic classifier (or diffusion battery) in combination with a condensation particle counter (CPC) is used, at least seven geometrically equally spaced particle sizes in the range of 0.1 μm to 0.3 μm should be used.

(b) If a laser particle counter is used in conjunction with a polydisperse challenge aerosol, eight geometrically equally spaced subranges in the range of 0.1 μm to 0.3 μm should be used.

FC-I-3230 TENSILE STRENGTH

FC-I-3231 Tensile Strength and Elongation

The average tensile breaking strength of the media shall be not less than 2.5 lb/in. (0.43 kN/m) width in the machine direction, no less than 2.0 lb/in. (0.35 kN/m) width in the cross direction, and the average elongation in both directions shall be no less than 0.5% at rupture when tested as specified in FC-I-4221.

FC-I-3232 Tensile Strength After Heated Air

The average tensile strength of the media shall be not less than 0.6 lb/in. (11 kg/m) width in the cross direction after exposure to heated air at 700°F ± 50°F (370°C ± 25°C) in a forced draft oven for 5 min when tested as specified in FC-I-4222.

FC-I-3233 Wet Tensile Strength

The average wet tensile breaking strength of the media after being soaked for 15 min in water at room ambient temperature shall be not less than 1.0 lb/in. (0.17 kN/m) of width in the cross direction when tested as specified in FC-I-4223.

FC-I-3234 Tensile Strength After Gamma Irradiation

The average tensile strength of the filter media shall not be less than 1.0 lb/in. (0.17 kN/m) of width in either the machine or cross direction after the media is exposed to gamma irradiation for an integrated dose of 6.0×10^7 rads to 6.5×10^7 rads at a dosage rate not to exceed 2.5×10^6 rads per hour when tested as specified in FC-I-4224. Water repellency after gamma irradiation will be tested at least once every 5 yr at the time of qualification.

FC-I-3240 WATER REPELLENCY

FC-I-3241 Prior to Irradiation

The average water repellency of the filter media shall not be less than 20 in. wg (5 kPa) with no single value being less than 18 in. wg (4.5 kPa) when tested as specified in FC-I-4231.

FC-I-3242 After Gamma Irradiation

The average water repellency of the filter media shall be no less than 6 in. wg (1.5 kPa) with no single value being less than 5 after the media is exposed to an integrated dose of 6.0×10^7 rads to 6.5×10^7 rads at a dose rate not to exceed 2.5×10^6 rads per hour when tested in accordance with FC-I-4231. Water repellency after gamma irradiation will be tested at least once every 5 yr at the time of qualification.

FC-I-3250 THICKNESS

Media thickness shall be a minimum of 0.015 in. (0.38 mm) and a maximum of 0.040 in. (1.02 mm) when measured as specified in FC-I-4240.

FC-I-3260 COMBUSTIBLE MATERIAL

The combustible material in the filter media shall not exceed 7% by weight when tested as specified in FC-I-4250.

FC-I-3270 FLEXING CHARACTERISTICS

FC-I-3271 Flexing

The media shall show no tears, breaks, cracks, or fiber separation after it is drawn back and forth, five times, around a 0.19 in. (4.8 mm) diameter mandrel and moving through an arc of at least 180 deg when tested as specified in FC-I-4261.

FC-I-3272 Test Aerosol Penetration

The penetration of the media by test aerosol of 0.3 µm light scattering particle size shall not exceed 0.03%, or the penetration of the media by the most penetrating particle size (MPPS) shall not exceed 0.10% for the most penetrating particle size after the media is drawn back and forth as required in FC-I-3271, when tested as specified in FC-I-4210.

FC-I-3300 WORKMANSHIP

The medium shall be free from contamination (foreign matter), thick or thin spots, wrinkles, and damage, such as tears, cracks, holes, abrasions, and punctures.

ARTICLE FC-I-4000 QUALIFICATION AND TESTING PROCEDURES (09)

FC-I-4100 QUALIFICATION TESTING

FC-I-4110 SAMPLE

A qualification sample of 10 linear feet (3.05 m), full width, shall be manufactured using the same methods, materials, equipment and processes as will be used during regular production.

FC-I-4111 Material Change

Any change in materials or source of materials after qualification shall require a new qualification sample.

FC-I-4112 Reverification of Qualification

Media shall be requalified at least every 5 yr. Tests shall be performed and certified by an independent test facility.

FC-I-4200 TEST PROCEDURES

FC-I-4210 AIRFLOW RESISTANCE AND PENETRATION

Three test specimens shall be tested for airflow resistance and aerosol penetration at a media velocity of 10.5 ft/min (5.33 cm/s) using a penetrometer (e.g. Q-127) according to ASTM D 737 and ASTM D 2986. Optionally, the MPPS penetration may be determined according to IEST-RP-CC021.1.

FC-I-4220 TENSILE STRENGTH

FC-I-4221 Tensile Strength and Elongation

Ten test specimens, five taken in each direction, shall be tested for tensile strength and elongation in accordance with TAPPI Standard T494 except that the test specimens shall be 1.00 in. ± 0.05 in. (25 mm ± 1 mm) wide with sides parallel within $^4/_{1000}$ in. (0.1 mm) and long enough to be clamped in the jaws when the test span is 4.0 in. ± 0.2 in. (100 mm ± 5 mm), leaving enough length so that any slack can be removed from the strip before clamping. Use a motorized tensile testing machine that has a constant rate of elongation and a flat jaw clamping device. The rate of separation of the jaws shall be set at 0.5 in./min (13 mm/min) or at a rate that will complete the test in 10 sec ± 2 sec, which ever is greater. Once set the rate shall be resettable and constant to ±4%.

FC-I-4222 Tensile Strength After Heated Air

Four test specimens 6 in. × 6 in. (150 mm × 150 mm) shall be subjected to heated air using a suitable commercial forced draft oven, capable of allowing full circulation of air to each test specimen. The test specimen shall be placed in the oven for 5 min after the temperature has reached 700°F ± 50°F (370°C ± 20°C). After the exposure, the specimen shall be removed from the oven and conditioned in accordance with TAPPI Standard T402. One test strip, 1.00 in. ± 0.05 in. (25 mm ± 1 mm) wide with sides parallel within $^4/_{1000}$ in. (0.1 mm) and long enough to be clamped in the jaws when the test span is 4.0 in. ± 0.2 in. (100 mm ± 5 mm), leaving enough length so that any slack can be removed from the strip before clamping taken in the cross direction width shall be tested for tensile strength in accordance with FC-I-4221.

FC-I-4223 Wet Tensile Strength

Three test specimens 1.00 in. ± 0.05 in. (25 mm ± 1 mm) wide with sides parallel within $^4/_{1000}$ in. (0.1 mm) and long enough to be clamped in the jaws when the test span is 4.0 in. ± 0.2 in. (100 mm ± 5 mm), leaving enough length so that any slack can be removed from the strip before clamping taken in the cross direction width shall be submerged in water at a depth of 10 in. (250 mm) for 15 min and then tested for tensile strength as specified in FC-I-4221.

FC-I-4224 Tensile Strength After Gamma Irradiation

Six test specimens 7 in. × 3 in. ± 0.2 in. (175 mm ± 5 mm), three with the 7 in. (175 mm) side in the machine direction and three with the 7 in. (175 mm) side in the cross direction, shall be exposed to irradiation in a ventilated chamber as specified in FC-I-3234. A test strip, 1.00 in. ± 0.05 in. (25 mm ± 1 mm) wide with sides parallel within $^4/_{1000}$ in. (0.1 mm) and long enough to be clamped in the jaws when the test span is 4.0 in. ± 0.2 in. (100 mm ± 5 mm), leaving enough length so that any slack can be removed from the strip before clamping taken from each of these specimens shall be tested for tensile strength in accordance with FC-I-4221.

FC-I-4230 WATER REPELLENCY

FC-I-4231 Prior to Gamma Irradiation

Three test specimens 2 $^3/_4$ in. ± $^1/_8$ in. × 5 $^1/_2$ in. ± $^1/_4$ in. (70 mm ± 19 mm × 140 mm ± 6 mm) shall be conditioned in accordance with TAPPI T402 and tested for water repellency using the Q-101 Water Repellency Test (125-8-1). The two surfaces of each test specimen shall be identified as top and bottom. The specimen shall then be cut into two 2 $^1/_4$ in. ± $^1/_8$ in. × 2 $^1/_4$ in. ± $^1/_8$ in. (70 mm ± 3 mm × 70 mm ± 3 mm) squares. The top surface of one and the bottom surface of the other square shall be tested. The lesser of the two results shall be considered the water repellency of the specimen.

FC-I-4232 After Gamma Irradiation

Three test specimens 7 in. ± $^1/_4$ in. × 5 in. ± $^1/_4$ in. (175 mm ± 6 mm × 75 mm ± 6 mm) shall be exposed to irradiation in a ventilated chamber as specified in FC-I-3234 and subsequently tested in accordance with FC-I-4231.

FC-I-4240 THICKNESS

The thickness of the medium shall be determined in accordance with TAPPI T411.

FC-I-4250 COMBUSTIBLE MATERIAL

The percentage of material combusted from of the sample shall be determined as specified in the IEST-RP-CC021.1, “Testing of HEPA and ULPA Filter Media,” section 4.10, “Test for weight loss at elevated temperature.”

FC-I-4260 FLEXING CHARACTERISTICS

FC-I-4261 Examination

Eight test specimens, 6 in. ± $^1/_4$ in. × 12 in. ± $^1/_4$ in. (150 mm ± 6 mm × 300 mm ± 6 mm) in the machine direction shall be bent perpendicular to the machine direction over a $^3/_{16}$ in. ± $^1/_{32}$ in. (5 mm ± 1 mm) mandrel so that 10 in. ± $^1/_2$ in. (250 mm ± 12 mm) of medium are drawn five times through an arc of 180 deg. Four specimens with the screen/wire side against the mandrel and four specimens with the felt side against the mandrel. Examine the flexed media 10 in. ± $^1/_2$ in. (250 mm ± 12 mm) section for compliance with FC-I-3271.

FC-I-4262 Test

After examination as specified in FC-I-4261, the center of each test specimen shall be tested for penetration in accordance with the procedure of FC-I-4210 for compliance with FC-I-3272.

FC-I-4300 QUALITY CONFORMANCE INSPECTION

Each roll of media shall be inspected for defects. Defects such as abrasions greater than $^1/_4$ in. (6 mm) diameter; burn holes, charring or scorching from the drying operation; and deviations outside the width tolerance are reasons for rejection.

ARTICLE FC-I-5000 QUALITY ASSURANCE PROVISIONS (09)

FC-I-5100 RESPONSIBILITY FOR INSPECTION

FC-I-5110 SUPPLIER'S RESPONSIBILITY

Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein.

FC-I-5120 OBJECTIVE EVIDENCE

The supplier shall provide objective evidence acceptable to purchaser that the requirements of Articles FC-I-3000 and FC-I-4000 have been satisfied.

(09)

ARTICLE FC-I-6000
PACKAGING AND SHIPPING

FC-I-6100 PACKAGING

Packaging shall conform to Level B of ASME NQA-1 suitable for storage under Level B of ASME NQA-1.

FC-I-6200 SHIPPING

Shipping of the media shall be undertaken to ensure the quality of the product upon arrival at the purchaser. Shipping shall comply with the rules and regulations applicable to the mode of transport being utilized.

NONMANDATORY APPENDIX FC-A
DIVISION OF RESPONSIBILITY

This Nonmandatory Appendix is intended to identify the roles normally assumed by the organizations responsible for fulfilling Code requirements when not specifically addressed in an article or subarticle. These are guidelines to assist with Code compliance and are not to be construed as legal or contractual responsibilities unless so invoked by the Owner or designee.

TABLE FC-A-1000 DIVISION OF RESPONSIBILITY **(09)**

FC-	Item	Responsible Party
3000	Materials	Engineer/Manufacturer
4000	Design	Manufacturer
4210	Penetration performance	Manufacturer
4220	Airflow performance	Manufacturer
5100	Qualification testing	Independent test laboratory
5200	Inspection	Manufacturer
5300	Product testing	Manufacturer
6000	Fabrication	Manufacturer
6210	Tolerance	Manufacturer
7000	Packaging, shipping, and storage	Manufacturer/Owner
8000	Quality assurance	Manufacturer
9000	Nameplates	Manufacturer

SECTION FD
TYPE II ADSORBER CELLS

ARTICLE FD-1000
INTRODUCTION

FD-1100 SCOPE

This section of the Code provides minimum requirements for the performance, design, construction, acceptance testing, and quality assurance for modular gas phase adsorber cells used in nuclear safety-related air or gas treatment systems.

FD-1110 PURPOSE

The purpose of this section is to ensure that adsorbers used for nuclear safety-related air and gas treatment systems are acceptable in all aspects of performance, design, construction, and testing.

FD-1120 APPLICABILITY

The Type II adsorber unit is a single cell composed of 2 in. adsorber beds, access panel(s) for recharging, and a gasketed flange. Impregnated activated carbon is the commonly used adsorbent. However, other adsorbent media demonstrated to perform equal to or better than impregnated activated carbons that meet all specification requirements are allowable. This section does not include the integration of the Type II cell into a complete air cleaning system mounting frame. Seismic qualification of the mounting frame is provided in Section FG.

FD-1130 DEFINITIONS AND TERMS

The following terms have special meaning in the content of this section.

adsorber cell/cell: a modular container for an adsorbent, with provision for sealing to a mounting frame, which can be used singly or in multiples to build up a system of any airflow capacity.

baffle: a nonperforated member oriented substantially perpendicular to the direction of airflow, connected to a wall or divider of the cell, and having the purpose of preventing wall effects and channeling.

bed/adsorber bed: a layer of adsorbent contained between two perforated sheets spaced at a specified distance; also, the assembly of perforated and nonperforated members that comprises the volume into which the adsorbent is packed.

blank/blank area: a nonperforated area within the perforated portions of a perforated sheet or screen.

channeling: a flow of gas or vapor through passages or areas of lower resistance that may occur within a bed due to nonuniform packing, segregation, irregular sizes or shapes of granules, or displacement of granules by direct impingement of high-velocity air.

margin: an unperforated area at the side or end of, or around the perforated area of, a perforated sheet or screen.

mechanical leak: the measure of the direct leakage through metal parts of the cell or its gasket due to defects.

penetration: the exit concentration of a given gas from an air cleaning device, expressed as percentage of inlet concentration.

refrigerant-11: trichloromonofluoromethane in accordance with ANSI/ASHRAE 34-89.

refrigerant-12: dichlorodifluoromethane in accordance with ANSI/ASHRAE 34-89.

residence time: the calculated time that a contaminant gas or vapor remains in contact with the adsorbent at a specified volume flow rate, based on net unbaffled screen areas and thickness of the bed.

through bolt: a bolt or other fastener that passes through the adsorbent bed.

wall effect: partial gas stream bypass of the adsorbent which occurs along an unbaffled metal to adsorbent interface.

ARTICLE FD-2000 REFERENCED DOCUMENTS

Common application documents referenced in this Code section are detailed in Article AA-2000. When ASTM material specifications are specified, the equivalent ASME material specification may be substituted. Where the date is not cited, the latest revision shall be used.

ANSI/ASHRAE 34-89, Number Designation and Safety Classification of Refrigerants[1]

Publisher: American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329

ASTM A 193, Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service

ASTM A 194, Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service

[1] May also be obtained from American National Standards Institute, (ANSI), 25 West 43rd Street, New York, NY 10036.

ASTM A 240, Specification for Heat-Resisting Chromium and Chromium–Nickel Stainless Steel Plate, Sheet, and Strip for Fusion-Weld Unfired Pressure Vessels

ASTM A 276, Specification for Stainless and Heat-Resisting Steel Bars and Shapes

ASTM A 320, Alloy Steel Bolting Materials for Low-Temperature Service

ASTM A 380, Specification for Cleaning and Descaling Stainless Steel Parts, Equipment, and Systems

ASTM A 479, Specification for Stainless and Heat-Resisting Steel Wires, Bars, and Shapes for Use in Boilers and Other Pressure Vessels

ASTM D 1056-85, Specification for Flexible Cellular Materials — Sponge or Expanded Rubber

Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

ARTICLE FD-3000
MATERIALS

FD-3100 ALLOWABLE MATERIALS

FD-3110 ADSORBENT

The adsorbent material used in these cells shall be in full compliance with Section FF.

FD-3120 SCREENS

Screen material shall meet the requirements of ASTM A 240, Type 304. Perforation shall be round and arranged in standard IPA (International Perforators Association) Pattern No. 105; hole size diameter shall be 0.045 in. maximum; open area of the perforated portion of the screen shall be 35% ± 5%. Margins and blank areas shall be as specified in Article FD-4000.

FD-3130 CASING

Casing material shall meet the requirements of ASTM A 240 (Type 304). The material thickness shall be as stated in Article FD-4000. Handles, spacers, and baffles shall meet the requirements of ASTM A 240 or ASTM A 479 as appropriate.

FD-3140 GASKETS AND SEAL PADS

The material for these parts shall be a closed cell neoprene or silicone rubber sponge, Grade SCE-43E1 or SCE-44E1, in accordance with ASTM D 1056.

FD-3150 ADHESIVE

Adhesive used to splice gaskets or to fasten gasket to cell shall be compatible with gasket material and appropriate to intended application.

FD-3160 THREADED FASTENERS

Bolting material shall be in accordance with ASTM A 320, Grade B8; or ASTM A 193, Grade B8. Nuts for use with this bolting material shall be in accordance with ASTM A 194, Grade 8.

FD-3170 RIVETS

When rivets are used for fabrication or attachment of fill ports, they shall be austenitic steel meeting the minimum requirements of Type 303. If there is a potential ''mechanical leak'' path, the rivets shall be closed-end type of construction.

FD-3200 LIMITS

Materials of construction for the Type II cell are limited to those materials herein specified. No caulking or sealing materials are allowed in the fabrication of these cells.

FD-3300 CERTIFICATION OF MATERIALS

Documentation for adsorbent media shall conform as specified in Section FF.

Certification for parts, material, and components shall be supplied to the purchaser as required below.

FD-3310 METAL PARTS

The cell manufacturers shall obtain certified test reports that the material, except for the handles, conforms to the appropriate standards of FD-3100. Handles serve an auxiliary function not critical to the performance of the cell.

FD-3320 GASKETS AND SEAL PADS

Certificate of Conformance to ASTM D 1056 is required for gaskets and/or seal pads.

FD-3330 ADHESIVE

No certification is required.

FD-3340 THREADED FASTENERS

Certificate of Conformance is required.

FD-3350 HARDWARE ITEMS (WASHERS AND RIVETS)

Certificate of Conformance is required.

ARTICLE FD-4000
DESIGN

FD-4100 GENERAL DESIGN

The cell shall consist of 2 in. thick (50.8 mm) minimum adsorbent beds in a modular unit as shown in Fig. FD-4100. Alternatively, the cell may be of a ‘‘wraparound’’ type, wherein all beds are perpendicular to direction of airflow.

The beds shall be enclosed by a nonperforated case on three sides (except for alternate design) and a faceplate on the fourth side. The cell shall be installed horizontally in a cabinetlike mounting frame to which the faceplate is clamped and sealed. Handles are provided on the front of the cell to facilitate handling and installation.

FD-4200 TECHNICAL REQUIREMENTS

FD-4210 DESIGN REQUIREMENTS

The cell shall meet the following specifications. When filled with sorbent, the cell shall have a minimum residence time of 0.25 sec at rated capacity of 333 cfm (9.43 m^3/min). The residence time shall be determined by the procedure in Mandatory Appendix I. The filled cell shall have a maximum airflow resistance of 1.25 in. wg (0.31 kPa) when tested at rated flow.

FD-4220 ADSORBER BED

(a) The adsorber bed shall consist of a volume bounded by perforated sheets and solid metal. Nowhere shall the adsorber bed be less than 2 in. (50.8 mm) thick. Adsorber frames shall be solid metal, and perforated sheets shall be fastened to the solid metal by welding. A minimum of $\frac{1}{2}$ in. (12.7 mm) solid margin shall be provided at perforated sheet-to-solid side interface.

(b) Frame corners shall be welded to provide a seal. The beds shall have internal spacers extending the full width and depth of the bed, or other such means of maintaining bed thickness and minimizing distortion when the cell is filled. If spacers are used, they shall have $\frac{1}{2}$ in. ± $\frac{1}{16}$ in. (12.7 mm ± 1.6 mm) baffles to prevent channeling. If through bolts are used, a $\frac{1}{2}$ in. (12.7 mm) baffle, minimum, shall be provided.

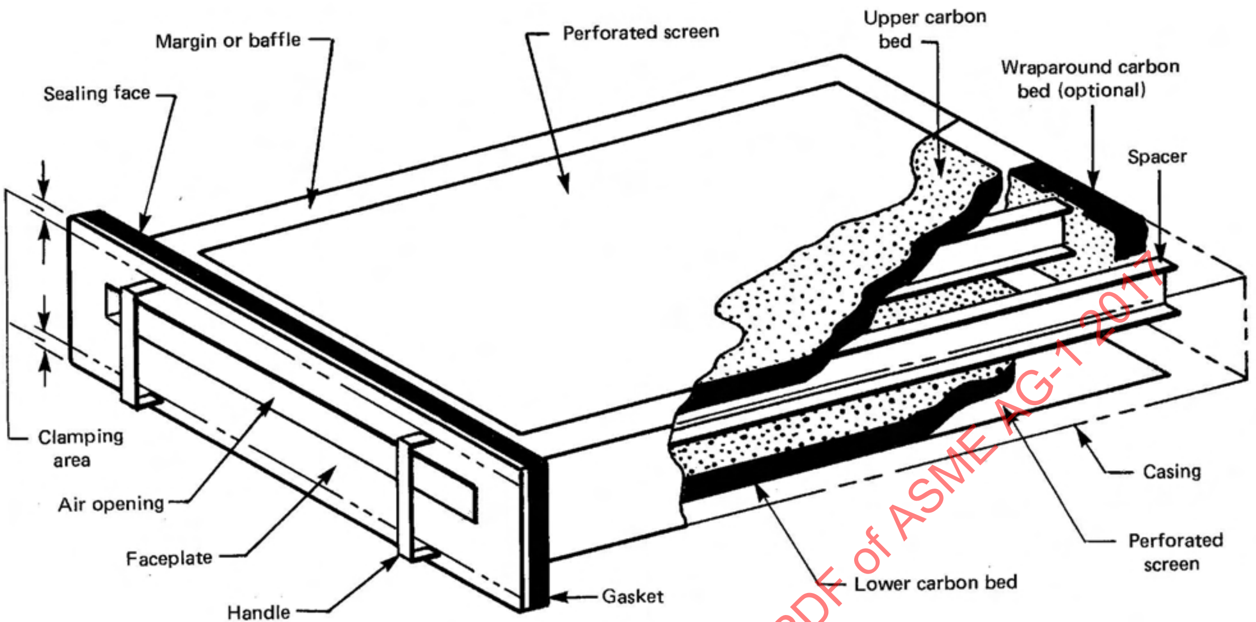
FD-4230 CASE AND ASSEMBLY

(a) The case form shall be made from nonperforated sheet and shall be formed and assembled in such a manner that no bypassing of the adsorbent beds is possible.

(b) The faceplate shall be interlocked with or welded to the bed assemblies (if separate) in such a manner that no bypassing, wall effect, or channeling is possible under service conditions. It is not intended that the cell faceplate support the weight of the installed cell. Handles shall be formed, attached by welding, and finished so they present no hazard to personnel and do not interfere with clamping of the cell into its mounting frame. The faceplate may be either welded or bolted to the body assembly. If welded, a filling hatch shall be provided in the body of the cell. If bolted, a seal pad shall be provided between the faceplate and cell body to seal this interface and impose a pressure on the adsorbent bed. The seal pad may be attached to the faceplate with adhesive or may be held mechanically, and the outer edge of the seal pad may be extended to form the gasket for sealing the cell into its mounting frame. If seal pads are not used, a one-piece gasket or a gasket formed from four strips with interlocking keyhole or dovetail corners shall be used. Gaskets shall be $\frac{3}{4}$ in. (19.1 mm) wide and $\frac{1}{4}$ in. (6.4 mm) thick; all excess adhesive shall be removed from visible surfaces of the gasket before it dries. No caulking compounds or sealants shall be used in the manufacture and assembly of cells.

(c) The faceplate design shall provide a 1 in. (25.4 mm) wide clear edge for clamping as depicted in Fig. FD-4100 to interface with standard mounting frame design.

FIG. FD-4100 TYPE II ADSORBER CELL



FD-4300 STRUCTURAL REQUIREMENTS

FD-4310 GENERAL

The Type II cells shall be designed in accordance with the structural requirements given in Article AA-4000 or qualified by test in accordance with AA-4350.

FD-4320 LOAD DEFINITION

Loads to be considered in the structural design of the Type II adsorber cells defined in AA-4211 are as follows:

(a) Deadweight (DW) consists of the metal enclosure that contains the adsorbent, bolting integral to the cell, and the adsorbent media. Instrumentation and ancillary equipment attached to the cell are treated as external loads (EL).

(b) The pressure (NOPD) differential that must be considered is from the upstream to downstream side of the media bed. This differential is a maximum of 1.25 in. wg (0.31 kPa) at rated airflows.

(c) The seismic acceleration and response spectra (OBE and SSE) shall be as provided in the design specification. Additional dynamic loads (ADL) will also be provided by the design specification as applicable.

FD-4330 LOAD COMBINATIONS

Unless stated otherwise in the design specification, the applicable loading conditions noted in Table AA-4212 for Type II cells are as follows:

(a) Service Level A: DW + EL + NOPD

(b) Service Level B: DW + EL + NOPD + OBE

(c) Service Level C: DW + EL + NOPD + SSE + ADL

(d) Service Level D: not applicable

FD-4340 ACCEPTANCE CRITERIA

FD-4341 Design by Analysis

If designed by analysis, the acceptance criteria are as listed in Table AA-4321. The design stress values S shall be $0.6S_y$.

FD-4342 Qualification by Test

If qualified by test, the acceptance criteria are

(a) no structural damage shall be evident by visual examination

(b) airflow resistance and refrigerant leak requirements of FD-5330 shall be met

ARTICLE FD-5000 INSPECTION AND TESTING

Inspection and testing of the Type II cell shall conform to the requirements of this section and to specific requirements set forth in Article AA-5000.

FD-5100 DIMENSIONAL INSPECTION

Overall dimensions shall be inspected to determine conformance to drawing requirements. Each cell shall be inspected to ensure it conforms to all dimensional requirements. Location and placement of stiffeners, supports, baffles, and handles shall be inspected to determine conformance to design requirements.

FD-5200 WELDING INSPECTION

FD-5210 SPOT WELDS

Spot welds shall be visually inspected in accordance with AA-6332.

FD-5220 OTHER WELDS

Fillet welds, butt welds, and seal welds shall be visually inspected in accordance with AA-6331.

FD-5300 QUALIFICATION TESTS

The cell design and filling method shall be qualified as outlined below. Equipment Manufacturer's requalification shall be required every 5 yr and if there is any change in design, filling procedure, or the adsorbent's physical properties.

FD-5310 DESIGN QUALIFICATION

Four cells shall be selected at random, filled with sorbent of the specified mesh size by the proposed filling method (FD-6300), and hard-mounted in the cells' service orientation to a rough handling machine. This machine shall have sharp cutoff cams and be capable of vibrating the mounted cell at a frequency of 200 cycles per min at an amplitude of $^3/_4$ in. ± $^1/_{32}$ in. (19.05 mm ± 0.08 mm) for a minimum of 10 min. After vibration testing, the test cell shall be inspected and there shall be no broken welds or other physical damage as a result of this test.

FD-5320 FILLING METHOD QUALIFICATION

Four cells shall be selected at random, filled with an adsorbent of the specified mesh size and hardness using the proposed filling method. The test cells shall be hard-mounted to a rough handling machine oriented with the fill at the top, and vibrated for 10 min at a frequency of 200 cycles per min at an amplitude of $^3/_4$ in. (19.05 mm). After rough handling, the fill port(s) shall be opened and the level of adsorbent in the cell examined. The level shall not have dropped more than one-half of the baffler or margin width perpendicular to the adsorbent surface. Three cells with fill parts reinstalled shall be moved in the same orientation as rough handled to a test tunnel. Care must be taken to avoid disturbing the adsorbent granules. Each cell shall be leak-tested in accordance with FD-5332, except that the cell is oriented with filling port up. If any one of the cells leaks, it may be replaced with the remaining cell. If any one of the three cells finally tested leaks, or if loss of adsorbent or excessive settling of adsorbent occurs in any of the four cells, the filling procedure shall be judged not qualified and must be adjusted as necessary; the tests shall be repeated. Airflow resistance shall not increase by more than 20% as a result of rough handling when tested in accordance with FD-5331.

FD-5330 ACCEPTANCE TESTS

Each cell to be delivered to the purchaser shall be tested for airflow resistance and refrigerant leak test.

FD-5331 Airflow Resistance Test

Install cell in test tunnel in its service orientation and adjust airflow through cell to 333 scfm ± 17 scfm (9.43 m^3/min ± 5.18 m^3/min). Airflow resistance shall not exceed 1.25 in. wg (0.31 kPa). Cells that do not meet this criteria shall be rejected.

FD-5332 Refrigerant Leak Test

Install cell in test tunnel in its service orientation, and adjust airflow to 333 scfm ± 17 scfm (9.43 m^3/min ± 5.18 m^3/min). The cell shall be tested with one of the refrigerants shown in Table FD-5332 with an inlet concentration of not less than 10,000 times the minimum sensitivity of the instrument. The instrument shall have a minimum sensitivity of the value specified in Table FD-5332 and it shall be essentially insensitive to hydrocarbons.

The refrigerant injection port shall be located in such a manner as to ensure proper mixing of the refrigerant. The downstream test port shall be located in such a manner as to ensure that a representative sample is obtained. Qualification data verifying location of injection and test port shall be on file and available for inspection.

Performance of the test consists of operating the test tunnel at rated flow rate and injecting the chosen refrigerant continuously in a concentration conforming to the above requirements. When a single detector is used, at least three upstream and three downstream determinations shall be made at intervals of approximately 1 min. However, the first determination shall not be made prior to 30 sec after start of injection of refrigerant gas. During the test the downstream concentration of the refrigerant gas shall not exceed 0.001 times the upstream concentration. Cells that do not meet this requirement shall be rejected.

TABLE FD-5332
DETECTOR SENSITIVITY FOR LEAK TEST

Refrigerant	Minimum Sensitivity (vppm)
R-11	0.0005
R-12	0.05

ARTICLE FD-6000
FABRICATION

The cells shall be fabricated using only those materials designated in Article FD-3000 and in accordance with the design outlined in Article FD-4000. All welding shall be in accordance with FD-6200. After manufacture, the cell shall be tested and inspected in accordance with Article FD-5000.

FD-6100 DIMENSIONS AND TOLERANCES

The cell shall conform to the requirements in Table FD-6100.

TABLE FD-6100
CELL DIMENSIONS AND TOLERANCES

Faceplate	Width, in. (mm)	$25^3/_4 \pm {}^1/_{16}$ (654 ± 1.6)
	Height, in. (mm)	$7^3/_4 \pm {}^1/_{16}$ (197 ± 1.6)
Body (Less Gasket)	Width, in. (mm)	24 + 0/–$^1/_8$ (610 + 0/–3.2)
	Height, in. (mm)	$6^1/_4$ + 0/–$^1/_8$ (160 + 0/–3.2)
	Depth, in. (mm)	30 (762), max.

GENERAL NOTES:
(a) Bed Thickness: 2 in. (50.8 mm) minimum between inside surfaces of screens of each bed.
(b) Bed Screen Displacement: ±$^1/_8$ in. (±3.2 mm) from manufacturing tolerance after cell is filled with adsorbent.

FD-6200 WELDING AND BRAZING

Procedure qualification, personnel qualification, and performance of welding and brazing during fabrication and installation shall be in accordance with AA-6300.

FD-6210 TESTING AND INSPECTION

Testing and inspection of welding and brazing utilized in fabrication and installation shall be performed in accordance with Article AA-6000.

FD-6220 REPAIRS

Weldments, brazements, or portions thereof that do not meet the acceptance criteria defined in Article AA-6000 shall be removed and rewelded or rebrazed in accordance with the original requirements.

Damaged gaskets shall be replaced. Damaged screens or material shall be replaced.

FD-6300 FILLING

Cells shall be filled with adsorbent specified by the purchaser using a filling method qualified in accordance with FD-5320. After filling, adsorbent fines shall be removed from the beds by blowing with clean, dry, oil-free compressed air or by vacuuming. After filling, each cell shall be tested in accordance with FD-5330.

FD-6400 CLEANING

Metal surfaces shall be cleaned and degreased in accordance with ASTM A 680 before any welding, installation of gaskets or seal pads, filling with adsorbent.

ARTICLE FD-7000
PACKAGING AND SHIPPING

FD-7100 PACKAGING

Each cell shall be individually wrapped and enclosed in a sealed plastic bag that is moisture and water-vapor resistant from −30°F to +140°F (−34.4°C to +60°C). The wrapped cell shall, in turn, be enclosed in a wood or heavy fiberboard carton with internal cushioning to dampen shock and vibration under accelerations up to 50 g. Cells shall be oriented in the carton or crate with screens horizontal. The cartons or crates shall be clearly marked with the legend ‘‘This Side Up’’ or similar imprint to ensure proper orientation of cartons and crates during handling, shipping, and storage.

FD-7200 LOADING FOR SHIPMENT

Cartons shall be banded to skids or pallets in the orientation specified in FD-7100. Wood separators and strapping protectors shall be provided between tiers of cartons and above the topmost cartons in the load. Sufficient strapping shall be used to prevent shifting of stacked cartons on the skid or pallet. Cells shall be stacked no higher than five tiers on a skid or pallet. Skids shall not be stacked more than two high unless bracing is provided to support the upper tiers to prevent damage to the bottom cells.

FD-7300 STORAGE

(a) Storage at all times (except during transit) shall be indoors in an area with

(1) ventilation

(2) minimum temperature of 40°F (4.4°C)

(3) maximum temperature of 120°F (48.9°C)

(4) minimum exposure to fume-producing materials or volatile organic solvents.

(b) Additionally

(1) Store filters in correct orientation (check marking arrows on cartons).

(2) Store filters in factory-packed cartons and do not remove until just prior to installation.

(3) Store filters such that tagging information is easily accessible.

FD-7400 CONTAINERS

The integrity of the packing container in general and the vapor container in particular should be maintained. Therefore, storage should not be near frequently traveled aisleways or corridors, near vibrating equipment, or among short-term storage items which require frequent personnel access. Care should be taken to avoid dropping or tipping of the storage containers.

ARTICLE FD-8000
QUALITY ASSURANCE

The Type II cell Manufacturer shall establish and comply with a quality assurance program and plan in accordance with Article AA-8000.

FD-8100 DOCUMENTATION

The following documentation shall be provided:

(a) table or drawing giving outline dimensions of the filter

(b) certified list of materials of construction

(c) adsorbent type with applicable test reports

(d) welder's qualification

(e) all qualification reports (seismic and filling method)

(f) certification of performance (resistance and leak test)

ARTICLE FD-9000
NAMEPLATES AND CERTIFICATION

(a) Each cell shall be legibly and permanently marked on the front of the faceplate or on a metal label affixed to the faceplate with the following information:

(1) Type II cell

(2) Manufacturer's name or symbol

(3) serial number

(4) month/year (of manufacture)

(5) empty weight

(b) Each cell shall bear a replaceable label with the following information:

(1) adsorbent Manufacturer's name or symbol

(2) adsorbent type and grade designation, lot, and batch

(3) filled weight

(4) adsorbent weight

(5) airflow resistance at specified airflow rating

(6) refrigerant leak test results

(7) date of filling

MANDATORY APPENDIX FD-I
CALCULATION OF RESIDENCE TIME OF ADSORBER CELLS

ARTICLE FD-I-1000 RESIDENCE TIME

Residence time, the theoretical time that the gas remains within the bed of the adsorber cell, at a specified airflow, by remaining in contact with the adsorbent, is calculated from the following equation:

Customary Units

$$T = \frac{t(A - B)}{28.8Q}$$

where

A = gross screen area of all screens on inlet side or outlet side, whichever is smaller, in.^{2}
B = total area of baffles, blanks, margins of all screens, in.^{2}
Q = total cell volumetric airflow, cfm
T = resident time, sec
t = thickness of bed, in.

SI Units

$$T = 3.6 \times 10^{-3} \frac{t(A - B)}{Q}$$

where

A = gross screen area of all screens on inlet side or outlet side, whichever is smaller, cm^2
B = total area of baffles, blanks, margins of all screens, cm^2
Q = total cell volumetric airflow, m^3/h
T = residence time, sec
t = thickness of bed, cm

NONMANDATORY APPENDIX FD-A
DIVISION OF RESPONSIBILITY

This Nonmandatory Appendix is intended to identify the roles normally assumed by the organizations responsible for fulfilling Code requirements when not specifically addressed in an article or subarticle. These are guidelines to assist with Code compliance and are not to be construed as legal or contractual responsibilities unless so invoked by the Owner or designee.

TABLE FD-A-1000
DIVISION OF RESPONSIBILITY

FD-	Item	Responsible Party
3000	Materials	Manufacturer/Owner
4000	Design	Manufacturer/Owner
5100	Physical testing	Manufacturer
5200	Radioactive testing	Manufacturer
5210	Qualification tests	Manufacturer
5220	Radioactive batch tests	Manufacturer
6000	Fabrication	Manufacturer
7100	Packaging and shipping	Manufacturer/Owner
7200	Storage	Owner
7300	Containers	Manufacturer/Owner
8000	Quality assurance	Manufacturer
8100	Documentation	Manufacturer
9000	Nameplate and certification	Manufacturer

SECTION FE
TYPE III ADSORBERS

ARTICLE FE-1000 INTRODUCTION

FE-1100 SCOPE

This section of the Code provides minimum requirements for the performance, design, testing, construction, and quality assurance of gas phase adsorber units used in nuclear safety-related air or gas treatment systems.

FE-1110 PURPOSE

The purpose of this section is to ensure that adsorbers used for nuclear safety-related air and gas treatment systems are acceptable in all aspects of performance, design, construction, and testing.

FE-1120 APPLICABILITY

FE-1121 Type III Adsorbers

The Type III adsorber is a gas phase adsorber characterized as being a single assembly, fixed and rechargeable in place, with an adsorbent.

FE-1122 Adsorbents

Because impregnated activated carbon is commonly used as a gas phase adsorbent media, only this adsorbent is specifically referenced in this Code. However, other adsorbent media demonstrated to perform equal to or better than impregnated activated carbons for all specification requirements are allowable.

FE-1123 Limitations

This section is not intended to include the application of the Type III adsorbers to power plant condenser off-gas systems, noble gas delay systems, or ventilation systems for ordinary cooling or heating.

FE-1124 Responsibility

The responsibility for meeting each requirement of this section shall be assigned by the Owner or designee. Appendix FE-B contains a suggested division of responsibility as a guide.

FE-1130 DEFINITIONS AND TERMS

Definitions that have common application are contained in Section AA of the Code. The following terms have special meaning in the context of this section.

adsorber/adsorber unit: an assembly of beds, baffles, supporting structural members, and auxiliary equipment that removes contaminants from an airstream constrained to pass through the adsorber.

baffle: a nonperforated member connected to a wall or divider of the bed to prevent wall effects or channeling.

bed/adsorber bed: a layer of adsorbent contained between two perforated sheets spaced at a specified distance. Also, the assembly of perforated and nonperforated members that comprises the volume into which the adsorbent is packed.

blank/blank area: a nonperforated area within the perforated portions of a perforated sheet or screen.

channeling: a flow of gas or vapor through passages or areas of lower resistance which may occur within a bed due to nonuniform packing, segregation, irregular sizes or shapes of granules, or displacement of granules by direct impingement of high-velocity air.

margin: an unperforated area at the side or end of a perforated sheet or screen.

mechanical leak: the measure of the direct leakage through metal parts of the adsorber or its joints due to defects in materials or fabrication methods.

penetration: the exit concentration of a given gas from an air cleaning device, expressed as percentage of inlet concentration of the gas.

refrigerant-11: trichloromonofluoromethane in accordance with ANSI/ASHRAE 34-89.

refrigerant-12: dichlorodifluoromethane in accordance with ANSI/ASHRAE 34-89.

residence time: the calculated time that a contaminant gas or vapor remains in contact with the adsorbent at a specified volume flow rate, based on net unbaffled screen area and thickness of the bed (see Appendix FE-I).

wall effect: partial gas stream bypass of the adsorbent that occurs along an unbaffled metal to adsorbent interface.

(09)

ARTICLE FE-2000 REFERENCED DOCUMENTS

Common application documents referenced in this Code section are detailed in Article AA-2000. Where ASTM material specifications are specified, the equivalent ASME material specification may be substituted. Where the date is not cited, the latest revision shall be used.

ANSI/ASHRAE 34-89, Number Designation and Safety Classification of Refrigerants[1]

Publisher: American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329

ASTM A 182, Specification for Forged or Rolled Alloy Steel Pipe Flanges, Forged Fittings and Valves and Parts for High Temperature Service

ASTM A 193, Specification for Alloy Steel Bolting Material for High Temperature Service

ASTM A 194, Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure and High Temperature Service

ASTM A 213, Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes

ASTM A 240, Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Fusion-Weld Unfired Pressure Vessels

ASTM A 269, Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

ASTM A 276, Specification for Stainless and Heat-Resisting Steel Bars and Shapes

ASTM A 312, Specification for Seamless and Welded Austenitic Stainless Steel Pipe

[1] May also be obtained from the American National Standards Institute (ANSI), 25 West 43rd Street, New York, NY 10036.

ASTM A 320, Specification for Alloy-Steel Bolting Materials for Low Temperature Service

ASTM A 351, Specification for Seamless Austenitic Steel Castings for High Temperature Service

ASTM A 376, Specification for Seamless Austenitic Steel Pipe for High Temperature Central Station Service

ASTM A 403, Specification for Factory-Made Wrought Austenitic Steel Welding Fittings

ASTM A 479, Specification for Stainless and Heat-Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels

ASTM A 511, Specification for Seamless Stainless Steel Tubing

ASTM A 554, Specification for Welded Stainless Steel Mechanical Tubing

ASTM D 903-49, Test Method for Peel or Stripping Strength of Adhesive Bonds (Revised 1983)

ASTM D 1056-85, Specification for Flexible Cellular Materials Sponge or Expanded Rubber

ASTM D 2000-80, Classification System for Rudder Products in Automotive Applications

ASTM D 2854-83, Test Method for Apparent Density of Activated Carbon

ASTM D 2862-82, Test Method for Particle Size Distribution of Granular Activated Carbon

Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

Designers, Specifiers, and Buyers Handbook for Perforated Metals

Publisher: Industrial Perforators Association (IPA), 5157 Deerhurst Crescent Circle, Boca Raton, FL 33486

ARTICLE FE-3000
MATERIALS

FE-3100 ALLOWABLE MATERIALS

FE-3110 ADSORBENT

Adsorbent materials used in Type III adsorbers shall be in compliance with Section FF of this Code.

FE-3120 SCREENS AND CASING

All material in contact with the adsorbent shall be stainless steel Type 304 or 304L.

FE-3130 GASKETS AND SEAL PADS

The material for these parts shall be closed-cell, ozone-resistant, neoprene or silicone rubber sponge Grade SCE-43E1 (or SCE-44E1) in accordance with ASTM D 1056.

FE-3140 OTHER COMPONENTS

Materials used in the fabrication of other components shall be selected in compliance with the following:

(a) stainless steel plate, sheet, and strip: ASTM A 240 **(09)**

(b) stainless steel bar and structurals: ASTM A 276 or A 479

(c) stainless steel tubing: ASTM A 511, A 554, A 213, or A 269

(d) stainless steel pipe: ASTM A 312 or A 376

(e) stainless steel fitting: ASTM A 182, A 351, or A 403

(f) stainless steel bolting: ASTM A 193, A 194, or A 320

(g) adhesives: ASTM D 903

ARTICLE FE-4000
DESIGN

FE-4100 GENERAL

FE-4110 TYPE III ADSORBERS

Type III adsorbers are characterized as consisting of single or multiple beds of activated carbon (adsorbent), fixed in place, and sized to process a given volume of air or gas. The bed is fabricated, using perforated sheet and structural pieces, into a welded assembly. Air enters the upstream face of the bed, passes through the packed adsorbent and exits from the downstream face. Figure FE-4110 illustrates a typical horizontal section for a Type III filter bed.

FE-4120 ADSORBER SERVICE EQUIPMENT

The Type III adsorber is loaded with adsorbent by means of the adsorbent service equipment that interfaces with the service openings or ports on the adsorber bed. It provides the means of loading bulk granular adsorbent into the adsorber bed. The method of loading shall ensure that the bed is uniformly filled.

FE-4121 Adsorbent Removal Equipment

The adsorbent service equipment also provides the means for removing spent adsorbent from the Type III adsorber. The service equipment shall include the necessary separating/filter capacity to control safety and health hazards arising from handling of the adsorbent. The spent adsorbent shall be containerized as specified for disposal.

FE-4200 TECHNICAL REQUIREMENTS

FE-4210 DESIGN CRITERIA

Design criteria for the following parameters shall be specified:

(a) type of gas to be treated
(b) volumetric flow rate (scfm)
(c) design pressure (internal and external)
(d) pressure-time transients
(e) temperature (operating range)
(f) relative humidity (operating range)
(g) contaminants to be removed
(h) adsorbent type
(i) required adsorber performance efficiency
(j) face velocity and bed thickness of the adsorbent or
(k) face velocity and residence time (see Appendix FE-I)
(l) component integrated radiation dose
(m) minimum and maximum pressure differential across the adsorber unit
(n) corrosion effects of contaminant, process gases or other potential sources (i.e., impregnants or other chemicals)
(o) seismic requirements
(p) adsorbent sampling requirements (quantity and frequency)
(q) spent adsorbent handling requirements
(r) fire protection requirements

FE-4220 SIZING

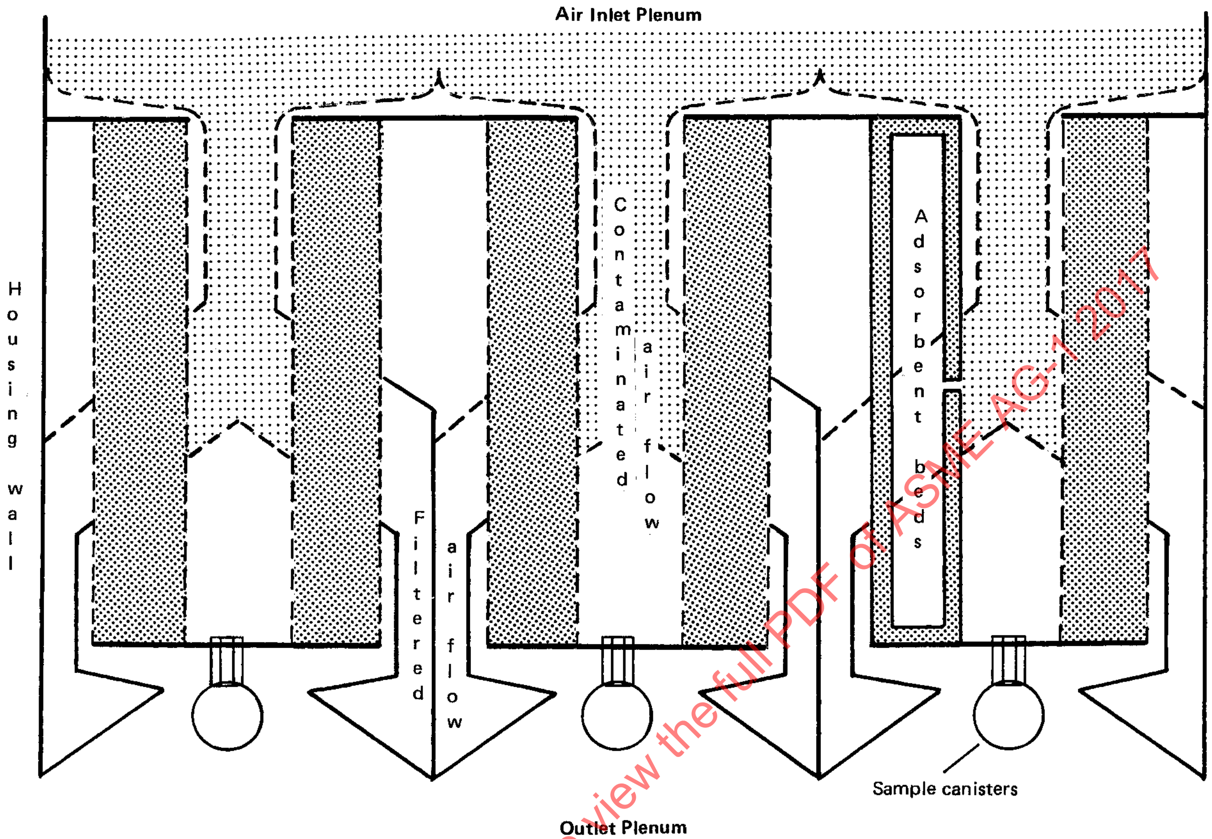
Each adsorber unit shall be sized to provide the specified total volumetric flow and meet the performance requirements as specified in FE-4210(i) and (j) or (k).

FE-4300 ADSORBENT BED DETAILS

(a) Each bed section shall consist of perforated sheets, spaced uniformly to form the bed. The sheets shall be assembled to a formed, nonperforated frame by welding. The frame, or a nonperforated margin on the sheet, shall be of such width as to prevent bypass. Each bed shall have 1 in. (25.4 mm) minimum margins in order to prevent wall effect in the gas flow. Location and placement of spacers, stiffeners, and supports shall be designed to ensure conformance to design requirements.

(b) The smooth side of the perforated sheet shall be in contact with the adsorbent.

FIG. FE-4110 HORIZONTAL SECTION OF TYPE III ADSORBER BED



(c) Caulking compounds or sealants shall not be used in the assembly of the beds or in the installation of the beds into the adsorber assembly.

(d) A reservoir of makeup adsorbent (to allow for settling) shall cover the entire top section of each bed. The reservoir shall have a minimum volume of adsorbent equivalent to 5% of the bed volume. The reservoir volume begins one design bed depth above the top perforation of any bed. Only that adsorbent above a bed that will flow freely into the bed shall be considered as part of the makeup reserve.

(e) The reservoir cover shall be designed to provide full access for filling and inspection. The reservoir cover shall have suitable handles and be secured to prevent gas leakage during normal operation. Gaskets shall conform to section FE-3130 and be compatible with the design criteria of FE-4210. Bolting patterns shall provide for uniform gasket compression in accordance with AA-4212.

(f) The adsorber unit shall be designed so that spent adsorbent can be removed and replaced. If vibration is required for fill/empty operations or to ensure uniform packing density, the vibrator shall be an integral part of the design and shall not affect the structural integrity of the adsorber unit.

(g) Provision shall be made to allow drainage of accumulated liquids from the adsorber. Such drains shall be designed to retain the adsorbent within the adsorber. Drains shall have a positive shutoff design that will preclude bypass or leakage of contaminated gases. Liquid drains shall be sized to accommodate the full flow rate of a fire deluge system if one is specified.

(h) Inspection and service openings shall be provided as necessary to allow access to the top of each adsorber section for visual examination and/or sample extraction.

FE-4400 STRUCTURAL REQUIREMENTS

FE-4410 GENERAL

The Type III adsorber shall be designed as a plate and shell type component using maximum stress theory in accordance with AA-4320 or by testing in accordance with AA-4350.

FE-4420 LOAD DEFINITION

Loads to be considered in the structural design of the Type III adsorber as defined in AA-4211 are as follows:

(a) Deadweight (DW) consists of the weight of the metal enclosure that contains the adsorbent, structural support members, all permanent hardware to service the bank and twice the expected adsorbent media. Instrumentation, test canisters, manifolds, and other like items shall be considered as external loads (EL).

(b) Normal operating pressure differential (NOPD) consists of the operating pressure across the bank from upstream to downstream of the adsorbent bed. This differential is normally a maximum of 0.62 in. wg (0.15 kPa) per inch of bed depth at rated flow.

(c) Seismic loads that are the result of either operating basis earthquake (OBE) or safe shutdown earthquake (SSE) shall be defined in the design specification. Additional dynamic loads (ADL), as required, will also be provided in the design specifications.

FE-4430 LOAD COMBINATIONS

The loading conditions (noted in Table AA-4212) for the Type III adsorber shall be defined as follows:

(a) Service Level A: DW + EL + NOPD

(b) Service Level B: DW + EL + NOPD + OBE

(c) Service Level C: DW + EL + NOPD + SSE + ADL

(d) Service Level D: not applicable

FE-4440 ACCEPTANCE CRITERIA

The allowable stress limits shall be calculated in accordance with Table AA-4321. Calculated design stress shall not exceed the allowable design stress of $S = 0.6S_y$.

FE-4500 ADSORBENT HANDLING SUBSYSTEMS

Adsorbent filling and emptying systems shall be designed as a compatible part of the Type III design.

FE-4510 ADSORBENT LOADING SYSTEM

FE-4511 Design

The adsorbent loading system shall be designed, tested, and qualified to meet the requirements of FE-4200. The design shall include provisions to receive, transport, and place bulk quantities of granular material with adequate containment of adsorbent fines. The design shall not adversely affect the particle size distribution of the adsorbent as discussed in Appendix FE-III. Design of this service equipment must take into consideration all operating conditions and requirements defined by the Owner. These should include access, toxicity of contaminants, and time required for changeout. Typical designs include pneumatic transfer systems and gravity feed hopper designs. Other methods that can be shown to meet the design criteria are also acceptable.

FE-4512 Loading

Loading systems shall provide for the uniform distribution and packing of adsorbent into the bed assembly. Packing characteristics of the loading system shall be demonstrated during qualification testing per FE-5620. Any design or process changes will require requalification.

FE-4513 Hoppers

Fill hopper designs shall match the adsorber service openings. Service opening to hopper connections shall include adequate seals or a containment system to control release of adsorbent fines.

FE-4520 ADSORBENT REMOVAL SYSTEM

Adsorbent removal connections from the adsorber beds shall be piped external to the filter housing and provided with a mechanically sealed, leak-tight closure system. The removal system or systems shall have a demonstrated capability for handling adsorbent that may be liquid saturated.

FE-4600 AUXILIARY SYSTEMS

FE-4610 ADSORBENT SAMPLING SYSTEMS

FE-4611 General

The Type III adsorber design shall include a means to obtain samples of the adsorbent. The preferred method is one which incorporates a set of sample canisters. Other methods or designs are acceptable if it can be shown (through Manufacturer's qualification testing) that they will provide representative sampling of the total bed thickness without introducing voids or bypass conditions.

FE-4612 Materials

Test canisters installed in adsorber units shall conform to the same material requirements as apply to the Type III adsorber.

FE-4613 Quantity

When test canisters are provided, there shall be a minimum of six canisters for each adsorber unit to support specified in-service testing.

FE-4614 Design Criteria

Test canister design shall be qualified in accordance with FE-5600. Test canisters shall be mounted such that the airflow is in a vertical direction and the effective flow rate is the same as the main bed. Canister bed depth, residence time, pressure drop, and the packing density of the canister adsorbent shall be the same as the adsorber. Filling methods shall be defined by the Manufacturer to ensure compliance with these requirements for initial and repeat filling operations. Documentation of qualification testing verifying compliance with these design criteria shall be provided.

FE-4615 Gaskets

The requirements for canister gaskets, seal pads, and adhesives shall be the same as those applying to other adsorber service openings.

FE-4620 FIRE PROTECTION

Fire protection is required and this function may be accomplished by any number of means, the simplest of which is to isolate the bed (stop the airflow, close all isolation dampers) and allow it to cool. Regardless of the type of fire protection system incorporated into the Type III adsorber, the Manufacturer shall provide a complete and comprehensive documentation package covering the proper care and response to fire conditions.

FE-4621 Temperature Sensors

Temperature sensors shall be installed in the gas stream, upstream and downstream of the Type III adsorber units. Detailed requirements are contained in Section IA.

FE-4622 Alternative Methods of Fire Detection

Other means of fire detection (CO, CO_2, smoke, or other types of detectors) that meet the reliability and sensitivity requirements of the system specification may be used. The active element(s) of any such system shall be properly located with respect to each bed to ensure coverage of the total bed as well as localized hot spots that may occur within the bed. This requirement can normally be satisfied by locating the detector in the gas stream, downstream of the adsorbent bed. Locating the sensor within the adsorbent bed is not permitted.

FE-4623 Fire Control Systems

FE-4623.1 Fire control systems for adsorbers are intended to limit the hazards associated with accidental ignition of the bed. Although infrequent, this may occur by internal heating or external causes (welding, etc.). In the event of ignition, control (and eventual cooling of the bed to less than 250°C) must be accomplished without release of significant contamination.

FE-4623.2 Fire control systems shall be designed and tested to demonstrate satisfactory performance under all anticipated accident situations. The design of the system shall consider not only the risk of fire, but shall also address such items as normal maintenance, accidental initiation, isolation, containment, cleanup, repair, reconditioning, and recertification of the bed. The preferred design incorporates automatic sensing and alarm of incipient ignition coupled with a manual activation of the fire control system after verification of the fire.

FE-4623.3 Gaseous blanketing/purge systems (N_2, CO_2, halogen, etc.) designed to smother a fire are preferred. They shall be designed to have sufficient capacity to fill all connected housings and ductwork (up to any isolation dampers) without overpressurizing the filter system. They shall also provide for monitoring the system leakage and supplying makeup gas as needed.

FE-4623.4 Water deluge piping systems, which may be required by other codes or specifications, shall be designed to saturate the adsorber media throughout the adsorber assembly, including the reservoir. Piping material shall be Type 304 or 304L series stainless steel in accordance with FE-3100. The deluge pipe system shall terminate on the exterior of the adsorber assembly or other remote location where it can be manually connected to the water supply system. Manual safety shutoff valves shall provide for isolation of the system until such time as it is temporarily connected to the water supply system. Connection to the water system shall be through a standard hose or jumper fitting. The deluge design shall provide a minimum water flow rate of 3.2 gal/cfm of adsorbent. Adsorber catch basins and drain pipes inside the adsorber assembly shall be designed to accommodate the full flow rate of the deluge system and be routed to an adequate drain.

ARTICLE FE-5000
INSPECTION AND TESTING

FE-5100 GENERAL

This section establishes the minimum requirements for inspection and testing of Type III adsorbers. Certain individual inspection items may require completion prior to final assembly and should be identified in the Manufacturer's plan. Documentation of all results shall be provided as required by FE-8200.

FE-5200 VISUAL INSPECTION

Type III adsorbers shall be visually inspected to ensure conformance with the requirements of Article FE-4000. Inspection shall be documented in accordance with Article AA-8000. A suggested checklist for visual inspection is contained in Appendix FE-A.

FE-5300 DIMENSIONAL INSPECTION

The Type III adsorber shall be inspected to determine conformance to design drawings.

FE-5310 BED DEPTH

Measurements of the adsorbent bed depth, including the contributing effects of screen waviness, shall be made to determine that it conforms to design requirements.

FE-5320 SCREENS

All perforated or screen areas shall be inspected for screen waviness in accordance with Appendix FE-II. This inspection is to be performed at the subassembly level of the bed to ensure access to all screens and to determine that the ''smooth'' side contacts the adsorbent.

FE-5330 ADSORBENT RESERVOIR

The adsorbent reservoir shall be inspected to determine conformance to design requirements. Necessary measurements and volume calculations shall be included in the inspection report to demonstrate compliance with the design criteria.

FE-5400 WELDING INSPECTION

FE-5410 SPOT WELDS

Spot welds shall be inspected per AA-6332.

FE-5420 SEAL WELDS

Seal welds and structural welds shall be inspected per AA-6331.

FE-5500 FABRICATION TOLERANCES

Tolerances for the fabrication of the adsorber beds shall be in compliance with the requirements in Appendix FE-II.

FE-5600 DESIGN QUALIFICATION

The adsorber unit performance and filling method shall be qualified as outlined in the mandatory appendices. All qualification testing shall include the test canisters (if applicable) as an integral part of the adsorber unit design. Modular units, representative in all functional and dimensional aspects (i.e., full size), shall be used for testing. Requalification shall be required if there are any changes in design, filling procedure (i.e., feed rate, vertical fall, vibration), or adsorbent physical properties.

FE-5610 FUNCTIONAL DESIGN QUALIFICATION

The adsorber design shall be tested and qualified in accordance with Appendix FE-IV. Deviation from specified acceptance criteria shall be cause for rejection of design.

FE-5620 FILLING METHOD QUALIFICATION

The adsorber unit filling method shall be tested and qualified in accordance with Appendix FE-III. Failure to meet specified acceptance criteria shall cause the filling method to be adjusted as necessary; both the performance and filling test shall be repeated.

FE-5630 SEISMIC QUALIFICATION

Each design shall meet the Owner's specified seismic requirements. Seismic analysis/testing shall be performed to the requirements of Article AA-4000.

FE-5700 ACCEPTANCE TESTS

The completed adsorber unit shall be tested for acceptance in accordance with AA-5700 and this section of the Code.

ARTICLE FE-6000
FABRICATION AND INSTALLATION

FE-6100 GENERAL

The fabrication and assembly of Type III adsorbers shall be performed in accordance with Owner approved design drawings and industry standards.

FE-6200 WELDING

All welding and welder qualifications shall be in accordance with the requirements of AA-6300.

FE-6300 CLEANING

All surfaces shall be cleaned prior to acceptance. No halogen bearing materials nor carbon steel tools shall be used to clean the stainless steel surfaces. Cleaning shall be performed in accordance with the procedures contained in Article AA-6000 and the Manufacturer's written procedure.

FE-6400 CONSTRUCTION AND INSTALLATION

The Type III adsorber shall be seal welded into the air cleaning component housing. All seal welds shall be accessible for inspection and repairs once the beds are in place.

FE-6500 REPAIRS

Should the screen of a Type III adsorber be damaged or defective, repair procedures shall be developed by the Manufacturer. The repair of small tears or burn-through holes can be patched by welding a piece of perforated material (at least $\frac{1}{2}$ in. larger than the defect) over the defect. The perforations in the patch should be aligned with those in the base material. Precautions against damaging the base screen during welding (such as the use of a copper backup plate) shall be taken.

ARTICLE FE-7000
PACKAGING AND SHIPPING

FE-7100 TYPE III ADSORBERS

Packaging, shipping, and storage of Type III adsorbers shall be in accordance with ASME NQA-1 Level C criteria. Type III adsorbers shall not be shipped with adsorbent in place.

FE-7200 ADSORBENT MATERIALS

The requirements are detailed in Section FF and as specified by the Owner.

ARTICLE FE-8000
QUALITY ASSURANCE

FE-8100 GENERAL

Quality assurance shall be in accordance with Article AA-8000 of this Code. The Manufacturer of this equipment shall develop and maintain a QA program acceptable to the Owner and provide required documentation as requested.

FE-8200 INSPECTION REPORTS AND DOCUMENTATION

The inspection reports and other documents to be provided in the documentation package are as follows:

(*a*) net bed area certification
(*b*) residence time calculations
(*c*) certificates of compliance on all materials
(*d*) certificate of conformance to this Code and purchase specifications
(*e*) nonconformance reports and resolutions
(*f*) qualifications reports (including type of adsorbent used)
(*g*) operational, maintenance, and repair manuals/procedures
(*h*) drawing package sufficient to support field testing, inspection, and repairs
(*i*) welder's qualification documentation

ARTICLE FE-9000
NAMEPLATES

FE-9100 PERMANENT NAMEPLATES

Each Type III adsorber shall be legibly and permanently marked with either a nameplate affixed to a wall or by metal stamping on the wall of the adsorber assembly. Such marking shall be done in a manner that is accessible and will not damage the structural integrity of the adsorber unit. The preferred location is on the downstream side of the adsorber. An additional nameplate shall be prepared and furnished for attachment to the exterior of the filter housing after final assembly.

The nameplate shall include the following information as a minimum:

TYPE III ADSORBER

MANUFACTURED IN ACCORDANCE WITH ASME CODE: (CODE NUMBER AND DATE)

BY: (MANUFACTURER'S NAME OR SYMBOL)

ADSORBER ASSEMBLY SERIAL NUMBER: ____________

RATED FLOW CAPACITY OF ADSORBER: ____________ scfm

DESIGN BED DEPTH: ____________ in.

ADSORBENT BED VOLUME: ____________ ft^3

FE-9200 FILLING LABEL

Each Type III adsorber shall be provided with a replaceable label to record the following information at the time of filling:

(a) adsorbent Manufacturer's name (and symbol if applicable)

(b) adsorbent type and grade designation, lot, and batch

(c) adsorbent density and weight of fill

(d) airflow resistance at specified airflow rating after filling

(e) refrigerant penetration test results of bed and canisters

(f) date of filling

(g) by whom filled

Test canisters shall be similarly labeled at the time of filling.

MANDATORY APPENDIX FE-I
RESIDENCE TIME CALCULATION

ARTICLE FE-I-1000
CALCULATION OF
RESIDENCE TIME OF ADSORBERS

The residence time T is calculated for a specific application by the following:

$$T = \frac{t(A - B)}{K \cdot Q} \quad (1)$$

where

A = gross screen area of all screens on inlet side or outlet side, whichever is smaller, $in.^2$

B = total area of baffles, blanks, margins of all screens, $in.^2$

K = conversion factor of (28.8), $in.^3\ min/ft^3\ sec$

Q = total cell volumetric airflow, cfm

T = resident time, sec

t = thickness of bed, in.

MANDATORY APPENDIX FE-II
SCREEN WAVINESS INSPECTION TEST

ARTICLE FE-II-1000
SCREEN WAVINESS

Screen waviness is a major concern for two reasons. Excessive waviness indicates too much variation in bed depth, and/or the minimum bed depth may be less than the design thickness.

ARTICLE FE-II-2000
PROCEDURE

Each section should be checked as follows:

(a) Lay a flat edge across the screen to identify any depressions of more than 5% of bed depth.

(b) Carefully note the associated low points and high points.

(c) Check both the low points and high points for bed depth using a bed depth probe. The bed depth probe is a small diameter rod that is sufficiently rigid yet will pass through the holes of the screen.

The length of the rod passing perpendicularly through the plane of one screen and touching the face of the opposite screen provides a measure of bed depth. The thickness of the screen may be neglected.

ARTICLE FE-II-3000
ACCEPTANCE CRITERIA

If the bed depth varies by more than plus/minus of the design bed depth, the assembly is unacceptable and corrective action is required.

MANDATORY APPENDIX FE-III
ADSORBER FILLING QUALIFICATION TEST PROCEDURE

ARTICLE FE-III-1000 SCOPE

This procedure describes the method for determining the effectiveness of candidate filling methods for Type III adsorbers.

ARTICLE FE-III-2000
PURPOSE

The purpose of this procedure is to ensure that the filling method is qualified for a Manufacturer's design.

ARTICLE FE-III-3000

The filling method shall be qualified by the following procedures. The objective of qualifying the filling method is to ensure that the resulting as-filled density of the adsorbent meets the specifications of Section FF. To ensure this, the same adsorber unit tested under Appendix FE-IV shall be tested to show compatibility of design with fill method.

ARTICLE FE-III-4000
PROCEDURE

FE-III-4100 ADSORBENT CHARACTERISTICS

Before filling the Type III adsorber with the specified adsorbent, the apparent density and adsorbent size distribution of the adsorbent shall be determined by ASTM D 2854 and ASTM D 2862. At least one sample shall be taken from each drum for testing.

FE-III-4110 BED VOLUME

Calculate total bed volume, including bottom hopper and top reservoir. These calculations are to be based on approved production drawing dimensions, which have been verified by inspection measurements.

FE-III-4120 ADSORBENT WEIGHT

Charge the Type III adsorber with adsorbent, recording the weight of adsorbent used to fill the bed to its design level.

FE-III-4130 PARTICLE SIZE DISTRIBUTION

After the adsorber is filled, samples shall be taken from at least three different locations within each bed section (bottom, middle, and top). A determination of particle size distribution of each sample shall be made according to ASTM D 2862. The numbering of samples shall be large enough to provide a statistically significant distribution. The method of sample extraction shall be specified by the Manufacturer, and should provide repeatable sample results within ±5%.

FE-III-4200 PACKING DENSITY

The packing density of the bed shall be calculated as follows:

$$CP = \frac{W - L}{V_B} \qquad (1)$$

where

CP = packing density, lb/ft^3
L = loss attributed to adsorbent fines or dusting, lb
V_B = measured bed volume, ft^3
W = measured weight of adsorbent in the bed (less moisture content), lb

FE-III-4300 ADSORBENT LOSSES

The filling process is a major contributor to the generation of dust or ''adsorbent fines.'' These fines result from the breakdown of the adsorbent by abrasion or through mechanical handling. Excessive generation of fines may result in significant variation of the adsorbent size distribution from initial values. The weight of these fines (those that are easily extracted from the bed) must be subtracted from the bed weight to obtain a true value of the bed packing density.

Therefore, as part of the adsorber qualification, after filling, any visible fines shall be collected by vacuum cleaning the beds and other areas of collecting with a cleaning system incorporating a high efficiency filter (HEPA). In those systems using pneumatic transfer for filling, the transfer/dust separator filter may be used. The net change in weight of the HEPA filter shall be used as the weight of fines generated for use in eq. (1).

ARTICLE FE-III-5000
QUALIFICATION REPORTS

The following information shall be reported:

(*a*) the results of all calculations and tests

(*b*) a detailed filling procedure

(*c*) the feed rate of the adsorbent

(*d*) the adsorbent size distribution of the samples and their associated bed location

ARTICLE FE-III-6000
ACCEPTANCE CRITERIA

The following acceptance criteria shall apply:

(a) The packing density shall be within ±10% of the average density, per ASTM D 2854.

(b) Adsorbent size distribution shall be within ±5% of the adsorbent particle size distribution of the original samples (see FE-III-4100).

MANDATORY APPENDIX FE-IV
TYPE III ADSORBER QUALIFICATION TEST PROCEDURE

ARTICLE FE-IV-1000 SCOPE

This procedure describes a method for determining the effectiveness of Type III adsorbers in removing contaminants by ensuring that the entire bed contributes to the removal. Alternate methods that can be shown to accomplish the purpose of this procedure with acceptable results may be used with the agreement of all parties.

ARTICLE FE-IV-2000
PURPOSE

The purpose of this test procedure is to ensure that the adsorber bed design uniformly removes a gaseous contaminant from the airflow passing through the bed. This qualification procedure describes a method of challenging an adsorber bed wtih a stimulant until breakthrough occurs.

ARTICLE FE-IV-3000 THEORY

Activated carbon has an adsorptive capacity for many different contaminants, each with a different degree of retention. By choosing an adsorbate that is safe to handle as well as having the correct adsorption characteristics, an adsorption test can be run in a relatively short time.

For a fixed length (depth) adsorbent bed, the adsorbate distribution in the adsorbent bed after several periods of steady operation will follow a definite pattern that can be illustrated by the following discussion.

Curve 1 of Fig. FE-IV-3000 illustrates the adsorbent concentration in the adsorbent shortly after the start of the adsorption process in a fresh bed. The adsorbate concentration approaches zero in a relatively short distance downstream of the entry face. Theoretically, zero concentration is attained only at infinite bed length, but for practical purposes, concentrations of 0.01% of the inlet concentration, C_i, or lower are considered essentially zero, hence the ability of an adsorber to be effective with a finite bed length.

If the addition of adsorbate continues for an additional period, the adsorbate distribution curve could be illustrated in Curve 2.

This method of analysis of a carbon bed is on the following principles:

(*a*) that the distribution of the adsorbate within the bed is a function of depth, i.e., that the curve moves into the bed in a linear fashion

(*b*) that the adsorbate/airflow through the bed can be interrupted and the bed media sampled such that the distribution is undisturbed

(*c*) that this sample taken from the bed can be sliced into thin layers, starting at the inlet face and ending at the outlet face

(*d*) that each slice can be tested for percent of saturation, i.e., for how much adsorbate it contains in relation to its saturation capacity (percentage of C_i)

(*e*) that the percentage of C_i versus the original position of the sample slice (depth) is representative of the adsorbate distribution curve

As adsorption is continued, the distribution curve ultimately stops lengthening and reaches a steady state. Curve 3 shows the distribution curve when it has just attained saturation at the inlet face. Note that the major portion of the bed has essentially zero adsorbate. Curve 4 shows a condition when the 100% saturation zone L_S has moved into the bed some distance. The curve length L_Z in the direction of gas flow represents a complete (0% to 100%) saturation distribution curve and is called the adsorption mass transfer zone *MTZ*. At that point in the operation of the filter (total operating time), for all of the bed upstream of the *MTZ*. L_S, the adsorption and desorption rates are essentially equal and the L_S zone is at equilibrium (saturated) with the influent concentration C_i. If adsorption is continued, the *MTZ* ultimately breaks through the downstream face of the bed as illustrated by the lower end of Curve 5. Length L_Z has remained constant but L_S has increased.

The mass transfer zone can be calculated using eq. (1) and some experimental data for each bed design of interest.

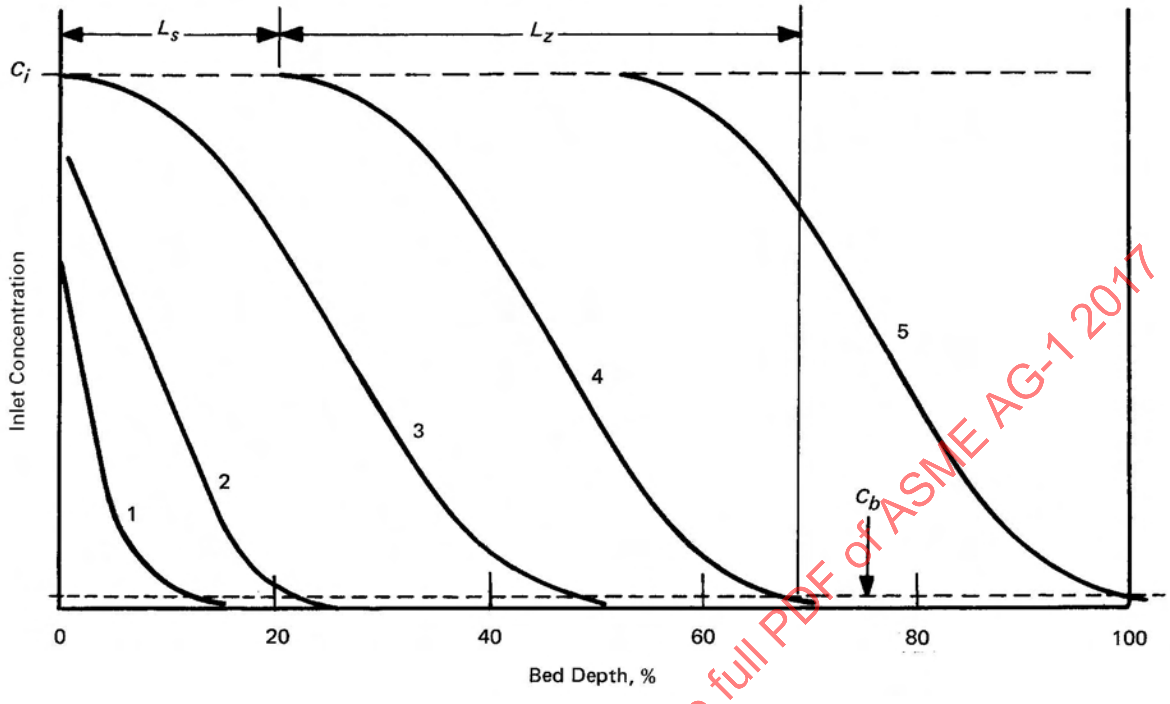
$$tb = \frac{W_S dA}{FC_i} \times [Lt(1 - f)L_Z] \quad (1)$$

where

A = effective bed face area, ft^2
d = adsorbent bulk density, lb/ft^3
C_i = inlet contaminant concentration, lb/lb of air
F = mass flow rate, lb air/unit time
f = constant — depending on the allowable (desired) breakthrough concentration C_b for the selected simulant, 0.5 in the example using H_2O
Lt = total bed depth, in.
L_z = length of *MTZ*, L_z in Fig. FE-IV-3000
tb = breakthrough time, time unit (sec, min, or hr)
Ws = adsorption capacity of adsorbent for contaminant, lb/lb of adsorbent

NOTE: Equation (1) may be evaluated using any other system of consistent units.

FIG. FE-IV-3000



This qualification method of challenging a bed with a selected contaminant until bed breakthrough first occurs (as illustrated by Curve 5 on Fig. FE-IV-3000) has proven to be reliable and safe. Samples are taken in the bed at a number of points where full saturation has not occurred and can be analyzed to get a graphic representation of the bed performance.

If the results of these measurements exceed the acceptance criteria, there are several possible causes. A careful analysis of the test setup should be made to ensure that the test results are valid. Evidence of damage or improper fabrication of the adsorber test section may be found. Finally, if all else fails, the filling method should be reviewed (Appendix FE-III). Any single factor or a combination may result in failure and must be corrected and the tests repeated before adsorber can be said to have met the qualification criteria.

ARTICLE FE-IV-4000 EXAMPLE

The following example and calculations illustrate the methods involved in arriving at the qualification of a 4 in. bed, using an inlet concentration of water vapor at 70% RH and analyzing the outlet for a minimum of 50% RH. At this RH, sufficient water will be absorbed to permit a chemical analysis of the activated carbon. It is estimated that Lz will be about 2 in., meaning 2 in. of the bed is unsaturated. Samples for analysis will be taken at the outlet adsorber screen.

FE-IV-4100 APPARATUS

Figure FE-IV-4100 shows the general test arrangement.

FE-IV-4200 TEST PROCEDURE

(*a*) Predetermine the moisture content of the adsorbent using ASTM D 2867.

(*b*) Fill the adsorber bed in accordance with the filling procedure.

(*c*) Assemble the test hardware in accordance with Fig. FE-IV-4100.

(*d*) Start up blower and adjust airflow volume to correct (rated) value using a calibrated orifice.

(*e*) Inject steam or water vapor into the main air stream at a rate to result in 70% ±5% RH in the flowing air.

FE-IV-4300 RH MEASUREMENT

An upstream sample is passed through a calibrated RH or dew point probe to determine that the upstream concentration is 70% ±5% RH.

FE-IV-4400 RH BREAKTHROUGH

Take periodic air samples downstream of the bed monitoring RH (or equivalent dew point) to determine when 50% RH breakthrough occurs.

FE-IV-4500 ADSORBENT SAMPLING

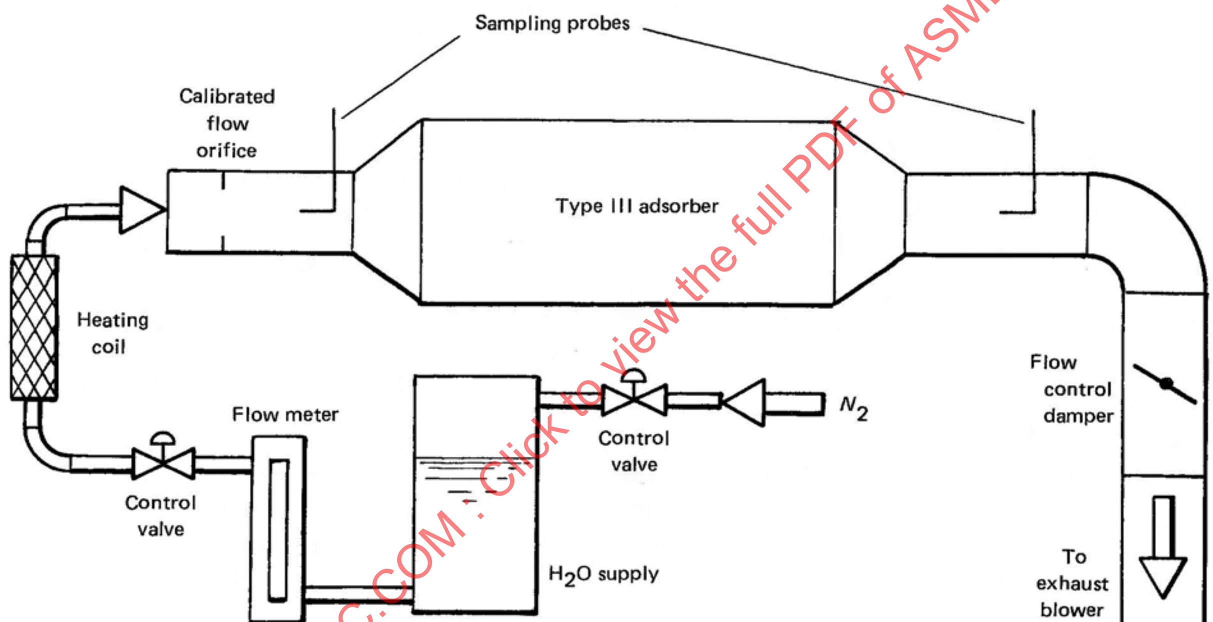
After breakthrough at 50% RH occurs, shut down the system. The adsorber cover is removed and the adsorbent is sampled (using a grain thief). Care must be taken to see that the adsorbent is not disturbed during sampling and that the sampling device is against the outlet screen when the sample is taken.

Samples are taken at three height levels and three width levels in each bed, representing nine equal zones of flow area. As the samples are taken, they are placed in sealed containers.

FE-IV-4600 MOISTURE CONTENT

Determine the moisture content of each adsorbent sample using ASTM D 2867.

FIG. FE-IV-4100



ARTICLE FE-IV-5000
ACCEPTANCE CRITERIA

Results of laboratory sample analysis shall be within ±20% of each other or the flow pattern in this bed is unacceptable.

NONMANDATORY APPENDIX FE-A
VISUAL INSPECTION RECOMMENDATIONS FOR TYPE III ADSORBERS

ARTICLE FE-A-1000 GENERAL

The thorough inspection of Type III adsorbers is of paramount importance to ensure the successful application of this equipment to nuclear air cleaning systems. Because it is extremely difficult to effect repairs or other corrective actions after the adsorber is fabricated and installed into the filter housing, the location of each inspection point should be determined by the Owner in cooperation with the Manufacturer. In many cases, the required inspections cannot be completed until the adsorber system is installed within the air cleaning system and made operational. The following recommendations should be considered as the minimum requirements for inspection and should be supplemented as appropriate.

FE-A-1100 ADSORBER SECTIONS

(*a*) dimensions meet the design drawing requirements
(*b*) perforated areas are free of holes or tears
(*c*) seal welds are continous
(*d*) sheets are flat within tolerances
(*e*) structural supports meet design requirements

FE-A-1200 ADSORBER ASSEMBLY

(*a*) adsorber sections are seal welded to top and bottom hopper sections
(*b*) hopper sections meet the minimum capacity requirements
(*c*) final assembly is clean and free of obstructions

FE-A-1300 ADSORBER SERVICE SYSTEMS

(*a*) do not allow bypass of the adsorber sections
(*b*) have adequate isolation/shutoff valves to meet the leakage requirements

FE-A-1400 INSPECTION OPENINGS

(*a*) covers are adequately gasketed to meet leakage specifications
(*b*) closure/clamping systems provide required clamping forces
(*c*) provide visual access to all adsorber sections

FE-A-1500 LABELING

(*a*) meets the requirements of Article FE-9000 and other system requirements
(*b*) is visible after the adsorber section is installed in its intended housing

NONMANDATORY APPENDIX FE-B
DIVISION OF RESPONSIBILITY

This Nonmandatory Appendix is intended to identify the roles normally assumed by the organizations responsible for fulfilling Code requirements when not specifically addressed in an article or subarticle. These are guidelines to assist with Code compliance and are not to be construed as legal or contractual responsibilities unless so invoked by the Owner or designee.

TABLE FE-B-1000
DIVISION OF RESPONSIBILITY

FE-	Item	Responsible Party
4210	Design criteria	Engineer
4220	Sizing	Engineer/Manufacturer
4300	Adsorbent bed details	Manufacturer
4400	Loading conditions	Engineer/Owner
4500	Adsorbent handling system	Manufacturer
4610	Adsorbent sampling system	Manufacturer
4620	Fire control systems	Engineer/Manufacturer
5200	Visual inspection	Manufacturer/Owner
5300	Dimensional inspection	Manufacturer/Owner
5400	Welding inspection	Manufacturer/Owner
5600	Design qualification	Manufacturer
5700	Acceptance tests	Engineer/Manufacturer
5800	Documentation	Manufacturer
6000	Fabrication	Manufacturer
7000	Packaging and shipping	Manufacturer/Owner
8000	Quality assurance	Manufacturer/Owner
9000	Nameplates	Manufacturer

SECTION FF
ADSORBENT MEDIA

ARTICLE FF-1000
INTRODUCTION

FF-1100 SCOPE

This section provides minimum requirements for the performance, design, acceptance testing, and quality assurance for adsorbent media used in air and gas cleaning systems in nuclear facilities.

FF-1110 PURPOSE

The purpose of this section is to ensure that adsorbent media used in nuclear facilities for nuclear safety-related air and gas treatment systems are acceptable in all aspects of performance, design, and testing.

FF-1120 APPLICABILITY

This section shall be applied to the use of adsorbent media installed in nuclear safety-related atmospheric cleanup systems for the removal of radioiodine compounds during and after an accident.

This section does not include the filling of adsorbent media into adsorber units of any type, nor does it cover criteria for the adsorber units that hold the adsorbent media in place. Criteria are specified only for virgin adsorbents prior to installation and use; technical specifications should be referred to for in-place testing criteria and for periodic verification of adsorbent performance.

The specific testing procedures and acceptance criteria contained in this section were developed for activated carbon as the adsorbent medium. However, any adsorbent medium that can be demonstrated to perform equal to or better than activated carbon for the conditions specified herein shall be acceptable.

This section shall not be applied to activated carbon used in respirator or personnel gas masks, noble gas delay systems, or liquid radwaste treatment systems.

FF-1130 DEFINITIONS AND TERMS

The following terms have special meaning in the context of this section.

activated carbon: a family of carbonaceous substances manufactured by processes that develop adsorptive properties.

batch: a quantity of adsorbent, not to exceed 10 m^3 in size, of the same grade or type that has been produced under the same Manufacturer's production designation using a consistent manufacturing procedure and equipment, and that has been homogenized to exhibit the same physical properties and performance characteristics throughout its mass.

batch test: a test performed on a representative sample of each batch of manufactured adsorbent.

coimpregnants: two or more different impregnants fixed on the carbon in conjunction, to further enhance radioiodine removal properties.

grade or type: the Manufacturer's designation for an adsorbent having a given set of performance capabilities and physical properties, manufactured according to a fixed set of procedures.

impregnated activated carbon: a material that, after activation, is impregnated with a chemical compound or compounds to increase its ability to retain organic iodides, particularly at high temperatures and humidity condition. Typical impregnants include iodides such as potassium iodide and triiodide, amines such as triethylenediamine (TEDA), and combinations thereof.

lot: one or more batches of adsorbent that comprises and satisfies a purchase order.

qualification test: a test performed at least once every 5 yr on three representative samples taken from a single batch of a Manufacturer's grade or type of adsorbent. This test qualifies the specific grade or type of adsorbent for all similar future uses for a period not to exceed 5 yr.

virgin activated carbon: a material that has not seen service and has not been reactivated.

ARTICLE FF-2000
REFERENCED DOCUMENTS

The codes and standards referenced below shall supplement those documents listed in Section AA.

ASTM D 26S2-79, Standard Definitions of Terms Relating to Activated Carbon

ASTM D 2854-83, Test for Apparent Density of Activated Carbon

ASTM D 2862-82, Test for Particle Size Distribution of Granular Activated Carbon

ASTM D 3466-76, Test for Ignition Temperature of Granular Activated Carbon

ASTM D 3467-77, Test for Carbon Tetrachloride Activity of Activated Carbon

ASTM D 3802-79, Test for Determining Ball-Pan Hardness of Activated Carbon

ASTM D 3803-89, Standard Test Methods for Radioiodine Testing of Nuclear Grade Gas-Phase Adsorbents

ASTM D 4069-81, Standard Specification for Impregnated Activated Carbon Used to Remove Gaseous Radioiodines from Gas Streams

Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

ARTICLE FF-3000
MATERIALS

Adsorbents are included in atmospheric cleanup systems at nuclear facilities to remove radioactive gases, primarily radioiodine compounds, by adsorption. Since activated carbon is the primary adsorbent used, this Code deals with activated carbon.

Activated carbon manufactured from coconut shell raw material has been traditionally used. However, carbons manufactured from raw material such as wood, coal, or petroleum coke may be used provided they satisfy the requirements of this section. Only virgin material shall be acceptable. Reactivation of activated carbon for use in nuclear safety-related systems is not allowed.

Activated carbon designed for radioiodine removal is impregnated to enhance its ability to retain radioiodine, primarily at high humidities. Commonly used impregnants include iodine compounds such as potassium iodide and iodine, and amines such as triethylenediamine. This section does not distinguish between impregnants. Reimpregnation of carbon that has been in service or outdated impregnated carbon is permitted, but must be qualified in accordance with this section.

ARTICLE FF-4000
DESIGN

FF-4100 GENERAL DESIGN

The adsorbent media shall be a free-flowing granular substance capable of being used in Type II (see Section FD), Type III (see Section FE), or other approved mechanical structures constituting adsorber units. In some instances, an impregnant may be adsorbed onto the medium to increase the radioiodine removal capability, particularly at high humidity conditions. If activated carbon is specified as the adsorbent medium, the activation and impregnation processes are left to the discretion of the Manufacturer; the requirements contained in Article FF-5000 shall be applicable. If another adsorbent medium is proposed, it shall meet the minimum performance requirements outlined in Article FF-5000 to conform with this Article.

FF-4200 ADSORBENT DEGRADATION

The adsorbent is qualified to perform under the temperature and relative humidity conditions of FF-5210, Qualification Tests. Furthermore, system design criteria and parameters in other sections of ASME AG-1 provide the conditions under which the adsorbent operates.

FF-4210 DESORPTION

(a) Desorption is the reverse of the process of adsorption and is primarily a function of temperature. Temperature conditions which are outside the limits under which the adsorbent was qualified can cause desorption, or conversely, adsorption efficiency may be less than qualified values.

(b) If normal or abnormal operation of the system outside the qualification temperatures is desired, the Owner shall requalify the adsorbent media to the other operating conditions.

FF-4220 DEGRADATION

In addition to experiencing the process of desorption, adsorbent can degrade as a result of other adverse conditions. These conditions include but are not limited to the following:

(a) Operation at relative humidity conditions above the limits under which the adsorbent was qualified may result in adsorbent efficiencies less than qualified values.

(b) Spurious activation of the water deluge system may saturate the adsorbent with water and leach any adsorbed material, either impregnant or adsorbed gases, from the adsorption surfaces.

ARTICLE FF-5000
INSPECTION AND TESTING

This Article specifies the inspection and testing criteria applicable to activated carbon adsorbent media for use in engineered safety feature atmosphere cleanup systems. Article AA-5000 shall apply, with the additional guidance given below.

FF-5100 PHYSICAL TESTING

FF-5110 BEFORE IMPREGNATION

Each batch of activated carbon to be impregnated shall undergo a physical test for carbon tetrachloride activity in accordance with ASTM D 3467 to a minimum level of 60% prior to impregnation.

FF-5120 AFTER IMPREGNATION

Each batch of activated carbon that has been impregnated shall undergo the following physical tests after impregnation:

(a) A test of apparent density in accordance with ASTM D 2854 to a minimum level of 0.38 g/ml.

(b) A test of particle size distribution in accordance with ASTM D 2862 to satisfy the following ASTM E 11 series of screens:

(1) retained on No. 6: 0.1% max.
(2) retained on No. 8: 5.0% max.
(3) through No. 8, retained on No. 12: 60% max.
(4) through No. 12, retained on No. 16: 40% min.
(5) through No. 16: 5.0% max.
(6) through No. 18: 1.0% max.

(c) Ignition temperature shall be measured in accordance with ASTM D 3466 and shall be a minimum level of 330°C.

(d) Ball-pan hardness shall be measured in accordance with ASTM D 3802 and shall be a minimum level of 92%.

FF-5200 RADIOACTIVE TESTING

In addition to specifications for the physical properties of activated carbon, this Article also requires testing of the adsorbent with radioactive material to verify removal capabilities. Qualification tests are to be repeated at least once every 5 yr, in accordance with ASTM D 4069. Batch tests are to be performed on each batch of material supplied, and as indicated in ASTM D 4069.

FF-5210 QUALIFICATION TESTS

Each grade or type of impregnated activated carbon shall be qualified at least once every 5 yr by satisfying the following radioactive qualification tests.

FF-5211 Methyl Iodide Removal (Low Temperature)

Verify methyl iodide removal efficiency to be not less than 99.0% at 80°C and 95% relative humidity when tested in accordance with ASTM D 3803.

FF-5212 Elemental Iodine Removal

Verify elemental iodine removal efficiency to be not less than 99.9% at 30°C and 95% relative humidity when tested in accordance with ASTM D 3803.

FF-5213 Methyl Iodide Removal (High Temperature)

Verify methyl iodide removal efficiency to be not less than 98% at 130°C and 95% relative humidity when tested in accordance with ASTM D 3803 for carbon to be installed in primary containment cleanup systems.

FF-5220 RADIOACTIVE BATCH TESTS

In addition to the radioactive qualification tests, each batch of impregnated activated carbon shall undergo radioactive batch tests at the time of manufacture to verify that the batch has the same characteristics as the carbon sample that has been qualified.

FF-5221 Methyl Iodide Removal

Each batch of impregnated activated carbon shall be tested for methyl iodide removal efficiency at 30°C and 95% relative humidity in accordance with ASTM D 3803. The minimum acceptable efficiency level shall be 97%.

FF-5222 Elemental Iodine Retention

Each batch of impregnate activated carbon shall be tested for elemental iodine retention efficiency at 180°C in accordance with ASTM D 3803. The minimum acceptable efficiency level shall be 99.5%.

FF-5300 ACCEPTABLE ASTM STANDARDS

The inspection and testing requirements of FF-5100 and FF-5200 are not intended to supersede or replace the requirements of ASTM D 4069 for impregnated activated carbon, but the requirements are included in this Article for completeness. Any impregnated activated carbon that satisfies the requirements of ASTM D 4069 shall be considered to be in conformity with this Code.

ARTICLE FF-6000
FABRICATION

There are no established industry standards, procedures, or guidelines for the activation of carbon or the impregnation of activated carbon. Rather, these procedures are left to the Manufacturer. The acceptability of the Manufacturer's product shall be determined by satisfactory conformity of the product with the inspection and testing requirements of Article FF-5000.

ARTICLE FF-7000
PACKAGING AND SHIPPING

For packaging and shipping, Article AA-7000 shall apply, with the additional guidance given below.

FF-7100 PROTECTION OF ADSORBENT MEDIA

After the adsorbent has satisfied the requirements of FF-5200 and is ready for shipment, all packaging, shipping, and storage procedures shall ensure that the media do not degrade by any means (aging, abrasion) before use. Accordingly, the media shall be packaged, shipped, and stored in containers designed to minimize influx of vapors and protect the contents from the environment. Media shall be packaged, shipped, and received in accordance with the requirements of Level B items as specified in ASME NQA-1. Media shall be stored in the original shipping containers with the seals intact.

FF-7200 STORAGE

Storage at all times (except during transit) shall be indoors in an area with

(a) ventilation
(b) minimum temperature of 40°F
(c) maximum temperature of 120°F
(d) relative humidity less than 70%
(e) minimum exposure to fume producing materials or volatile organic solvents
(f) protection from mechanical shock and vibration

FF-7300 CONTAINERS

The integrity of the packing container in general and the vapor container in particular should be maintained; therefore, storage should not be near frequently traveled aisleways or corridors, near vibrating equipment, or among short term storage items that require frequent personnel access. Care shall be taken to avoid dropping or tipping the storage containers.

ARTICLE FF-8000
QUALITY ASSURANCE

The quality assurance requirements of Article AA-8000 shall apply to the Manufacturer of adsorbent media and to all contractors performing any of the medium testing or inspection functions for the Manufacturer, the Supplier, or the user.

FF-8100 DOCUMENTATION

The following documentation shall be provided:

(a) type of tests
(b) date performed
(c) procedure followed (by reference is acceptable)
(d) all test conditions (per ASTM D 3803)
(e) laboratory performing the tests
(f) test results
(g) identity and signature of person performing laboratory work

ARTICLE FF-9000
NAMEPLATE AND CERTIFICATION

Article AA-9000 nameplate and certification requirements shall apply, with the additional guidance given below. In addition to a shipping label, the following information shall be affixed to each shipping container:

(a) Manufacturer
(b) date of manufacture
(c) grade or type of adsorbent
(d) batch identification
(e) Purchaser's identification number

This information shall be attached to the packing container in such a manner that it becomes an integral part of the container and shall not be removed until the adsorbent is used. All labels shall be of a material that allows the required information to remain visible and legible at all times during shipping and storage and until the media are completely used.

NONMANDATORY APPENDIX FF-A
DIVISION OF RESPONSIBILITY

This Nonmandatory Appendix is intended to identify the roles normally assumed by the organizations responsible for fulfilling Code requirements when not specifically addressed in an article or subarticle. These are guidelines to assist with Code compliance and are not to be construed as legal or contractual responsibilities unless so invoked by the Owner or designee.

TABLE FF-A-1000
DIVISION OF RESPONSIBILITY

FF-	Item	Responsible Party
3000	Materials	Manufacturer/Owner
4000	Design	Manufacturer/Owner
5100	Physical testing	Manufacturer
5200	Radioactive testing	Manufacturer
5210	Qualification tests	Manufacturer
5220	Radioactive batch tests	Manufacturer
6000	Fabrication	Manufacturer
7100	Packaging and shaping	Manufacturer/Owner
7200	Storage	Owner
7300	Containers	Manufacturer/Owner
8000	Quality assurance	Manufacturer
8100	Documentation	Manufacturer
9000	Nameplate and certification	Manufacturer

SECTION FG
MOUNTING FRAMES
CONAGT AIR-CLEANING EQUIPMENT
NUCLEAR SAFETY-RELATED EQUIPMENT

ARTICLE FG-1000
INTRODUCTION

FG-1100 SCOPE

This section of the Code provides the requirements for the design, fabrication, inspection, acceptance testing, and quality assurance of mounting frames for medium efficiency filters, moisture separators, as well as high efficiency particulate air (HEPA) filters and Type II (tray type) adsorber cells used in nuclear safety-related air and gas treatment systems.

FG-1110 PURPOSE

The purpose of this section is to ensure that medium efficiency filter, moisture separator, HEPA filter, and Type II adsorber cell mounting frames used in nuclear safety applications are acceptable in all aspects of performance, design, construction, acceptance, and testing.

FG-1120 LIMITATIONS

This section of the Code does not include the integration of medium efficiency filter, moisture separator, HEPA filter, or Type II adsorber cell mounting frames into a complete air cleaning system. This section does not include the design of medium efficiency filters, moisture separators, HEPA filters, or adsorbers, which are covered in other Division II Code Sections.

FG-1130 RESPONSIBILITY

Appendix FG-A contains a suggested division of responsibility.

ARTICLE FG-2000
REFERENCED DOCUMENTS

Common application documents referenced in this Code section are detailed in Article AA-2000. Unless otherwise shown, the latest edition and addenda are applicable.

AISC S328, Specification for Structural Steel Buildings Load and Resistance Design Factor

AISC 329, Allowable Stress Design Specification for Structural Joints Using ASTM A 325 or A 490 Bolts

Publisher: America Institute of Steel Construction, Inc. (AISC), One East Wacker Drive, Chicago, IL 60601-1802

AISI SG-673, Cold Formed Steel Design Manual, Specification for the Design of Cold-Formed Steel Structural Members

Publisher: American Iron and Steel Institute (AISI), 2000 Town Center, Southfield, MI 48075

ANSI B46.1, Surface Texture (Surface Roughness, Waviness, and Lay)

Publisher: American National Standards Institute (ANSI), 25 West 43rd Street, New York, NY 10036

ASTM A 36, Carbon Structural Steel, Specification for

ASTM A 53, Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless, Specification for

ASTM A 106, Seamless Carbon Steel Pipe for High-Temperature Service, Specification for

ASTM A 108, Steel, Bars, Carbon, Cold Finished, Standard Quality, Specification for

ASTM A 236, Structural Steel, Specification for

ASTM A 240, Heat Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels, Specification for

ASTM A 276, Stainless and Heat-Resisting Steel Bars and Shapes, Specification for

ASTM A 283, Low and Intermediate Tensile Strength Carbon Steel, Specification for

ASTM A 284, Steel Plates for Machine Parts and General Construction, Low and Intermediate Tensile Strength Carbon-Silicon Steel, Specification for

ASTM A 366, Steel Sheet, Carbon, Cold-Rolled, Commercial Quality, Specification for

ASTM A 414, Steel, Sheet, Carbon, for Pressure Vessels, Specification for

ASTM A 446, Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Structural (Physical) Quality, Specification for

ASTM A 500, Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes, Specification for

ASTM A 501, Hot-Formed Welded and Seamless Carbon Steel Structural Tubing, Specification for

ASTM A 525, Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, General Requirements for, Specification for

ASTM A 526, Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Commercial Quality, Specification for

ASTM A 527, Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Lock-Form Quality, Specification for

ASTM A 528, Steel Sheet, Zinc-Coated (Galvanized) by the Hot Dip Process, Drawing Quality, Specification for

ASTM A 568, Steel, Sheet, Carbon, Structural and High-Strength, Low-Alloy Hot-Rolled and Cold-Rolled, Specification for General Requirements for

ASTM A 569, Steel, Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip, Commercial Quality, Specification for

ASTM A 570, Steel, Sheet and Strip, Carbon, Hot-Rolled, Structural Quality, Specification for

ASTM A 575, Steel Bars, Carbon, Merchant Quality, M-Grades, Specification for

ASTM A 576, Steel Bars, Carbon, Hot-Wrought, Special Quality, Specification for

ASTM A 591, Steel Sheet, Cold-Rolled, Electrolytic Zinc-Coated, for Light-Coating Mass Applications, Specification for

ASTM A 611, Steel, Sheet, Carbon, Cold-Rolled, Structural, Specification for

ASTM A 620, Steel, Sheet, Carbon, Drawing Quality, Cold Rolled, Specification for

ASTM A 621, Steel and Strip, Carbon, Hot-Rolled, Drawing Quality, Specification for

ASTM A 635, Steel Sheet and Strip, Heavy-Thickness Coils, Carbon, Hot-Rolled, Specification for

ASTM A 642, Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Drawing Quality, Special Killed, Specification for

ASTM A 659, Steel, Carbon (0.16 Maximum to 0.25 Maximum Percent), Hot-Rolled Sheet and Strip, Commercial Quality, Specification for

ASTM A 666, Annealed or Cold-Rolled Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar, Specification for

Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

ARTICLE FG-3000
MATERIALS

FG-3100 ALLOWABLE MATERIALS

Table FG-3100 provides a list of the allowable materials used in the construction of mounting frames. Those materials shall confirm to the specification requirements of materials given in Table FG-3100. Where ASTM material specifications are invoked, the equivalent ASME material may be substituted.

FG-3200 MATERIAL LIMITATIONS

Tape, mastics, caulk, lubricants, and sealant materials shall not be allowed for sealing welded joints in moisture separator, HEPA filter, and adsorber cell mounting frames.

TABLE FG-3100
ALLOWABLE MATERIALS

ASTM Designator	ANSI Designator	Publication Title
Carbon Steel Plates and Sheets		
A 236		Structural Steel, Specification for,
A 283		Low- and Intermediate-Tensile Strength Carbon Steel Plats, Specification for,
A 284		Pressure Vessel Plates, Carbon Steel, Low and Intermediate Strength, Specification for,
A 366		Steel, Carbon, Cold-Rolled Sheet, Commercial Quality, Specification for,
A 414		Carbon Steel Sheet for Pressure Vessels, Specification for,
A 568		General Requirements for Steel, Carbon and High-Strength Low-Alloy Hot-Rolled Sheet, and Cold-Rolled Sheet, Specification for,
A 569		Steel, Carbon (0.15 Maximum Percent), Hot-Rolled Sheet and Strip, Commercial Quality, Specification for,
A 570		Hot-Rolled Carbon Steel Sheet and Strip, Structural Quality, Specification for,
A 611		Steel, Cold-Rolled Sheet, Carbon, Structural Quality, Specification for,
A 620		Steel, Sheet, Carbon Drawing Quality, Special Killed, Cold-Rolled, Specification for,
A 621		Steel Sheet and Strip, Carbon, Hot-Rolled, Drawing Quality, Specification for,
A 635		Steel Sheet and Strip, Heavy Thickness Coils, Carbon, Hot-Rolled, Specification for
A 659		Steel, Carbon (0.16 Maximum to 0.25 Maximum Percent), Hot-Rolled Sheet and Strip, Commercial Quality, Specification for,
Stainless Steel Plates and Sheets		
A 240		Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels, Specification for,
A 666		Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip Plate, and Flat Bar
Galvanized Steel Plates and Sheets		
A 446		Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Structural (Physical Quality), Specification for,
A 525		Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, General Requirements for, Specification for,
A 526		Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Commercial Quality, Specification for,
A 527		Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Lock-Form Quality, Specification for,
A 528		Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Drawing Quality, Specification for,
A 591		Steel Sheet, Cold-Rolled, Electrolytic Zinc-Coated, for Light-Coating Mass Applications, Specification for,
A 642		Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Drawing Quality, Special Killed, Specification for,
Carbon Steel Structural Members		
A 36		Structural Steel, Specification for,
A 106		Seamless Carbon Steel Pipe for High-Temperature Services, Specification for,
A 108		Steel, Bars, Carbon, Cold-Finished, Standard Quality, Specification for
A 500		Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes, Specification for,
A 501		Hot-Formed Welded and Seamless Carbon Steel Structural Tubing, Specification for,
A 575		Steel Bars, Carbon, Merchant Quality, M-Grades, Specification for,
A 576		Steel Bars, Carbon, Hot-Wrought, Special Quality, Specification for,

TABLE FG-3100
ALLOWABLE MATERIALS (CONT'D)

ASTM Designator	ANSI Designator	Publication Title
Stainless Steel Structural Members		
A 276		Stainless and Heat-Resisting Steel Bars and Shapes, Specification for,
A 312		Seamless and Welded Austenitic Stainless Steel Pipe, Specification for,
A 479		Stainless and Heat-Resisting Steel Wire, Bars and Shapes for Use in Boilers and Other Pressure Vessels, Specification for,
A 511		Seamless Stainless Steel Mechanical Tubing, Specification for,
A 554		Welded Stainless Steel Mechanical Tubing, Specification for,
Galvanized Steel Structural Members		
A 53		Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless, Specification for,
	C80.3	Electrical Metallic Tubing, Zinc-Coated
Stainless Steel Bolts and Nuts		
A 193		Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service, Specification for,
A 194		Carbon and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service, Specification for,
A 493		Stainless and Heat-Resisting Steel for Cold-Heading and Cold-Forging Bar and Wire, Specification for,
Carbon Steel Bolts and Nuts		
A 307		Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength, Specification for,
A 325		High-Strength Bolts for Structural Steel Joints, Specification for,
A 449		Quenched and Tempered Steel Bolts and Studs, Specification for,
A 548		Steel Wire, Carbon, Cold-Heading Quality, for Tapping or Sheet Metal Screws, Specification for,
A 563		Carbon and Alloy Steel Nuts, Specification for,
	B18.21.1	Lock Washers
	B18.22.1	Plain Washers
Nonferrous Nuts		
F 467		Nonferrous Nuts for General Use, Specification for,
Coatings		
A 123		Zinc (Hot-Galvanized-Coatings) on Products Fabricated from Rolled, Pressed, and Forged Steel Shapes, Plates, Bars, and Strip, Specification for,
A 153		Zinc Coating (Hot-Dip) on Iron and Steel Hardware, Specification for,
B 633		Electrodeposited Coatings of Zinc on Iron and Steel, Specification for,
B 766		Electrodeposited Coatings of Cadmium, Specification for,

ARTICLE FG-4000 DESIGN

FG-4100 GENERAL DESIGN

The design and construction of mounting frames shall incorporate requirements not only for structural strength and rigidity, but also for sealing surfaces, in order to provide continuously leak-tight, individual positive sealing of HEPA filters and Type II adsorber cells to the mounting frames. Designs and construction of clamping devices shall also incorporate structural strength and rigidity requirements for uninterrupted, positive sealing of HEPA filters and Type II adsorber cells. HEPA filter and adsorber cell mounting frames shall be designed for structural welding to the housing wall, and for seal welding of adjoining members. Medium efficiency filter and moisture separator mounting frames shall be designed for structural welding to the housing wall but need not be seal welded to the housing wall. Moisture separator mounting frames shall be equipped with water collection troughs and drains.

FG-4110 HEPA FILTER MOUNTING FRAMES

A typical filter mounting frame is shown in Fig. FG-4110-1.

FG-4111 HEPA Filter Mounting Frame Dimensions

Primary and cross members of face sealed HEPA filter frames shall have a minimum frame width of 4 in. (100 mm). This shall include a 1 in. (25 mm) wide filter-seating surface to compensate for any misalignment of the filter during installation, and a 2 in. (50 mm) space between filters horizontally and vertically, to provide adequate room for clamping, handling, using power tools or torque wrenches during filter change, and for manipulating a test probe between the units. The openings for HEPA filters shall be square within $\frac{1}{16}$ in. (1.5 mm) and shall be 2 in. (50 mm) smaller than the filter size. Reference Table FC-4000-1 for filter sizes.

FG-4112 HEPA Filter Clamping

Major requirements of filter clamping systems toward effecting positive sealing are magnitude and uniformity of clamping. Essential to continuous sealing is minimal relative movement between clamping system components and the frame, due to component deformation under the loads specified for mounting frames in FG-4220 and FG-4300. HEPA filters are to be clamped with at least the equivalent of four pressure points. Each filter is to be independently clamped. The calculated stress within any element of the clamping device shall not exceed 25% of the material yield strength at the required sealing load of FG-4112.1 or FG-4112.2.

FG-4112.1 Clamping of Gasket-Sealed Filters. The clamping of filters sealed using gaskets shall produce a uniformity of gasket compression of 65% ± 15% of the average original gasket thickness.

FG-4112.2 Clamping of Fluid-Sealed Filters. Each clamp shall be designed to hold the fluid-sealed filter onto the knife-edge flange. The knife-edge flange shall be a minimum of $\frac{5}{8}$ in. (16 mm) deep and a minimum of 14 gauge (1.9 mm) thick. The tolerance on each knife-edge shall be plane within $\frac{1}{8}$ in. (3 mm).

FG-4113 HEPA Filter Support

Supports or cradles are required for HEPA filters to facilitate installation. The supports shall permit inspection of the filter-to-frame interface when the filter is installed. Refer to Fig. FG-4110.1.

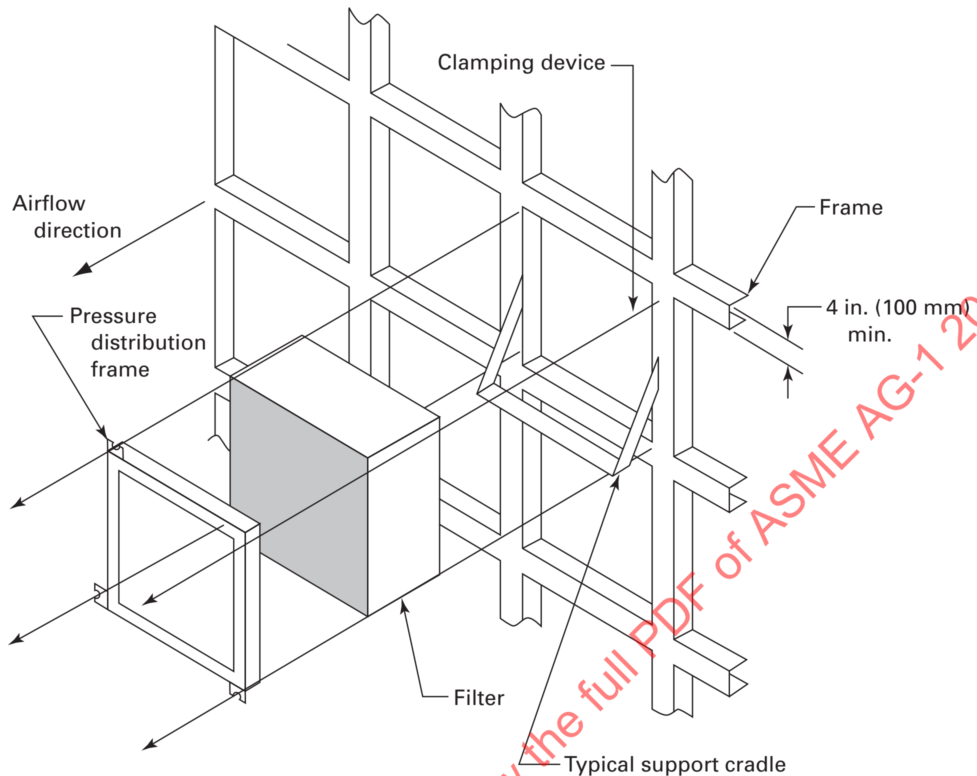
FG-4114 HEPA Filter Mounting Frame Penetrations

No penetration of HEPA filter mounting frames shall be allowed.

FG-4120 TYPE II ADSORBER CELL MOUNTING FRAMES

A typical adsorber cell mounting frame is shown in Fig. FG-4120-1.

FIG. FG-4110-1 TYPICAL FILTER MOUNTING FRAME



FG-4121 Type II Adsorber Cell Mounting Frame Dimensions

Mounting frame openings for installing Type II adsorber cells shall be: $6^3/_8$ in. × $24^1/_8$ in. ($+^1/_8$, 0) [162 mm × 613 mm (+3, −0)]. A minimum frame width (space between openings) of 4 in. (100 mm) is required for vertical members, and 2 in. (50 mm) for horizontal members for Type II adsorber cell mounting frames.

FG-4122 Type II Adsorber Cell Clamping

Major requirements of adsorber cell clamping systems toward effecting positive sealing are magnitude and uniformity of clamping. Essential to continuous sealing is minimal relative movement between clamping system components and the frame, due to component deformation under the loads specified for mounting frames in FG-4200 and FG-4300. Type II adsorber cells shall be clamped with at least the equivalent of four pressure points. Each cell shall be independently clamped. The calculated stress within any element of the clamping device shall not exceed 25% of the material yield strength at the required gasket compression of FG-4123. Clamping shall be accomplished in the first $3^1/_2$ in. (90 mm) of the right and left sides of the adsorber face plate and within 1 in. (25 mm) of the top and bottom edge of the face plate (to avoid interference with handles).

FG-4123 Type II Adsorber Cell Sealing

Type II adsorber cells employing gaskets for sealing to the frame shall be sealed by a method that will produce a gasket compression of at least 65% ± 15% of the original gasket thickness.

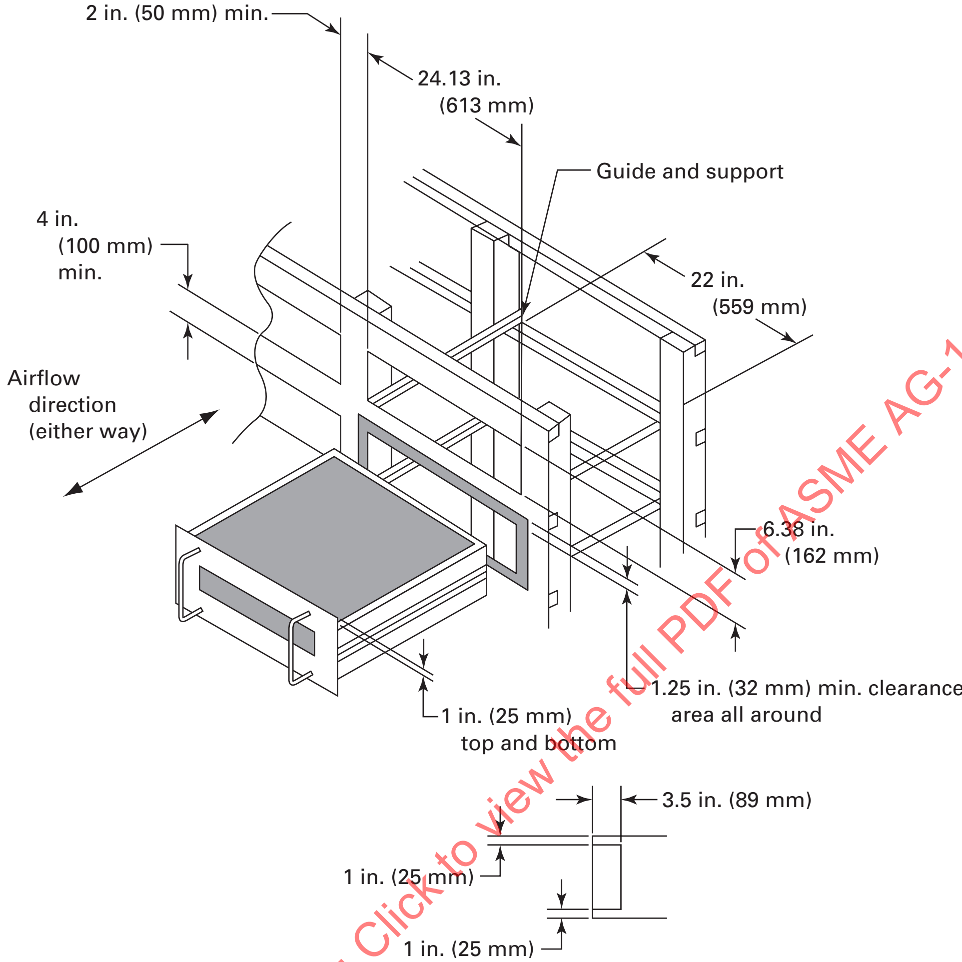
FG-4124 Type II Adsorber Cell Support

A structure shall be provided for behind the Type II adsorber frame openings to support the weight of the cells. Structure minimum length is 30 in. (760 mm), and shall be built without backstops. Refer to Fig. FG-4120-1.

FG-4125 Type II Adsorber Cell Mounting Frame Penetrations

No penetration of adsorber mounting frame shall be allowed, except for those required for the attachment

FIG. FG-4120-1 TYPICAL TYPE II ADSORBER MOUNTING FRAME



of test canisters. Any penetration in the mounting frame shall be seal welded and isolatable.

FG-4130 MEDIUM EFFICIENCY FILTER MOUNTING FRAMES

A typical mounting frame is shown in Fig. FG-4110-1.

FG-4131 Medium Efficiency Filter Mounting Frame Dimensions

Primary and cross members of face sealed medium efficiency filter frames shall have a minimum frame width of 4 in. (100 mm). This shall include a 1 in. (25 mm) wide filter seating surface to compensate for any misalignment of the filter during installation and a 2 in. (50 mm) space between filters horizontally and vertically, so as to provide adequate room for clamping, handling, and using power tools or torque wrenches during filter change. The openings for medium efficiency filters shall be square within $^1/_{16}$ in. (1.5 mm) and shall be 2 in. (50 mm) smaller than the filter size.

FG-4132 Medium Efficiency Filter Clamping

Medium efficiency filters shall be clamped with at least the equivalent of four pressure points. Each cell shall be independently clamped.

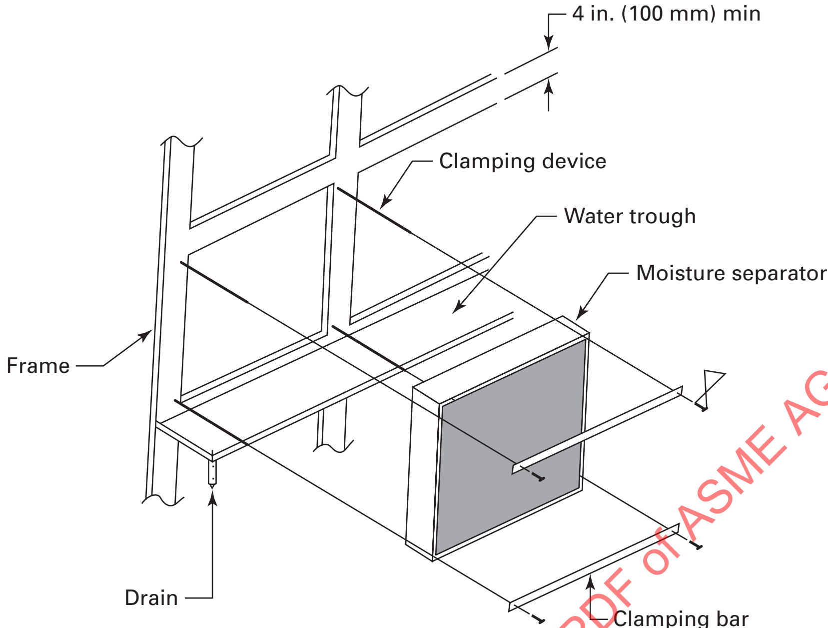
FG-4134 Medium Efficiency Filter Mounting Frame Penetrations

Any penetrations in the mounting frame shall not degrade the overall performance of the installed devices.

FG-4140 MOISTURE SEPARATOR MOUNTING FRAMES

A typical moisture separator mounting frame is shown in Fig. FG-4140-1.

FIG. FG-4140-1 TYPICAL MOISTURE SEPARATOR MOUNTING FRAME



FG-4141 Moisture Separator Mounting Frame Dimensions

Primary and cross members of face sealed moisture separator frames shall have a minimum frame width of 4 in. (100 mm). This shall include a 1 in. (25 mm) wide filter seating surface to compensate for any misalignment of the moisture separator during installation and a 2 in. (50 mm) space between moisture separators horizontally and vertically, so as to provide room for clamping, handling, and using power tools or torque wrenches during moisture separator change. The openings for moisture separators shall be square within $^1/_{16}$ in. (1.5 mm) and shall be 2 in. (50 mm) smaller than the moisture separator size. A minimum 1 in. (25 mm) deep water-collection tray shall extend at least 4 in. (100 mm) from the downstream side of the full width of the moisture separator bank. Individual water-collection trays shall serve each row of moisture separators and each tray shall have a drain designed to allow the maximum volume of water from each row of moisture separators to drain without overflowing the tray. The moisture removal capacity for each moisture separator is listed in Table FA-4200-1.

FG-4142 Moisture Separator Clamping

The requirements for separator clamping systems include magnitude and uniformity of clamping pressure. Moisture separators shall be clamped with at least the equivalent of four pressure points. Each moisture separator shall be independently clamped.

FG-4143 Moisture Separator Support

Supports are required for moisture separators to facilitate installation. Water troughs may serve the function of supports.

FG-4144 Penetrations

Any penetrations in the mounting frame shall not degrade the overall performance of the installed devices.

FG-4150 COMMON REQUIREMENTS

Requirements in this section are applicable to mounting frames for HEPA and medium efficiency filters, Type II adsorber cells, and moisture separators.

FG-4151 Galling Prevention

Threaded surfaces in the region of clamping device movement lubricated with a chemically compatible lubricant to prevent galling, as specified in the Design Specification, or the clamping device nuts shall be of a dissimilar metal that is environmentally and structurally compatible with the threaded surface.

FG-4200 STRUCTURAL REQUIREMENTS

FG-4210 GENERAL

Mounting frames shall be designed in accordance with the structural requirements given in Article AA-4000. Additional structural requirements and load definitions specific to Type II adsorber cell mounting frames appear in FD-4300.

FG-4220 LOAD DEFINITION

Loads listed in AA-4211 having the following definitions shall be considered in the structural design of mounting frames: dead weight (DW) is the weight of the mounting frame members.

External Load (EL) shall be 100 pounds-force (lb-f) [445 Newtons (N)] for each filter and moisture separator and 200 lb-f (890 N) for each Type II adsorber cell. These loads are based on the wet weight of the filters, moisture separators, and Type II adsorber cells.

Normal Operating Pressure Differential (NOPD) shall be 1.25 in. w.g. (310 Pa) for Type II adsorber cells as defined in FD-1120 and shown in Fig. FD-4100; 1.5 times the dirty filter pressure drop for filters; and 2.0 in. w.g. (500 Pa) for moisture separators as defined in Table FA-4210, unless specified otherwise by the Owner in the Design Specification. The dirty filter pressure drop value shall be stated in the Design Specification.

System Operation Pressure Transient (SOPT) shall be provided in the Design Specification.

The seismic acceleration and response spectra [Operating Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE)] shall be provided in the Design Specification. Additional Dynamic Loads (ADL) and Design Pressure Differential (DPD) may also be provided in the Design Specification.

FG-4230 LOAD COMBINATIONS

Unless stated otherwise in the Design Specification, the applicable loading conditions noted in Table AA-4212 for mounting frames shall be as follows:

(a) Service Level A. DW + EL + NOPD + SOPT

(b) Service Level B. DW + EL + NOPD + SOPT + OBE + ADL

(c) Service Level C. DW + EL + NOPD + SOPT + SSE + ADL

(d) Service Level D. Not required unless DPD is applicable

FG-4240 ACCEPTANCE CRITERIA

The acceptance criteria are listed in Table AA-4321. The stress design value, S, as defined in Article AA-4000, shall be calculated as $0.6S_y$, where S_y is yield stress.

FG-4300 STRUCTURAL DESIGN ANALYSIS

The mounting frame shall be analyzed as a statically indeterminate lattice. Sole allowable exceptions constitute the procedures outlined in FG-4310 through FG-4330 that yield more conservative designs, based upon standard beam equations.

FG-4310 FILTER MOUNTING FRAME DEFLECTION LIMITS

The HEPA filter mounting frame shall deflect no more than 0.007 in. (0.2 mm) per 1 in. (25 mm) span under a load equivalent to EL plus NOPD of HEPA filters. The medium efficiency filter mounting frame shall deflect no more than 0.10 in. (2.5 mm) per 1 in. (25 mm) span under a load equal to EL plus NOPD of medium efficiency filters. The uniform frame loading due to NOPD shall be determined from equation

$$W = 0.036\ (1.5)\Delta p\ C \qquad (1)$$

where

0.036 = a conversion factor, in. wg to psig

1.5 = a load factor, unitless

C = center-to-center vertical spacing of filters on bank, in.

W = uniform loading on frame, lb-f/in.

Δp = dirty filter pressure drop across bank, in. wg.

The value of W shall be multiplied by 0.175 to convert lb-f/in. into SI units of kN/m.

The value determined from eq. (1) and the EL shall be used in standard beam equations to determine the minimum second area moment of inertia required. Based upon the minimum second area moment of inertia required for the member, the size and shape shall either be determined by analysis; or be selected directly from the tables of structural shape properties given in Part 1 of the AISC Manual of Steel Construction.

FG-4320 TYPE II ADSORBER CELL AND MOISTURE SEPARATOR MOUNTING FRAME DEFLECTION LIMITS

The mounting frame shall deflect no more than 0.007 in. (0.2 mm) per 1 in. (25 mm) span for Type

II adsorber cells and 0.1 in. (2.5 mm) per 1 in. (25 mm) for the moisture separator under a load equivalent to the mounting weight when in a water flooded condition plus 1.17 lb-f/in. (0.20 N/mm) to account for NOPD. The load value shall be used in standard beam equations to determine the minimum second area moment of inertia required. Based on the minimum second area moment of inertia, the size and shape of the material shall either be determined by analysis; or be selected directly from the tables of structural shape properties given in Part 1 of the AISC Manual of Steel Construction.

FG-4330 PRESSURE IMPULSE LOADING

In addition to flexural strength, the mounting frame shall also be capable of withstanding a pressure impulse loading of at least 3 psid (20 kPa differential) across the bank without exceeding the elastic limit of the frame materials. The section modulus for the structural shape selected shall be obtained from the tables of structural shape properties in Part 1 of the AISC Manual of Steel Construction and be compared with the minimum values obtained from the equation

$$M = \frac{1.25\ (W_i L^2/8)}{S} \qquad (2)$$

where

1.25 = load factor, dimensionless

8 = the constant in the denominator of standard equation for the maximum bending moment of a beam that carries a uniformly distributed load and has a simple support at each end

L = length of the member representing either the span of the bank width or the span of the bank height, whichever is greater, in.

M = section modulus, in.^{3}

S = maximum allowable stress, lb-f/in.^{2}

W_i = pressure impulse loading on frame = $\Delta p_i\ C$; = 3 C, lb-f/in. for: Δp_i = gage pressure drop of pressure impulse = 3 lb-f/in.^{2} and C = center-to-center spacing of filters on the bank; in the direction parallel to either: the span of the bank width; or, the span of the bank height; whichever is less, in.

The values obtained in eq. (2) shall be less than the value in the AISC Manual for the structural shape selected for the mounting frame.

The value of M obtained from eq. (2) shall be multiplied by $16.4 \cdot 10^3$ to convert in.^{3} into SI units of mm.^{3}

ARTICLE FG-5000
INSPECTION AND TESTING

Inspection and testing of the medium efficiency and HEPA filter, the moisture separator, and Type II adsorber mounting frames shall conform to the requirements of this section and to the general requirements in Article AA-5000.

FG-5100 DIMENSIONAL INSPECTION

Overall dimensions shall be inspected to determine conformance to Manufacturer's drawing requirements. Length and spacing of members shall be inspected such that the openings are within tolerance. See FG-4100 for details.

FG-5200 ALIGNMENT AND SURFACE FINISH FOR HEPA FILTER AND TYPE II ADSORBER CELL MOUNTING FRAMES

The alignment of adjoining members shall be inspected, as well as the filter seating surface. Adherence to the following tolerances for HEPA filter and Type II adsorber cell mounting frames is required.

FG-5210 HEPA FILTER AND TYPE II ADSORBER CELL MOUNTING FRAME ALIGNMENT

FG-5211 Perpendicularity

Mounting frame adjoining members shall be perpendicular, with a maximum offset of $^1/_{64}$ in. (0.4 mm) per foot (300 mm) of frame member, or $^1/_{16}$ in. (1.5 mm) deviation over the entire frame member length, whichever is greater.

FG-5212 Planarity of Adjoining Members

Adjoining members shall be aligned not to exceed planarity of $^1/_{64}$ in. (0.4 mm) at any point on the joint between the members.

FG-5220 HEPA FILTER AND TYPE II ADSORBER CELL MOUNTING FRAME FLATNESS

Each HEPA filter or adsorber cell seating surface shall be plane within $^1/_{16}$ in. (1.5 mm). The HEPA filter or adsorber cell seating surface is defined as a 1 in. (25 mm) perimeter around the HEPA filter or adsorber cell opening only. The entire mounting frame shall be plane within $^1/_2$ in. (13 mm) total allowance in any area of 8 ft × 8 ft (2.4 m × 2.4 m). Waviness not exceeding $\pm ^1/_{32}$ in. (±0.8 mm) per 6 in. (150 mm) is permissible as long as the overall flatness is not compromised.

FG-5230 HEPA FILTER AND TYPE II ADSORBER CELL MOUNTING FRAME DIMENSIONS

Length and spacing of the members shall be true within +0 in., $-^1/_8$ in. (+0 mm, −3 mm)

FG-5240 HEPA FILTER AND TYPE II ADSORBER CELL MOUNTING FRAME SURFACE FINISH

The filter seating surfaces shall be 125 μin. (3 μm) AA, maximum, in accordance with ANSI B46.1. Pits, roll scratches, weld spatter, and other surface defects within the 1 in. (25 mm) filter seating surfaces shall be ground smooth. After welding, ground areas shall merge smoothly with the surrounding base metal.

FG-5300 ALIGNMENT AND SURFACE FINISH FOR MEDIUM EFFICIENCY FILTER AND MOISTURE SEPARATOR MOUNTING FRAMES

The alignment of adjoining members shall be inspected, as well as the filter seating surface. Tolerances for medium efficiency filter and moisture separator cell mounting frames shall be as specified in subsections FG-5310 through FG-5340.

FG-5310 MEDIUM EFFICIENCY FILTER AND MOISTURE SEPARATOR MOUNTING FRAME ALIGNMENT

FG-5311 Perpendicularity

Mounting frame adjoining members shall be perpendicular with a maximum offset of $^1\!/_4$ in. (6 mm) over the entire frame member length, with no deviation greater than $^1\!/_8$ in. (3 mm) per 1 ft (300 mm) of frame member.

FG-5312 Planarity of Adjoining Members

Adjoining members shall be aligned not to exceed a planarity of $^1\!/_8$ in. (3 mm) at any point on the joint between the members.

FG-5320 MEDIUM EFFICIENCY FILTER AND MOISTURE SEPARATOR MOUNTING FRAME FLATNESS

Each medium efficiency filter or moisture separator seating surface shall be plane within $^1\!/_8$ in. (3 mm). The medium efficiency filter or moisture separator seating surface is defined as a 1 in. (25 mm) perimeter around the medium efficiency filter or moisture separator opening only. The entire mounting frame shall be plane within $^1\!/_2$ in. (13 mm) total allowance in any area of 8 ft × 8 ft (2.4 m × 2.4 m). Waviness not exceeding ± $^1\!/_{16}$ in. (1.5 mm) per 6 in. (150 mm) is permissible only as long as the overall flatness is not compromised.

FG-5330 MEDIUM EFFICIENCY FILTER AND MOISTURE SEPARATOR MOUNTING FRAME DIMENSIONS

Length and spacing of the members shall be true within +0 in., $-^1\!/_8$ in. (+0 mm, −3 mm).

FG-5340 MEDIUM EFFICIENCY FILTER AND MOISTURE SEPARATOR MOUNTING FRAME SURFACE FINISH

The filter seating surface finish shall be 125 μin. (3 μm) AA, maximum, in accordance with ANSI B46.1.

FG-5400 WELD INSPECTION

Seal and structural welds shall be inspected in accordance with AA-6300.

FG-5500 COATING INSPECTION

Coating, when required, shall be inspected per AA-6500.

ARTICLE FG-6000
FABRICATION

FG-6100 GENERAL

The fabrication and assembly of the mounting frames shall be performed in accordance with approved design drawings.

FG-6200 WELDING

All welding procedures and welder qualifications shall be in accordance with the requirements of AA-6300.

FG-6300 CLAMPING DEVICES

Required bolt or stud size shall be 1/2-1/3-UNC or 5/8-11-UNC.

FG-6400 CLEANING

All surfaces shall be cleaned per Article AA-6000 prior to acceptance. No halogen bearing materials or carbon steel tools shall be used to clean frames constructed of stainless steel. Cleaning shall be performed in accordance with Manufacturer's written procedure.

FG-6500 COATING

Coating of the frames, if applicable, shall be in accordance with AA-6500.

ARTICLE FG-7000
PACKAGING AND SHIPPING

Packaging and shipping of mounting frames shall be in accordance with ASME NQA-1 Level D Criteria if shipped by themselves. Mounting frames installed in a housing or duct become part of that equipment and the packaging requirements of HA or SA shall apply. See Article AA-7000 for general requirements.

ARTICLE FG-8000
QUALITY ASSURANCE

The mounting frame manufacturer shall establish and comply with a quality assurance program that complies with Article AA-8000.

ARTICLE FG-9000
NAMEPLATES

The following information, as a minimum, shall be permanently marked on an accessible non-sealing surface of the mounting frame:

TYPE OF FRAME BY: (Manufacturer's name or symbol)

FRAME SERIAL NUMBER: (or other identification)

PURCHASE ORDER NUMBER:

YEAR OF MANUFACTURE:

This shall not apply to frames installed as integral parts of air handling units or ducts.

Any other stampings necessary shall be specified in the design specifications.

NONMANDATORY APPENDIX FG-A
DIVISION OF RESPONSIBILITY

This Nonmandatory Appendix is intended to identify the roles normally assumed by the organizations responsible for fulfilling Code requirements when not specifically addressed in an article or subarticle. These are guidelines to assist with Code compliance and are not to be construed as legal or contractual responsibilities unless so invoked by the Owner or designee.

TABLE FG-A-1000
DIVISION OF RESPONSIBILITY

FG-	Item	Responsible Party
3000	Materials	Engineer/Manufacturer
4100	General design	Engineer/Manufacturer
4110	HEPA Filter Mounting Frames	Engineer/Manufacturer
4111	HEPA Filter Mounting Frame Dimensions	Engineer/Manufacturer
4112	HEPA Filter Clamping	Engineer/Manufacturer
4113	HEPA Filter Support	Manufacturer
4114	HEPA Filter Mounting Frame Penetrations	Manufacturer
4120	Type II Adsorber Cell Mounting Frames	Engineer/Manufacturer
4121	Type II Adsorber Cell Mounting Frame Dimensions	Engineer/Manufacturer
4122	Type II Adsorber Cell Clamping	Engineer/Manufacturer
4123	Type II Adsorber Cell Sealing	Engineer/Manufacturer
4124	Type II Adsorber Cell Support	Manufacturer
4125	Type II Adsorber Cell Mounting Frame Penetrations	Manufacturer
4130	Medium Efficiency Filter Mounting Frames	Engineer/Manufacturer

TABLE FG-A-1000
DIVISION OF RESPONSIBILITY (CONT'D)

FG-	Item	Responsible Party
4131	Medium Efficiency Filter Mounting Frame Dimensions	Engineer/Manufacturer
4132	Medium Efficiency Filter Clamping	Engineer/Manufacturer
4133	Medium Efficiency Filter Support	Manufacturer
4134	Medium Efficiency Filter Mounting Frame Penetrations	Manufacturer
4141	Moisture Separator Mounting Frame Dimensions	Engineer/Manufacturer
4142	Moisture Separator Clamping	Engineer/Owner
4143	Penetrations	Engineer/Manufacturer
4151	Galling Prevention	Engineer/Manufacturer
4200	Structural requirements	Manufacturer
4210	General requirements	Engineer
4220	Load definition	Engineer
4230	Load combinations	Engineer
4240	Acceptance criteria	Engineer
4300	Structural design analysis	Manufacturer
4310	Mounting Frame Deflection Limits	Engineer/Manufacturer
4320	Type II Adsorber Cell and Moisture Separator Mounting Frame Deflection Limits	Engineer/Manufacturer
4330	Pressure Impulse loading	Engineer/Manufacturer
5000	Inspection and testing	Manufacturer/Owner
5100	Dimensional inspection	Manufacturer
5200	Alignment and Surface Finish For HEPA Filter and Type II Adsorber Cell Mounting Frames	Manufacturer
5210	HEPA Filter and Type II Adsorber Cell Mounting Frame Alignment	Manufacturer
5220	HEPA Filter and Type II Adsorber Cell Mounting Frame Flatness	Manufacturer

TABLE FG-A-1000
DIVISION OF RESPONSIBILITY (CONT'D)

FG-	Item	Responsible Party
5230	HEPA Filter and Type II Adsorber Cell Mounting Frame Dimensions	Manufacturer
5240	HEPA Filter and Type II Adsorber Cell Mounting Frame Surface finish	Manufacturer
5300	Alignment and Surface Finish for Medium Efficiency Filter and Moisture Separator Mounting Frames	Manufacturer
5310	Medium Efficiency Filter and Moisture Separator Mounting Frame Alignment	Manufacturer
5320	Medium Efficiency Filter and Moisture Separator Mounting Frame Flatness	Manufacturer
5330	Medium Efficiency Filter and Moisture Separator Mounting Frame Dimensions	Manufacturer
5340	Medium Efficiency Filter and Moisture Separator Mounting Frame Surface Finish	Manufacturer
5350	Medium Efficiency Filter Clamping	Manufacturer
5400	Weld inspection	Manufacturer
5500	Coating Inspection	Manufacturer
6000	Fabrication	Manufacturer
6100	General	Manufacturer
6200	Welding	Manufacturer
6300	Clamping devices	Manufacturer
6400	Cleaning	Manufacturer
6500	Coating	Manufacturer
7000	Packaging and shipping	Manufacturer/Owner
8000	Quality assurance	Manufacturer/Owner
9000	Nameplates	Manufacturer/Owner

SECTION FH
OTHER ADSORBERS

Figures

Table

Nonmandatory Appendix

ARTICLE FH-1000
INTRODUCTION

FH-1100 SCOPE

This section of the Code provides requirements for the performance, design, construction, acceptance testing, inspection, and quality assurance for Type IV modular gas phase adsorber cells used in air or gas treatment systems in nuclear facilities. This section does not include integration of the adsorber into a complete air treatment system or its mounting frames. This section also does not cover interfaces with the housing or fire protection equipment.

FH-1110 PURPOSE

The purpose of this section is to ensure that the Type IV adsorbers used for air and gas treatment systems are acceptable in all aspects of design, construction, testing, and performance.

FH-1120 APPLICABILITY

This section applies to the Type IV adsorber, which is a fabricated component composed of adsorber beds arranged in a "V" or "U" configuration. These adsorbers are not to be used as a housing or containment boundary.

FH-1130 DEFINITIONS AND TERMS

Terms used in this section are defined in Article AA-1000, and FD-1130.

ARTICLE FH-2000
REFERENCED DOCUMENTS

When ASTM material specifications are referenced, the equivalent ASME material specifications may be substituted. When the date of the reference is not cited, the latest revision is used.

ASTM A 167, Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet and Strip

ASTM A 193/A 193M, Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service

ASTM A 194/A 194M, Standard Specification for Carbon and Alloy Steel Nuts and Bolts for High-Pressure and High-Temperature Service

ASTM A 240, Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

ASTM A 276, Standard Specification for Stainless and Heat-Resisting Steel Bars and Shapes

ASTM A 320/A 320M, Standard Specification for Alloy Steel Bolting Materials for Low-Temperature Service

ASTM A 380, Standard Practice for Cleaning and Descaling Stainless Steel Parts, Equipment, and Systems

ASTM D 1056-00, Standard Specification for Flexible Cellular Materials — Sponge or Expanded Rubber

Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

ARTICLE FH-3000 MATERIALS

FH-3100 ALLOWABLE MATERIALS

FH-3110 ADSORBENT

The adsorbent material used in these cells shall meet the requirements of Section FF for nuclear systems.

FH-3120 SCREENS

Unless otherwise specified by the Owner, the screens shall meet the requirements of ASTM A 167 or ASTM A 240, Type 304, 304L, or Type 316 stainless steel.

Margins and blank areas shall be as specified in FH-4220 and FH-4230.

FH-3130 CASING

Casing material shall meet the requirements of ASTM A 167, or A 240, Type 304, Type 304L, or Type 316 stainless steel.

The material thickness shall be as stated in FH-4230. Spacers and baffles shall meet the requirements of ASTM A 167, ASTM A 240, or ASTM A 276 as appropriate.

FH-3140 ADHESIVES AND SEALANTS

FH-3141 Adhesives

Adhesives used to splice gaskets, bond gasket to cell, or to seal possible areas of bypass between adsorbent and casing shall be compatible with the gasket material and appropriate to the intended application.

FH-3142 Sealants

Sealants used to seal perforated screens to the casing shall remain functional following rough handling tests as specified in FH-5311. Adsorbers that show cracks or other visible failure of sealants following rough handling tests shall be rejected.

FH-3143 Gel Seals

Gel seals shall be formed from a sealant installed into the perimeter channel around the face of the adsorber.

The gel material shall meet the design requirements of FH-4250.

FH-3150 RIVETS

When rivets are used for fabrication or attachment of fill port covers, they shall be austenitic stainless steel of Type 300 series. The rivets shall be of the closed-end type.

FH-3200 LIMITS

Material of construction for the Type IV cell are limited to those materials herein specified.

FH-3300 CERTIFICATION OF MATERIALS

Documentation for adsorbent media shall conform to the design specification.

Certification for parts, material, and components shall be supplied to the Owner as required below and in Article FH-8000. The Manufacturer's Certificate of Conformance is required.

Fabricated metal parts shall conform to one of the material specifications permitted by Article FH-2000. The cell manufacturer shall obtain certified material test reports for these parts.

FH-3310 FABRICATED METAL PARTS

The cell manufacturer shall obtain Certificate of Conformance that the material obtained for fabricated metal parts conforms to the appropriate standards of Article FH-2000.

FH-3320 GASKETS AND SEAL PADS

Certificate of Conformance to ASTM D 1056 is required for gaskets and/or seal pads.

FH-3330 ADHESIVES AND SEALANTS

Manufacturer's Certificate of Conformance is required.

FH-3340 PURCHASED HARDWARE ITEMS (WASHERS AND RIVETS)

Manufacturer's Certificate of Conformance is required.

ARTICLE FH-4000
DESIGN

FH-4100 GENERAL DESIGN

The "V" configuration is illustrated in Figs. FH-4000-1, FH-4000-1A, and FH-4000-2, with additional dimensions and representative operating parameters shown in Table FH-6000. The "U" configuration is illustrated in Fig. FH-4000-3. The Type IV adsorber beds have fill port covers for recharging, and a gasket or seal around the perimeter of either the air-entering or the air-leaving face of the adsorber. Air circulates through an adsorbent bed held between perforated screens. The bed depth shall be specified by the Owner to meet the performance requirements.

The depth of the cell beds shall be determined by the nature of the contaminant(s) to be controlled, the conditions under which the adsorber must operate, and the residence time required to adsorb the contaminant(s) under those conditions. The beds shall be arranged in a configuration within a modular unit size: 24 in. × 24 in. × length (610 mm × 610 mm × length) as specified in FH-6100. The beds shall be enclosed by a nonperforated case to create a four sided, box-shaped assembly. In a normal upright position, the air-entering and air-exiting sides of the adsorber case are the front and back where the beds join. A gasket or gel seal shall be located around the perimeter, which interfaces with the mounting frame.

FH-4200 TECHNICAL REQUIREMENTS

FH-4210 DESIGN REQUIREMENTS

FH-4211 Residence Time Requirements

The cell shall have a minimum residence time of 0.125 sec/in. bed depth at its rated capacity. The residence time shall be determined by the procedure in FH-4212.

FH-4212 Residence Time Calculation

Residence time, the theoretical time that the gas remains in contact with the adsorbent within the adsorber cell, at a specified airflow, is calculated from the following equation:

(U.S. Customary Units)

$$T = t(A/2 - B)/28.8Q$$

where

28.8 = product of 1.728 in.^{3}/ft^3 and $^1/_{60}$ min/sec
A = gross screen area of all screens on inlet side and on the outlet side, in.^{2}
B = total area of baffles, blanks, margins, of all screens, in.^{2}
Q = total cell volumetric airflow, cfm
T = residence time, sec
t = minimum thickness of bed, in.

(SI Units)

$$T = 3.6\ t(A/2 - B)/Q$$

where

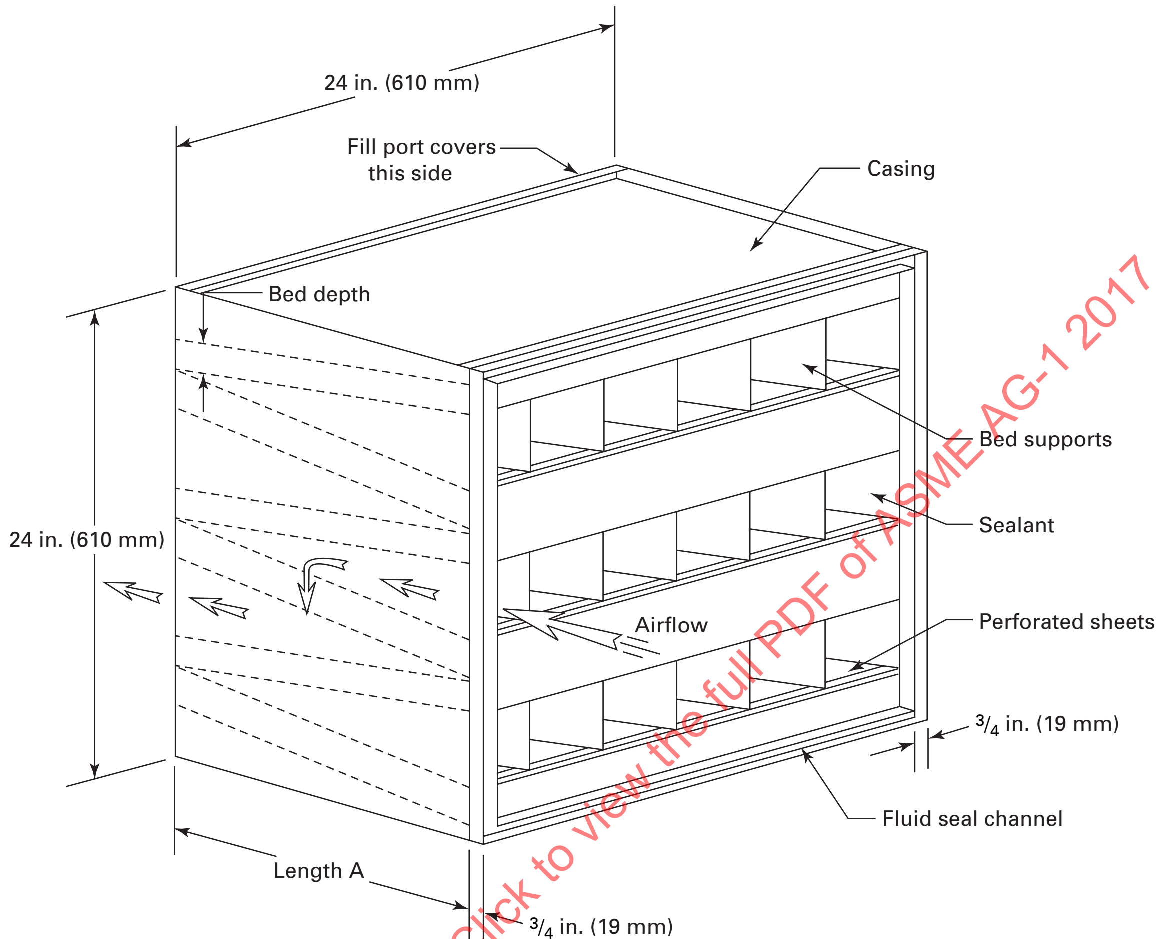
3.6 = product of 3,600 sec/hr and 10^{-3} m/mm
A = gross screen area of all screens on inlet side and on the outlet side, m^2
B = total area of baffles, blanks, margins of all screens, m^2
Q = total cell volumetric airflow, m^3/h
T = residence time, sec
t = minimum thickness of bed, mm

FH-4220 ADSORBER BEDS

The adsorber bed shall consist of a volume bounded by perforated screens and the solid metal of the cell case. The adsorber bed thickness shall not be less than the specified value at any point. Joints where the front and back edges of the cells connect shall be made airtight by an integral solid metal design or welding. No sealants shall be used at these joints.

The beds shall have internal spacers or external wedges extending the full width of the beds, or other

FIG. FH-4000-1 TYPE IV "V" ADSORBERS MODEL (FLUID SEAL VERSION)



means of maintaining bed thickness and minimizing distortion when the cell beds are filled.

FH-4230 CASE AND ASSEMBLY

The adsorber case houses the adsorber beds subassembled into the adsorber module.

The adsorber case (frame) shall be solid metal, and perforated screens shall be fastened to the solid metal by welding at the front and back of the frame. Tack welding may be used at the top and bottom. To prevent air from bypassing the beds, the internal sides of the case shall be coated (poured) with an adhesive or sealant in accordance with FH-3140 to seal the beds to the sides of the case. A minimum of $\frac{1}{2}$ in. (13 mm) solid margin shall be provided at the perforated sheet-to-solid side interface. Blank areas are areas in which no air can flow through the bed, such as spacer flanges.

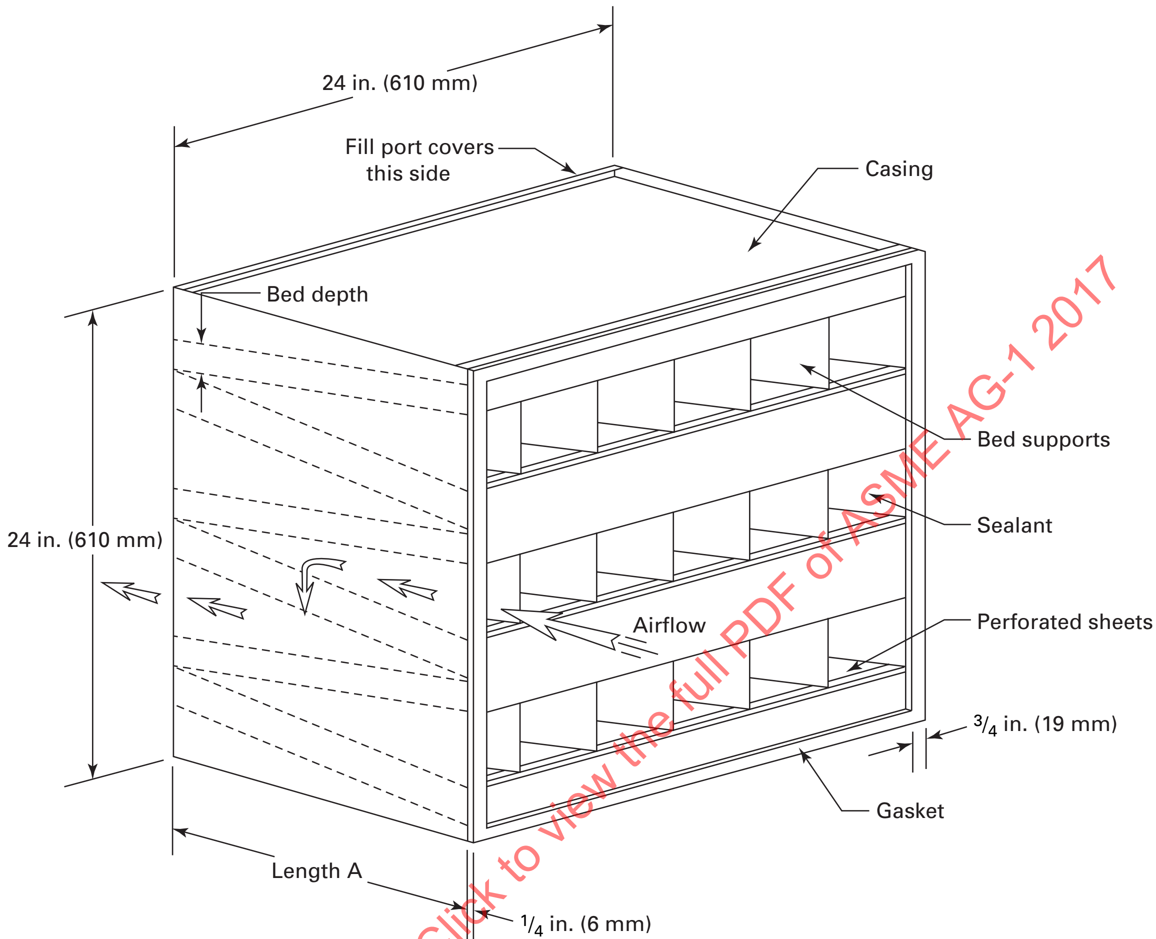
The adsorber case shall be made from 14 gage USS nonperforated stainless steel sheet [0.0751 in. (1.83 mm)] minimum thickness, Type 304, conforming to ASTM A 167, or ASTM A 240. The case shall be formed and assembled in such a manner that no bypassing of the adsorbent beds is possible. The front side of the case shall have a minimum $\frac{3}{4}$ in. (19 mm) wide flanged perimeter for the attachment of the gasket. The back side filling hatches shall consist of holes or slots for placing the adsorbent in the beds and fill port covers attached with fasteners such as pop rivets in accordance with FH-3150. Cover plates shall be stainless steel, 0.120 in. (11 gage USS) (3.05 mm) minimum thickness, conforming to ASTM A 167, Type 304, or ASTM A 240.

FH-4240 GASKETS

FH-4241 Material

Gaskets shall be oil-resistant, closed cell neoprene or silicone sponge type, Grade 2C3 or 2C4, in accordance with ASTM D 1056. If gasket material joints are

FIG. FH-4000-1A TYPE IV "V" BED ADSORBERS MODEL (GASKETED VERSION)



required, they shall be joined in a manner that ensures a seal. This may be done by gluing dovetail joints or by vulcanizing joints into a continuous material. There shall be no more than four gasket joints per adsorber cell.

The gasket flange and the gasket shall each be a minimum of $\frac{3}{4}$ in. (19 mm) in width.

FH-4242 ADHESIVE SEAL

The gasket shall be sealed to the adsorber module with an adhesive per FH-3141.

The edge of the gasket shall not extend beyond the outside of the adsorber module.

FH-4250 GEL SEALS

Gel seals shall be formed from a sealant installed into a perimeter channel around the face of the adsorber. The gel sealant shall be self-adherent and self-healing. The gel material shall be flame retardant and self-extinguishing, and shall not give off toxic fumes when exposed to flame.

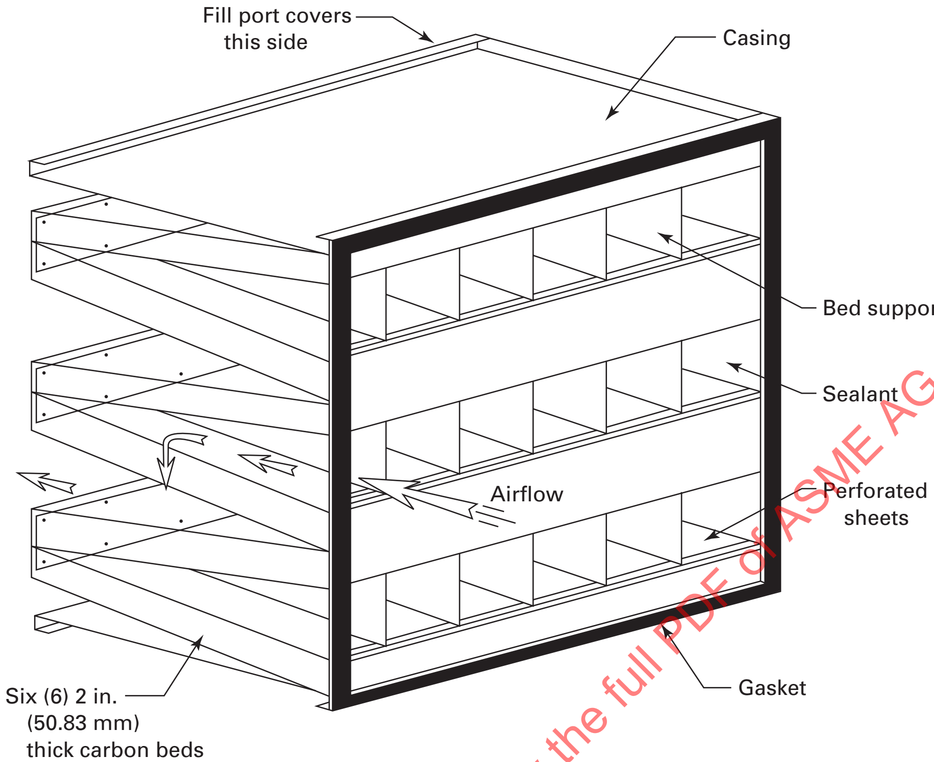
The gel material shall withstand the qualification tests in FH-5300, and provide a seal between the adsorber and its mounting frame, while exposed to the load combinations in FH-4330 and the in-service environmental conditions. It shall provide a seal sufficient for the adsorber to pass an in-place leak test as specified in TA-4700.

FH-4300 STRUCTURAL REQUIREMENTS

FH-4310 GENERAL

The Type IV adsorber cells shall be designed in accordance with the structural requirements in Article AA-4000 or qualified by test in accordance with AA-4350.

FIG. FH-4000-2 TYPE IV "V" ADSORBERS MODEL, EXPLODED VIEW



FH-4320 LOAD DEFINITION

Loads to be considered in the structural design of the Type IV adsorber cells defined in AA-4211 are as follows:

(a) Deadweight (DW) consists of the weight of the metal enclosure that contains the adsorbent, plus the weight of the adsorbent medium for the adsorbent used in the application, plus a 10% safety factor.

Instrumentation and ancillary equipment, such as thermocouple probes attached to the cell, are treated as external loads (EL).

(b) The net operating pressure differential (NOPD) that must be considered is from the upstream to downstream side of the adsorber.

(c) The seismic acceleration and response spectra Operating Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE) shall be defined in the Design Specification. Additional dynamic loads (ADL) will also be provided by the Design Specification when applicable.

FH-4330 LOAD COMBINATIONS

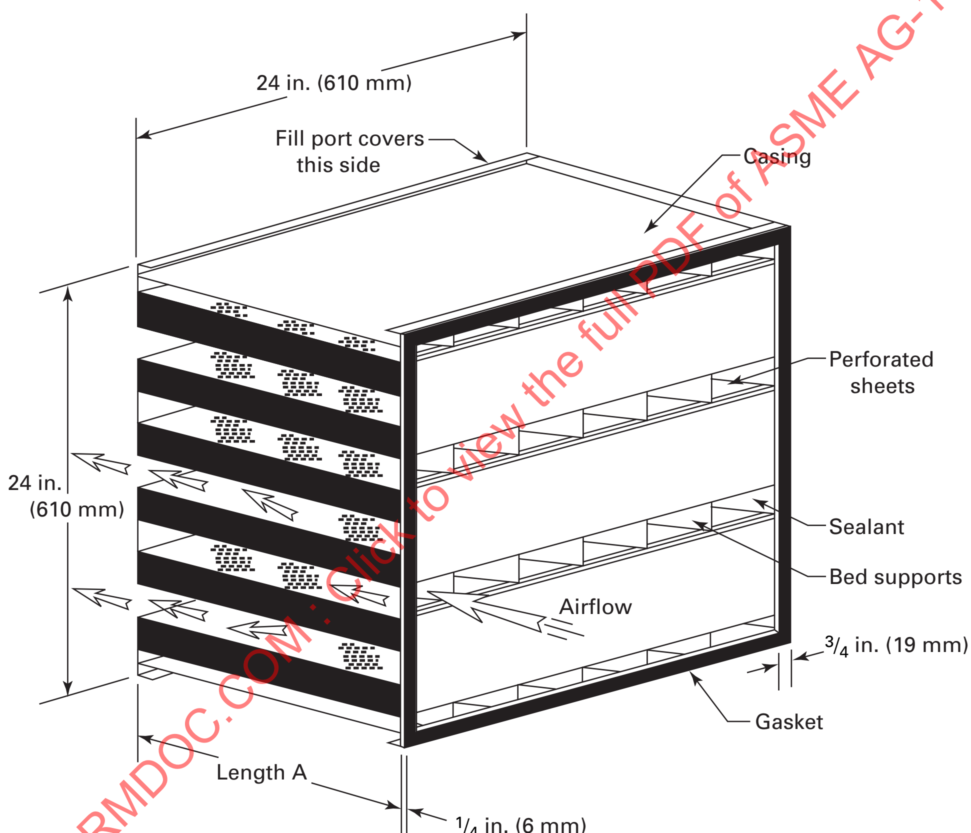
Unless stated otherwise in the Design Specification, the applicable loading conditions noted in Table AA-4212 for Type IV cells are as follows:

(a) Service Level A. DW + EL + NOPD
(b) Service Level B. DW + EL + NOPD + OBE
(c) Service Level C. DW + EL + NOPD + SSE + ADL
(d) Service Level D. Not applicable

FH-4340 ACCEPTANCE CRITERIA

The acceptance criteria are listed in Table AA-4321. The design stress value S shall be 0.6 S_u, as defined in AA-4332.3

FIG. FH-4000-3 TYPE IV "U" BED ADSORBERS MODEL (GASKETED VERSION)



ARTICLE FH-5000
INSPECTION AND TESTING

Inspection and testing of Type IV cells shall conform to the requirements of this section, and to the specific requirements set forth in Article AA-5000.

FH-5100 DIMENSIONAL INSPECTION

Each cell shall be inspected to ensure it conforms to all dimensional design requirements in Table FH-1. Location and placement of stiffeners, supports, and baffles shall be inspected to determine conformance to design requirements.

FH-5200 WELDING INSPECTION

FH-5210 SPOT WELDS

Spot welds shall be visually inspected in accordance with AA-6332.

FH-5220 OTHER WELDS

Fillet welds, butt welds, and seal welds shall be inspected in accordance with AA-6331.

FH-5300 QUALIFICATION TESTS

The cell design and filling method shall be qualified as outlined below, or as required by the design specifications. The manufacturer is required to requalify the cell design and filling method every 5 yr, or if there is any change in design, filling procedure, or the adsorbent's physical properties.

FH-5310 FILLING METHOD QUALIFICATION

FH-5311 Rough Handling Test

Four cells, filled with specified adsorbent by the proposed filling method (FH-6300), shall be hard mounted to a rough handling machine in the cell's service orientation. The machine shall have sharp cutoff cams and be capable of vibrating the mounted cell at a frequency of 200 cycles/mm at an amplitude of $^3/_4$ in. ± $^1/_{32}$ in. (19 mm ± 0.8 mm) for a minimum of 10 min.

After the rough handling test, the test cell shall be visually inspected, and there shall be no broken welds or other physical damage as a result of the test. If there are any broken welds or physical damage, the cell design shall be judged not qualified. If no damage is observed, the fill port(s) shall be opened and the level of adsorbent in the cell shall be visually inspected. The level in each of the beds shall not have dropped more than one-half the baffle or margin width perpendicular to the adsorbent surface. If any one of the cells has a loss of adsorbent, or settling greater than or equal to this amount, then the filling procedure shall be judged not qualified. Airflow resistance shall not increase by more than 20% as a result of a rough handling test conducted in accordance with this section.

FH-5312 Leak Test

After meeting the requirements of rough handling per FH-5311, three cells with fill port cover(s) reinstalled shall be installed in a test duct in their service orientation. Each cell shall be leak tested in accordance with FH-5420.

During the Challenge Vapor Leak Test sequence, the adsorbent shall not be disturbed from the compacted state created in the rough handling test. If any one of the cells tested exceeds the allowable leak per FH-5420, or there is a loss of adsorbent or excessive settling occurs in any of the three cells, the filling procedure shall be judged not qualified.

FH-5400 ACCEPTANCE TESTS

Each cell to be delivered to the purchaser shall be tested for airflow resistance and challenge vapor leakage. Each cell shall meet the criteria listed in the design specification. Cells that do not meet the criteria listed in the design specifications shall be rejected.

FH-5410 AIRFLOW RESISTANCE TEST

Install the cell in the test duct in its service orientation, and adjust airflow through the cell to its rated flow, ±5%. Airflow resistance shall not exceed design specifications.

FH-5420 REFRIGERANT LEAK TEST

The performance test consists of operating the test duct at its rated flow, and injecting a challenge vapor into the air stream upstream of the adsorber being tested. Operating the detector according to the Manufacturer's instructions, one upstream and one downstream concentration shall be taken, and a leak determination calculated. The leak shall not exceed the design specifications. Cells that do not meet this requirement shall be rejected.

Install adsorber module in test duct in its service orientation and adjust airflow to between 150 cfm and 250 cfm (255 m 3/hr and 425 m 3/hr). The adsorber shall be tested by a challenge vapor with an upstream concentration of not less than 10,000 times the minimum sensitivity of the challenge vapor measuring instrument.

The test duct shall be qualified both by demonstrating uniformity of the upstream challenge vapor, and by demonstrating that the downstream sampling location represents a well-mixed vapor concentration. The upstream vapor uniformity shall be ±20% of the average as measured at the centers of a minimum of four equal areas in a plane immediately upstream of the adsorber being tested. The downstream sample port shall be designed such that a leak greater than the allowable limit anywhere in the tested adsorber shall be measured. These qualifications of the test duct shall be done at the initial construction of the test duct or after any changes to the duct, and the documentation of the qualification shall be available on request.

ARTICLE FH-6000
FABRICATION

The cells shall be fabricated using only those materials designated in Article FH-3000 and in accordance with the design outlined in Article FH-4000.

All welding shall be in accordance with FH-6200. After manufacture, the cell shall be inspected and tested in accordance with FH-5200 and FH-5400.

FH-6100 DIMENSIONS AND TOLERANCES

The cell shall conform to the dimensional requirements shown in Table FH-6100. Depth dimensions exclude gaskets. (The number of beds per adsorber, and the thickness of the beds, will be a function of the residence time requirements calculated from FH-4200.) At no point in the bed shall the bed depth be less than the depth used in the residence time calculations.

FH-6200 WELDING

Procedure qualification, personnel qualification, and performance of welding during fabrication and installation shall be in accordance with AA-6300.

FH-6210 TESTING AND INSPECTION

Testing and inspection of welding utilized in fabrication and installation shall be performed in accordance with Article AA-6000.

TABLE FH-6100
DIMENSIONAL REQUIREMENTS

Dimensions	IP	SI
Height	24 + 0, − $^1/_{16}$ in.	610 + 0, − 1.6 mm
Width	24 + 0, − $^1/_{16}$ in.	610 + 0, − 1.6 mm
Minimum length	11.5 + $^1/_{16}$, − 0 in.	290 + 1.6, − 0 mm
Maximum length	18.75 + $^1/_{16}$, − 0 in.	475 + 1.6, − 0 mm

GENERAL NOTE: Face diagonal tolerances are ±$^1/_8$ in. (3.2 mm)

FH-6220 REPAIRS

Weldments, or portions thereof that do not meet the acceptance criteria defined in Article AA-6000, shall be removed and rewelded in accordance with the original requirements.

Damaged gaskets shall be replaced. Damaged metal parts shall be replaced or repaired as necessary to meet all requirements of this Code section.

FH-6300 FILLING

Cells shall be filled with adsorbent specified by the owner using a filling method qualified in accordance with FH-5300. After filling, adsorbent fines shall be removed from the beds by blowing with clean, dry, oil-free compressed air or by vacuuming. After filling, each cell shall be tested in accordance with FH-5311 and FH-5312. The filling method shall be deemed qualified if the results of the tests conducted in accordance with FH-5311 and FH-5312 are acceptable.

FH-6400 CLEANING

Metal surfaces shall be cleaned and degreased in accordance with ASTM A 380 before any welding, installation of gaskets or sealants, and filling with adsorbent.

ARTICLE FH-7000
PACKAGING AND SHIPPING

FH-7100 PACKAGING

Packing and shipping shall be in accordance with NQA-1, per Article AA-7000, Basic Requirement 13, and Supplement 13S-1.

Each cell shall be individually wrapped and enclosed in a sealed plastic bag that is water- and water-vapor resistant over a temperature range from −30°F to 140°F (−34°C to 60°C). The wrapped cell shall, in turn, be enclosed in a wood or fiberboard carton with internal cushioning.

Cells shall be oriented in the carton or crate with screens horizontal. The cartons or crates shall be clearly marked with the legend THIS SIDE UP or similar imprint, to ensure proper orientation of cartons and crates during handling, shipping, and storage.

FH-7200 LOADING FOR SHIPMENT

Cartons shall be banded to skids or pallets in the orientation specified in FH-7100.

Wood separators and strapping protectors shall be provided between tiers of cartons and above the topmost cartons in the load.

Sufficient strapping shall be used to prevent shifting of stacked cartons on the skid or pallet. Cells shall be stacked no higher than three tiers on the skid or pallet.

FH-7300 STORAGE

(a) Storage at all times (except during transit) shall be indoors in an area with

(1) ventilation

(2) minimum temperature of 40°F (4°C)

(3) maximum temperature of 120°F (48°C)

(4) protection from exposure to fume-producing materials or volatile organic compounds

(b) In addition, cells shall be

(1) stored in correct orientation (check marking arrows on cartons)

(2) stored in factory-packed cartons and removed from the cartons just prior to installation

(3) stored such that tagging information is easily accessible

FH-7400 CONTAINERS

The integrity of the packing container and the vapor container shall be maintained throughout shipping, handling, and storage. Storage should not be near frequently traveled aisles or corridors, near vibrating equipment, or among short-term storage items that require frequent personnel access. Care should be taken to avoid dropping or tipping the storage containers.

ARTICLE FH-8000
QUALITY ASSURANCE

The Type IV adsorber cell manufacturer shall establish and comply with a quality assurance program in accordance with Article AA-8000.

FH-8100 DOCUMENTATION

The following documentation shall be kept on file at the Manufacturer's facility, and provided when required:

(a) table or drawing giving outline dimensions of the cell

(b) certified list of materials of construction

(c) adsorbent type with applicable test reports

(d) welding procedures and procedure qualifications

(e) all qualification reports (seismic and filling method)

(f) certification of performance (resistance and leak test)

(g) residence time

(h) certification of the appropriate flow rate

ARTICLE FH-9000
NAMEPLATES AND CERTIFICATION

FH-9100 GENERAL

Each cell shall be legibly and permanently marked on a noncorroding nametag affixed to the cell with the following information:

(a) Type IV adsorber
(b) Manufacturer's name or symbol
(c) serial number
(d) month/year (of manufacture)
(e) empty weight
(f) residence time

Each cell shall bear a replaceable label with the following information:

(g) adsorbent Manufacturer's name or symbol
(h) adsorbent type and grade designation, lot, and batch
(i) filled weight
(j) adsorbent weight
(k) airflow resistant at specified airflow rating
(l) challenge vapor leak test results
(m) date of filling

NONMANDATORY APPENDIX FH-A
DIVISION OF RESPONSIBILITY

This Nonmandatory Appendix is intended to identify the roles normally assumed by the organizations responsible for fulfilling Code requirements when not specifically addressed in an article or subarticle. These are guidelines to assist with Code compliance and are not to be construed as legal or contractual responsibilities unless so invoked by the Owner or designee.

TABLE FH-A-1000
DIVISION OF RESPONSIBILITY

FH-	Item	Responsible Party
3000	Materials	Manufacturer/Owner
4000	Design	Manufacturer/Owner
5200	Weld inspection	Manufacturer
5300	Qualification tests	Manufacturer
6000	Fabrication	Manufacturer
7100	Packaging and shipping	Manufacturer
7200	Loading for shipment	Manufacturer
7300	Storage	Owner
8000	Quality assurance	Manufacturer
8100	Documentation	Manufacturer
9000	Nameplate and certification	Manufacturer

SECTION FI
METAL MEDIA FILTERS

(In the Course of Preparation)

SECTION FJ
LOW EFFICIENCY FILTERS

(In the Course of Preparation)

SECTION FK
SPECIAL ROUND AND DUCT-CONNECTED HEPA FILTERS

Figures

Tables

Nonmandatory Appendix

ARTICLE FK-1000 INTRODUCTION

FK-1100 SCOPE

This section of the Code provides requirements for the performance, design, construction, acceptance testing, and quality assurance for special High Efficiency Particulate Air (HEPA) filters constructed for radial flow, circular axial flow, rectangular duct-connected configurations, and rectangular axial flow.

FK-1110 PURPOSE

The purpose of this section is to ensure that special HEPA filters used in nuclear applications are acceptable in all aspects of performance, design, construction, acceptance, and testing.

FK-1120 APPLICABILITY

FK-1121 Special HEPA Filters

This section applies to extended media dry-type filters for use in air and gas streams with a 250°F (121°C) maximum continuous temperature.

FK-1121.1 Types of HEPA Filters. Four types of special HEPA filters are addressed as follows:

(a) Type 1. Radial flow filters
(b) Type 2. Axial flow circular filters
(c) Type 3. Axial flow rectangular or circular filters with inlet and/or outlet connections
(d) Type 4. Axial flow rectangular filters that are size variations of those addressed in Section FC

Type 1, 2, and 3 filters are depicted in Fig. FK-4100-1 through Fig. FK-4100-8. Type 4 filters are depicted in Section FC.

FK-1121.2 Types of Filter Pack. Four types of filter pack are addressed as follows:

(a) Type A. Folded filter media with corrugated separator/supports
(b) Type B. Mini-pleat medium with glass fiber or noncombustible thread separators
(c) Type C. Continuous corrugated filter media folded without separators
(d) Type D. Folded filter media with glass fiber ribbon separators of glass fiber media or noncombustible threads glued to the filter media

FK-1122 Limitations

This section does not cover the following items:

(a) filter mounting frames
(b) integration of HEPA filters into air cleaning systems
(c) filter housings and ducting, including ducting and housing related pressure boundary and structural capability requirements.
(d) filters listed in Section FC

FK-1123 Service Life

HEPA filters are components of a nuclear air treatment system that degrade with service. The user/owner of the facility shall incorporate written specifications on the service life of the HEPA filters for change-out criteria. Nonmandatory Appendix FK-A provides guidance on determining the acceptable service life for each application of HEPA filters.

FK-1130 DEFINITIONS AND TERMS

This Code section delineates definitions and terms unique to this code section. Definitions and terms that have common applications are listed in Article AA-1000.

axial flow: flow in a direction essentially perpendicular to the filter face.

filter case: the outer frame of an axial flow filter in which the filter pack is sealed.

filter end cap: the circular ends of a radial flow HEPA filter in which the filter pack and filter grille are sealed/mounted.

filter grille: perforated or expanded metal tube that forms the outer and inner frame of a radial flow filter.

HEPA filter: high efficiency particulate air filter. A throwaway, extended-media dry-type filter in a rigid casing enclosing the full depth of the pleats, having a minimum efficiency of 99.97% (that is, a maximum particulate penetration of 0.03%) for 0.3 μm diameter test aerosol particles.

independent filter test laboratory: an autonomous body not affiliated with a HEPA filter manufacturer or supplier subject to this Code section but capable of performing the tests necessary to demonstrate the ability of HEPA filters to meet this Code section.

mechanical or metal grab ring: circular metal ring provided at the inlet of a Type 1 radial flow HEPA filter used to facilitate filter insertion and removal by remote mechanical handling systems.

media velocity: the linear velocity of the air or gas into filter media.

most penetrating particle size: that particle size for which the penetration of the filter medium by the test aerosol is a maximum at a specified velocity.

particle size: the apparent linear dimension of the particle in the plane of observation as observed with an optical microscope; or the equivalent diameter of a particle detected by automatic instrumentation. The equivalent diameter is the diameter of a reference sphere having known properties and producing the same response in the sensing instrument as the particle being measured.

penetrometer: a device for generating a test aerosol and for evaluating the aerosol penetration and air resistance of fabricated HEPA filters.

radial flow: flow in essentially a perpendicular direction outward from a centerline, or conversely flow in essentially a perpendicular direction inward to a centerline.

rated airflow: designated airflow capacity of a HEPA filter at a not to exceed initial filter resistance.

spigot: a fitting connected to the housing that serves as a seating surface for a radial flow HEPA filter.

test aerosol: a dispersion of particles in air for testing the penetration of filter media or filters.

Type 1: Type 1 is the special HEPA filter type assigned to a radial flow HEPA filter. Radial flow HEPA filters are made from a medial pack formed to produce an annulus with internal and external supporting grilles. The media pack and grilles are sealed into the flange and end cap with adhesive. The normal direction of flow is from the inside face to the outside face. Type 1 filters may use an internal gasket seal, external gasket seal, or gelatinous seal. In some applications, a mechanical or metal grab ring may be employed.

Type 2: Type 2 is the special HEPA filter type assigned to axial flow circular filters. The Type 2 filter case is formed from pipe, tube, or by rolling material to the desired dimension. Type 2 filters may use flanges, gasket seals, or gellatinous seals.

Type 3: Type 3 is the special HEPA filter type assigned to an axial flow rectangular filter with inlet and/or outlet connections, or an axial flow circular filter with inlet and/or outlet connections.

Type 4: Type 4 is the special HEPA filter type assigned to axial flow rectangular filters that are size variations of those HEPA filters addressed in Section FC [e.g., 24 in. high by 30 in. wide (610 mm high by 762 mm wide)].

ARTICLE FK-2000
REFERENCED DOCUMENTS

Common application documents referenced in this Code section are detailed in Article AA-2000. Where ASTM materials are specified, the equivalent ASME material specification may be substituted. Unless otherwise shown, the latest edition and addenda are applicable.

Voluntary Product Standard PS-1-95 for Construction and Industrial Plywood (APA PS-1)

Publisher: APA — The Engineered Wood Association (APA) (formerly American Plywood Association), 7011 South 19th Street, Tacoma, WA 98466

ASME B18.21.1-1999, Internal Tooth Lock Washer

ASME B18.22.1-1965 (R 1981), Plain Washer

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 A 193/A 193M-04c, Specification for Alloy-Steel Stainless Steel Bolting Materials for High Temperature Service

ASTM A 194/A 194M-04a, Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure and High Temperature Service

ASTM A 240/A 240M-04a, Specification for Heat Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

ASTM A 320-04, Specification for Alloy — Steel Bolting Materials for Low Temperature Service

ASTM A 580/A 580M-98 (R 2004), Standard Specification for Stainless Steel Wire

ASTM A 581/A 581M-95b (R 2004), Standard Specification for Free Machining Stainless Steel Wire and Wire Rods

ASTM A 740-98 (R 2003), Specification for Hardware Cloth (Woven or Welded Galvanized Steel Wire Fabric)

ASTM B 209-04, Specification for Aluminum and Aluminum Alloy Sheet Plate

ASTM D 1056-00, Standard Specification for Flexible Cellular Materials — Sponge or Expanded Rubber

ASTM D 3359-02, Test Methods for Measuring Adhesion by Tape Test

ASTM E 84-04, Test Methods for Surface Burning Characteristics of Building Materials

ASTM F 1267-01, Specification for Metal, Expanded, Steel

Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959

FED-STD-141D-2001, Paint, Varnish, Lacquer, and Related Materials; Method of Inspection, Sampling and Testing

FF-N-105B, Nails, Brads, Staples, and Spikes, Cut and Wrought

MIL-STD-282, Filter Units, Protective Clothing, Gas Mask Components, and Related Products: Performance Test Methods

Publisher: Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402

IEST-RP-CC007, Testing UPLA Filters, 1992 Edition

Publisher: Institute of Environmental Sciences and Technology (IEST), 5005 Newport Drive, Rolling Meadows, IL 60008-3841

UL 586, Standard for Safety High Efficiency, Particulate Air Filter Units, 2004 Edition

Publisher: Underwriters Laboratories, Inc. (UL), 333 Pfingsten Road, Northbrook IL 60062-2096